G

GABA *See* GAMMA-AMINOBUTYRIC ACID.

gabbro A coarse-grained basic intrusive igneous rock with a similar composition to *basalt, i.e. mainly plagioclase feldspar, and pyroxine, with some olivine. Accessory minerals include apatite, hornblende, ilmenite, and magnetite.

Gabor, Dennis (1900–79) Hungarian-born British physicist, who worked as a research engineer from 1927 until 1933, when he joined the British Thomson-Houston company. In 1948 he joined the staff of Imperial College, London. In that same year, while working on electron microscopes, he invented *holography, for which he was awarded the 1971 Nobel Prize for physics.

Gabriel reaction A method of making a primary *amine (free from any secondary or tertiary amine impurities) from a haloalkane (alkyl halide) using potassium phthalimide. It is named after Siegmund Gabriel (1851–1924).

gadolinium Symbol Gd. A soft silvery metallic element belonging to the *lanthanoids; a.n. 64; r.a.m. 157.25; r.d. 7.901 (20°C); m.p. 1313°C; b.p. 3266°C. It occurs in gadolinite, xenotime, monazite, and residues from uranium ores. There are seven stable natural isotopes and eleven artificial isotopes are known. Two of the natural isotopes, gadolinium–155 and gadolinium–157, are the best neutron absorbers of all the elements. The metal has found limited applications in nuclear technology and in ferromagnetic alloys (with cobalt, copper, iron, and cerium). Gadolinium compounds are used in electronic components. The element was discovered by Jean de Marignac (1817–94) in 1880.

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Gaia hypothesis The theory, based on an idea put forward by the British scientist James Ephraim Lovelock (1919–), that the whole earth, including both its biotic (living) and abiotic (nonliving) components, functions as a single self-regulating system. Named after the Greek earth goddess, it proposes that the responses of living organisms to environmental conditions ultimately bring about changes that make the earth better adapted to support life; the system would rid itself of any species that adversely affects the environment. The theory has found favour with many conservationists.

gain *See* AMPLIFIER.

galactic centre The region at the centre of a galaxy. In the Milky Way (our Galaxy) it corresponds to a radio source in the direction of Sagittarius. This source, called Sagittarius A, may correspond to a massive *black hole.

galactic merger The joining of two galaxies that approach within each other's gravitational fields. They spiral together, forming one galaxy and producing a starburst, in which many new stars are created by the collapse of interstellar clouds. Streams of stars, some large enough to be dwarf galaxies, form tails behind the new galaxy.

galactic nucleus A bulge of older stars (population II, *see* POPULATION TYPE) that surrounds the centre of a galaxy. The spiral arms of a spiral galaxy (such as the Milky Way) originate at the galactic nucleus.

galactose A simple sugar, $C_6H_{12}O_6$, stereoisomeric with glucose, that occurs naturally as one of the products of the enzymic digestion of milk sugar (lactose) and as a constituent of gum arabic.

galactosidase *See* LACTASE.

galaxy A vast collection of stars, dust, and gas held together by the mutual gravitational attraction between its components. Galaxies are usually classified as elliptical, spiral, or irregular in shape. **Elliptical galaxies** appear like ellipsoidal clouds of stars, with very little internal structure apart from (in some cases) a denser nucleus. **Spiral galaxies** are flat disc-shaped collections of stars with prominent spiral arms. **Irregular galaxies** have no apparent structure or shape.

The sun belongs to a spiral galaxy known as the **Galaxy** (with a capital G) or the **Milky**

Way System. There are some 10^{11} stars in the system, which is about 30 000 parsecs across with a maximum thickness at the centre of about 4000 parsecs. The sun is about 10 000 parsecs from the centre of the Galaxy.

The galaxies are separated from each other by enormous distances, the nearest large galaxy to our own (the Andromeda galaxy) being about 6.7×10^5 parsecs away.

galaxy cluster A group of *galaxies containing many hundreds of members extending over a radius of up to a few megaparsecs (there also exist small groups of galaxies, such as the *Local Group, with a few tens of members). The richest and most regular clusters, such as the **Coma cluster**, with thousands of members, are gravitationally bound systems; it is not certain whether other less regular and less concentrated clusters are also bound. As well as galaxies, the clusters contain hot **intracluster gas**, at temperatures between 10^7 and 10^8 K; this can be detected by its X-ray emission. On a scale larger than clusters there are also **superclusters**, with extents of the order of a hundred megaparsecs, containing about a hundred galaxies. It is not known whether superclusters are gravitationally bound. *See also* MISSING MASS.

Galen (*c.* 130–*c.* 200) Greek physician, who studied in Pergamum, Corinth, and Alexandria. He practised in Pergamum before moving to Rome. Galen's writings from this time became the basis of medical teaching and practice for 1500 years.

galena A mineral form of lead(II) sulphide, PbS, crystallizing in the cubic system; the chief ore of lead. It usually occurs as grey metallic cubes, frequently in association with silver, arsenic, copper, zinc, and antimony. Important deposits occur in Australia (at Broken Hill), Germany, the USA (especially in Missouri, Kansas, and Oklahoma), and the UK.

Galilean satellites The four largest satellites (moons) of Jupiter, so-called because they were discovered and described by Galileo in 1610. They are, in order of increasing distance from the planet, Io, Europa, Ganymede and Callisto. The largest is Ganymede, which, with a diameter of 5262 kilometres, is about 7% larger than the planet Mercury.

Galilean telescope *See* TELESCOPE.

Galilean transformations A set of equations for transforming the position and motion parameters from a frame of reference with origin at O and coordinates (x,y,z) to a frame with origin at O′ and coordinates at (x',y',z'). They are:

$$x' = x - vt$$

$$y' = y$$

$$z' = z$$

$$t' = t$$

The equations conform to Newtonian mechanics. *Compare* LORENTZ TRANSFORMATIONS.

Galileo Galilei (1564–1642) Italian astronomer and physicist. In 1583 he noticed that the time of swing of a *pendulum is independent of its amplitude, and three years later invented a hydrostatic balance for measuring *relative densities. He became a professor in Padua in 1592 and it was there (in 1610) that he made his first astronomical telescope. With it he discovered four satellites of Jupiter, mountains on the moon, and sunspots. Returning to Pisa, his birthplace, he studied motion, demonstrating that the speed of a falling body is independent of its weight. He also gave open support to the sun-centred theory of the universe advocated by *Copernicus, a stand that brought him into conflict with the church. He was summoned to Rome, forced to retract before the Inquisition, and banished under house arrest.

gall An abnormal growth of a plant tissue or organ elicited by a foreign organism. Galls most frequently occur as swellings or pits in stems, roots, leaves, and buds. Organisms responsible for their formation include bacteria, viruses, fungi, nematodes, mites, and insects. The gall structure is typically very distinct from surrounding normal tissue and often is characteristic of the eliciting organism. The mechanisms underlying gall formation are known in only a few cases. The bacterium **Agrobacterium tumefaciens*, which is responsible for crown galls, induces a genetic change in infected host tissue by transfer of a plasmid bearing tumour-forming genes.

gall bladder A small pouch attached to the *bile duct, present in most vertebrates. *Bile, produced in the *liver, is stored in the gall bladder and released when food (especially fatty substances) enters the duodenum.

gallium Symbol Ga. A soft silvery metallic element belonging to group 13 (formerly IIIB) of the periodic table; a.n. 31; r.a.m. 69.72; r.d. 5.90 (20°C); m.p. 29.78°C; b.p. 2403°C. It occurs in zinc blende, bauxite, and kaolin, from which it can be extracted by fractional electrolysis. It also occurs in gallite, $CuGaS_2$, to an extent of 1%; although bauxite only contains 0.01% this is the only commercial source. The two stable isotopes are gallium–69 and gallium–71; there are eight radioactive isotopes, all with short half-lives. The metal has only a few minor uses (e.g. as an activator in luminous paints), but gallium arsenide is extensively used as a semiconductor in many applications. Gallium corrodes most other metals because it rapidly diffuses into their lattices. Most gallium(I) and some gallium(II) compounds are unstable. The element was first identified by Paul Lecoq de Boisbaudran (1838–1912) in 1875.

SEE WEB LINKS

- Information from the WebElements site

gallon **1. (Imperial gallon)** The volume occupied by exactly ten pounds of distilled water of density 0.998 859 gram per millilitre in air of density 0.001 217 gram per millilitre. 1 gallon = 4.546 09 litres (cubic decimetres). **2.** A unit of volume in the US Customary system equal to 0.832 68 Imperial gallon, i.e. 3.785 44 litres.

GALP *See* GLYCERALDEHYDE 3-PHOSPHATE.

Galvani, Luigi (1737–98) Italian physiologist. In the late 1770s he observed that the muscles of a dead frog twitched when touched by two different metals. He concluded that the muscle was producing electricity, later disproved by *Volta (who showed that the two metals and body fluids formed a battery). Galvani invented *galvanized iron and the *galvanometer.

galvanic cell *See* VOLTAIC CELL.

galvanized iron Iron or steel that has been coated with a layer of zinc to protect it from corrosion. Corrugated mild-steel sheets for roofing and mild-steel sheets for dustbins, etc., are usually galvanized by dipping them in molten zinc. The formation of a brittle zinc–iron alloy is prevented by the addition of small quantities of aluminium or magnesium. Wire is often galvanized by a cold electrolytic process as no alloy forms in this process. Galvanizing is an effective method of protecting steel because even if the surface is scratched, the zinc still protects the underlying metal. *See* SACRIFICIAL PROTECTION.

galvanometer An instrument for detecting and measuring small electric currents. In the moving-coil instrument a pivoted coil of fine insulated copper wire surrounds a fixed soft-iron core between the poles of a permanent magnet. The interaction between the field of the permanent magnet and the sides of the coil, produced when a current flows through it, causes a torque on the coil. The moving coil carries either a pointer or a mirror that deflects a light beam when it moves; the extent of the deflection is a measure of the strength of the current. The galvanometer can be converted into an *ammeter or a *voltmeter. Digital electronic instruments are increasingly replacing the moving-coil type. *See also* BALLISTIC GALVANOMETER.

gametangium An organ that produces gametes. The term is usually restricted to the sex organs of algae, fungi, mosses, and ferns. *See* ANTHERIDIUM; ARCHEGONIUM; OOGONIUM.

gamete A reproductive cell that fuses with another gamete to form a zygote. Examples of gametes are ova and spermatozoa. Gametes are *haploid, i.e. they contain half the normal (diploid) number of chromosomes; thus when two fuse, the diploid number is restored (*see* FERTILIZATION). Gametes are formed by *meiosis. *See also* SEXUAL REPRODUCTION.

gametogenesis The processes involved in the formation of gametes. Gametes are normally formed by *meiosis but sometimes by *mitosis (as in the gametophyte generation of the ferns). In mammals gametogenesis in the female is known as *oogenesis and occurs in the ovaries; in the male it is known as *spermatogenesis and occurs in the testes.

gametophyte The generation in the life cycle of a plant that bears the gamete-producing sex organs. The gametophyte is *haploid. It is the dominant phase in the life cycle of mosses and liverworts, the *sporophyte generation depending on it either partially or completely. In clubmosses, horsetails, and ferns it is the *prothallus. In seed plants it is very much reduced. For example, in angiosperms the pollen grain is the male gametophyte and the embryo sac is the female gametophyte. *See also* ALTERNATION OF GENERATIONS.

gamma-aminobutyric acid (GABA) An

inhibitory *neurotransmitter in the central nervous system (principally the brain) that is capable of increasing the permeability of *postsynaptic membranes. GABA is synthesized by *decarboxylation of the amino acid glutamate.

gamma globulin *See* GLOBULIN.

gammahydroxybutyric acid *See* 4-HYDROXYBUTANOIC ACID.

gamma-iron *See* IRON.

gamma radiation Electromagnetic radiation emitted by excited atomic nuclei during the process of passing to a lower excitation state. Gamma radiation ranges in energy from about 10^{-15} to 10^{-10} joule (10 keV to 10 MeV) corresponding to a wavelength range of about 10^{-10} to 10^{-14} metre. A common source of gamma radiation is cobalt–60, the

$$^{60}_{27}\mathrm{Co} \xrightarrow{\beta} {}^{60}_{28}\mathrm{Ni} \xrightarrow{\gamma} {}^{60}_{28}\mathrm{Ni}$$

The de-excitation of nickel–60 is accompanied by the emission of gamma-ray photons having energies 1.17 MeV and 1.33 MeV.

gamma-ray astronomy *Astronomy involving gamma ray photons (with energies in excess of 100 MeV). The cosmic radiation with the highest energy can be detected by electron–photon cascades, which take place in the atmosphere. Gamma rays having lower energies can only be detected above the atmosphere. Many high-energy processes in *astrophysics are responsible for the production of gamma rays; one example is the decay of neutral *pions.

An interesting phenomenon is the **gamma-ray burst**. These events last for a few seconds, during which they are the strongest source of gamma rays in the sky. It is thought that they may be the result of the formation of a *black hole, either when a large star collapses or when two neutron stars collide.

ganglion A mass of nervous tissue containing many *cell bodies and *synapses, usually enclosed in a connective-tissue sheath. In vertebrates most ganglia occur outside the central nervous system; exceptions are the *basal ganglia in the brain. In invertebrates ganglia occur along the nerve cords and the most anterior pair (**cerebral ganglia**) are analogous to the vertebrate brain; invertebrate ganglia constitute a part of the central nervous system.

gangue Rock and other waste material present in an ore.

ganoid scale *See* SCALES.

garnet Any of a group of silicate minerals that conform to the general formula $A_3B_2(SiO_4)_3$. The elements representing A may include magnesium, calcium, manganese, and iron(II); those representing B may include aluminium, iron(III), chromium, or titanium. Six varieties of garnet are generally recognized:
pyrope, $Mg_3Al_2Si_3O_{12}$;
almandine, $Fe_3^{2+}Al_2Si_3O_{12}$;
spessartite, $Mn_3Al_2Si_3O_{12}$;
grossularite, $Ca_3Al_2Si_3O_{12}$;
andradite, $Ca_3(Fe^{3+},Ti)_2Si_3O_{12}$;
uvarovite, $Ca_3Cr_2Si_3O_{12}$.
Varieties of garnet are used as gemstones and abrasives.

gas A state of matter in which the matter concerned occupies the whole of its container irrespective of its quantity. In an *ideal gas, which obeys the *gas laws exactly, the molecules themselves would have a negligible volume and negligible forces between them, and collisions between molecules would be perfectly elastic. In practice, however, the behaviour of real gases deviates from the gas laws because their molecules occupy a finite volume, there are small forces between molecules, and in polyatomic gases collisions are to a certain extent inelastic (*see* EQUATION OF STATE).

gas chromatography A technique for separating or analysing mixtures of gases by *chromatography. The apparatus consists of a very long tube containing the stationary phase. This may be a solid, such as kieselguhr (**gas–solid chromatography**, or **GSC**), or a nonvolatile liquid, such as a hydrocarbon oil coated on a solid support (**gas–liquid chromatography**, or **GLC**). The sample is often a volatile liquid mixture, which is vaporized and swept through the column by a carrier gas (e.g. hydrogen). The components of the mixture pass through the column at different rates because they adsorb to different extents on the stationary phase. They are detected as they leave, either by measuring the thermal conductivity of the gas or by a flame detector.

Gas chromatography is usually used for analysis; components can be identified by the time they take to pass through the column. It is sometimes also used for separating mixtures.

Gas chromatography is often used to separate a mixture into its components, which

are then directly injected into a mass spectrometer. This technique is known as **gas chromatography–mass spectroscopy** or **GCMS**.

gas constant (universal molar gas constant) Symbol *R*. The constant that appears in the **universal gas equation** (*see* GAS LAWS). It has the value 8.314 510(70) J K^{-1} mol^{-1}.

gas-cooled reactor *See* NUCLEAR REACTOR.

gaseous exchange The transfer of gases between an organism and the external environment in either direction. It occurs by diffusion across a *concentration gradient and includes the exchange of oxygen and carbon dioxide in respiration and photosynthesis. Successful gaseous exchange requires a large surface area, as is provided by the alveoli of the lungs and the leaves of plants.

gas equation *See* GAS LAWS.

gas giant Any of the four large outer planets of the solar system – *Jupiter, *Saturn, *Uranus, or *Neptune – or a planet with similar physical characteristics found in another solar system.

gas laws Laws relating the temperature, pressure, and volume of an *ideal gas. *Boyle's law states that the pressure (p) of a specimen is inversely proportional to the volume (V) at constant temperature (pV = constant). The modern equivalent of *Charles' law states that the volume is directly proportional to the thermodynamic temperature (T) at constant pressure (V/T = constant); originally this law stated the constant expansivity of a gas kept at constant pressure. The pressure law states that the pressure is directly proportional to the thermodynamic temperature for a specimen kept at constant volume. The three laws can be combined in the **universal gas equation**, $pV = nRT$, where n is the amount of gas in the specimen and R is the *gas constant. The gas laws were first established experimentally for real gases, although they are obeyed by real gases to only a limited extent; they are obeyed best at high temperatures and low pressures. *See also* EQUATION OF STATE.

gasohol A mixture of petrol (gasoline) and alcohol (i.e. typically ethanol at 10%, or methanol at 3%), used as an alternative fuel for cars and other vehicles in many countries. The ethanol is obtained as a *biofuel by fermentation of agricultural crops or crop residues, for example sugar cane waste. The percentage of ethanol in the fuel is denoted by the **E number**. Many cars can use a mixture of 85% ethanol and 15% petrol, called E85. Ethanol-based gasohol has a higher octane rating and burns more completely than conventional petrol, thus lowering some emissions. However, the ethanol can damage certain engine components, such as rubber seals. Methanol-based gasohol is more toxic and corrosive, and its emissions include formaldehyde, a known carcinogen. It is not widely used.

gas oil A high-density petroleum fraction (between kerosene and lubricating oil), whose molecules have up to 25 carbon atoms. It is used as a domestic and industrial heating fuel.

gasoline *See* PETROLEUM.

gas-phase electrophoresis *See* ION-MOBILITY SPECTROMETRY.

gas thermometer A device for measuring temperature in which the working fluid is a gas. It provides the most accurate method of measuring temperatures in the range 2.5 to 1337 K. Using a fixed mass of gas a **constant-volume thermometer** measures the pressure of a fixed volume of gas at relevant temperatures, usually by means of a mercury *manometer and a *barometer.

gastric Of or relating to the stomach.

gastric juice An acidic mixture of inorganic salts, hydrochloric acid (*see* OXYNTIC CELL), mucus, and *pepsinogens secreted by **gastric glands** in the stomach lining.

gastric mill (proventriculus) A type of *gizzard occurring in many crustaceans. It is situated in the anterior region of the stomach and consists of a set of bones (ossicles) and muscles that grind food particles. The food particles are then filtered by bristles in the posterior section of the stomach.

gastrin A hormone, produced in the stomach, that controls the release of gastric juice. The secretion of gastrin is stimulated by the presence of food in the stomach. It is one of the hormones that integrates and controls digestive processes (*see also* SECRETIN).

Gastropoda A class of molluscs that includes the snails, whelks, limpets, land and sea slugs, and conches. Molluscs have a well-developed head with tentacles, a large flattened foot, and a coiled twisted shell. They

occupy marine, freshwater, and terrestrial habitats; in the terrestrial and some freshwater gastropods the *mantle cavity acts as a lung instead of enclosing gills.

gastrula The stage in the *development of an animal embryo that succeeds the *blastula. It begins with the production of the primary *germ layers and the embryo becomes converted to a cup-shaped structure containing a cavity (the *archenteron).

gas turbine An internal-combustion engine in which the products of combustion of a fuel burnt in compressed air are expanded through a turbine. Atmospheric air is compressed by a rotary compressor driven by the turbine, fed into a combustion chamber, and mixed with the fuel (kerosene, natural gas, etc.); the expanding gases drive the turbine and power is taken from the unit by means of rotation of the turbine shaft (as in locomotives) or thrust from a jet (as in aircraft).

gate **1.** An electronic circuit with a single output and one or more inputs; the output is a function of the input or inputs. In the **transmission gate** the output waveform is a replica of a selected input during a specific interval. In the **switching gate** a constant output is obtained for a specified combination of inputs. These gates are the basic components of digital computers. *See* LOGIC CIRCUITS. **2.** The electrode in a field-effect *transistor that controls the current through the channel.

Gattermann reaction A variation of the *Sandmeyer reaction for preparing chloro- or bromoarenes by reaction of the diazonium compound. In the Gattermann reaction the aromatic amine is added to sodium nitrite and the halogen acid (10°C), then fresh copper powder (e.g. from Zn + $CuSO_4$) is added and the solution warmed. The diazonium salt then forms the haloarene, e.g.

$$C_6H_5N_2^+Cl^- \rightarrow C_6H_5Cl + N_2$$

The copper acts as a catalyst. The reaction is easier to perform than the Sandmeyer reaction and takes place at lower temperature, but generally gives lower yields. It was discovered in 1890 by the German chemist Ludwig Gattermann (1860–1920).

gauche conformation *See* CONFORMATION.

gauge boson A spin-one vector boson that mediates interactions governed by *gauge theories. Examples of gauge bosons are photons in *quantum electrodynamics, gluons in *quantum chromodynamics, and W and Z bosons that mediate the interactions in the Weinberg–Salam model unifying electromagnetic and weak interactions (*see* ELECTROWEAK THEORY). If the *gauge symmetry of the theory is unbroken, the gauge boson is massless. Examples of massless gauge bosons include the photon and gluon. If the gauge symmetry of the theory is a *broken symmetry, the gauge boson has a nonzero mass, examples being the W and Z bosons. Treating gravity, as described by the general theory of *relativity, as a gauge theory, the gauge boson is the massless spin-two *graviton.

gauge theory Any of a number of *quantum field theories put forward to explain fundamental interactions. A gauge theory involves a symmetry *group for the fields and potentials (the **gauge group**). In the case of electrodynamics, the group is Abelian whereas the gauge theories for strong and weak interactions use non-Abelian groups. Non-Abelian gauge theories are known as **Yang–Mills theories**. This difference explains why *quantum electrodynamics is a much simpler theory than *quantum chromodynamics, which describes the strong interactions, and *electroweak theory, which is the unified theory of the weak and electromagnetic interactions. In the case of quantum gravity, the gauge group is even more complicated than the gauge groups for either the strong or weak interactions.

In gauge theories the interactions between particles can be explained by the exchange of particles (intermediate vector bosons, or *gauge bosons), such as gluons, photons, and W and Z bosons.

gauss Symbol G. The c.g.s. unit of magnetic flux density. It is equal to 10^{-4} tesla.

Gauss, Karl Friedrich (1777–1855) German mathematician and physicist, who became director of Göttingen Observatory in 1806. One of the greatest mathematicians of all time, he contributed to the theory of numbers and proved the fundamental theorem of algebra. His collaboration with Wilhelm *Weber on electromagnetism led to the invention of an electric telegraph, and he worked out the relationship between electric flux and electric field (*see* GAUSS' LAW).

Gaussian distribution *See* NORMAL DISTRIBUTION.

Gaussian units A system of units for electric and magnetic quantities based upon c.g.s. electrostatic and electromagnetic units. Although replaced by *SI units in most branches of science, they are, like Heaviside–Lorentz units, still used in relativity theory and in particle physics. In Gaussian units, the electric and magnetic constants are both equal to unity.

Gauss' law The total electric flux normal to a closed surface in an electric field is proportional to the algebraic sum of the electric charges within the surface. A similar law applies to surfaces drawn in a magnetic field and the law can be generalized for any vector field through a closed surface. It was first stated by Karl Gauss.

gaussmeter A *magnetometer, especially one calibrated in gauss.

Gauss' theorem *See* DIVERGENCE THEOREM.

Gay-Lussac's law **1.** When gases combine chemically the volumes of the reactants and the volume of the product, if it is gaseous, bear simple relationships to each other when measured under the same conditions of temperature and pressure. The law was first stated in 1808 by Joseph Gay-Lussac (1778–1850) and led to *Avogadro's law. **2.** *See* CHARLES' LAW.

gaylussite A mineral consisting of a hydrated mixed carbonate of sodium and calcium, $Na_2CO_3.CaCO_3.5H_2O$.

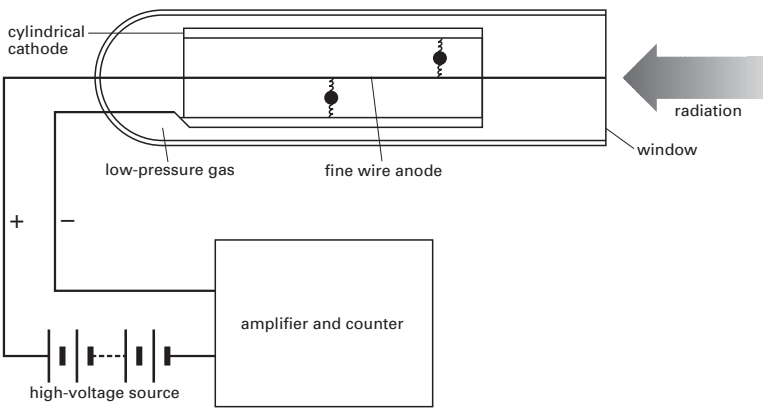
GCMS *See* GAS CHROMATOGRAPHY.

gebi- *See* BINARY PREFIXES.

Gegenschein (German: counterglow) A faint elliptical patch of light visible on a moonless night on the ecliptic at a point 180° from the position of the sun. It is caused by the reflection of sunlight by meteoric particles (*see also* ZODIACAL LIGHT).

Geiger, Hans Wilhelm (1882–1945) German physicist, who carried out research with *Rutherford at Manchester University before returning to Germany in 1912. In 1908 he and Rutherford produced the *Geiger counter, improved in 1928 as the Geiger–Müller counter. In 1909 his scattering experiments with alpha particles led to Rutherford's nuclear theory of the atom.

Geiger counter (Geiger–Müller counter) A device used to detect and measure *ionizing radiation. It consists of a tube containing a low-pressure gas (usually a mixture of methane with argon or neon) and a cylindrical hollow cathode through the centre of which runs a fine-wire anode (see illustration). A potential difference of about 1000 volts is maintained between the electrodes. An ionizing particle or photon passing through a window into the tube will cause an ion to be produced and the high p.d. will accelerate it towards its appropriate electrode, causing an avalanche of further ionizations by collision. The consequent current pulses can be counted in electronic circuits or simply amplified to work a small loudspeaker in



Geiger counter.

the instrument. It was first devised in 1908 by Hans Geiger. Geiger and W. Müller produced an improved design in 1928.

Geissler tube An early form of gas-discharge tube designed to demonstrate the luminous effects of an electric discharge passing through a low-pressure gas between two electrodes. Modified forms are used in spectroscopy as a source of light. It was invented in 1858 by Heinrich Geissler (1814–79).

g

gel A lyophilic *colloid that has coagulated to a rigid or jelly-like solid. In a gel, the disperse medium has formed a loosely-held network of linked molecules through the dispersion medium. Examples of gels are silica gel and gelatin.

gelatin(e) A colourless or pale yellow water-soluble protein obtained by boiling collagen with water and evaporating the solution. It swells when water is added and dissolves in hot water to form a solution that sets to a gel on cooling. It is used in photographic emulsions and adhesives, in bacteriology for preparing culture media, in pharmacy for preparing capsules and suppositories, and in jellies and other foodstuffs.

gel electrophoresis *See* ELECTROPHORESIS.

gel filtration A type of column *chromatography in which a mixture of liquids is passed down a column containing a gel. Small molecules in the mixture can enter pores in the gel and move slowly down the column; large molecules, which cannot enter the pores, move more quickly. Thus, mixtures of molecules can be separated on the basis of their size. The technique is used particularly for separating proteins but it can also be applied to other polymers and to cell nuclei, viruses, etc.

gelignite A high explosive made from nitroglycerin, cellulose nitrate, sodium nitrate, and wood pulp.

Gell-Mann, Murray (1929–) US theoretical physicist, who held a professorship at the California Institute of Technology. In 1955 he proposed the property of *strangeness for certain fundamental particles. In 1961 he and Yuval Ne'eman (1925–2006) proposed the eightfold way to define the structure of particles. This led to Gell-Mann's postulate of the quark (*see* ELEMENTARY PARTICLES). In 1969 he was awarded the Nobel Prize for physics.

gem Designating molecules in which two functional groups are attached to the same atom in a molecule. For example, the compound 1,1-dichloroethane (CH_3CHCl_2) is a gem dihalide and can be named *gem*-dichloroethane. *Compare* VICINAL.

gemmation A type of *vegetative propagation in which small clumps of undifferentiated cells (**gemmae**) develop on the surface of a plant. These are shed and dispersed to other areas, where they grow to produce new individuals. Gemmation is found only in certain lower plants, such as mosses and liverworts.

gene A unit of heredity composed of DNA. In classical genetics (*see* MENDELISM; MENDEL'S LAWS) a gene is visualized as a discrete particle, forming part of a *chromosome, that determines a particular characteristic. It can exist in different forms called *alleles, which determine which aspect of the characteristic is shown (e.g. tallness or shortness for the characteristic of height).

A gene occupies a specific position (*locus) on a chromosome. In view of the discoveries of molecular genetics, it may be defined as the sequence of nucleotides of DNA (or RNA) concerned with a specific function, such as the synthesis of a single polypeptide chain or of a messenger RNA molecule, corresponding to a particular sequence of the *genetic code. One or more of these **structural genes**, coding for protein, may be associated with other genes controlling their expression (*see* OPERON).

gene amplification The multiple replication of a section of the *genome, which occurs during a single cell cycle and results in the production of many copies of a specific sequence of the DNA molecule. For example, in the oocytes of amphibians and other animals, in which large numbers of ribosomes are needed, the genes encoding ribosomal RNA are greatly amplified. Viral genes that cause the formation of tumours (*see* ONCOGENE) are amplified in tumour cells.

gene bank *See* DNA LIBRARY.

gene cloning (DNA cloning) The production of exact copies (**clones**) of a particular gene or genes using genetic engineering techniques. The DNA containing the target gene(s) is split into fragments using *restric-

tion enzymes. Alternatively, complementary DNA (cDNA) can be made from messenger RNA by the enzyme reverse transcriptase. These fragments are then inserted into cloning *vectors, such as bacterial plasmids or bacteriophages, which transfer the recombinant DNA to suitable host cells, such as the bacterium *E. coli*.

Inside the host cell the recombinant DNA undergoes replication; thus, a bacterial host will give rise to a colony of cells each containing identical cloned DNA fragments. Various screening methods may be used to identify such colonies, enabling them to be selected and cultured. The collection of bacterial colonies containing the cloned fragments represents a *DNA library. Gene cloning facilitates *DNA sequencing; it also enables large quantities of a desired protein product to be produced: human insulin, for example, is now produced by bacteria containing the cloned insulin gene.

gene expression The manifestation of the effects of a gene by the production of the particular protein, polypeptide, or type of RNA whose synthesis it controls. Individual genes can be 'switched on' (exert their effects) or 'switched off' according to the needs and circumstances of the cell at a particular time. A number of mechanisms are thought to be responsible for the control of gene expression; the *Jacob–Monod hypothesis postulates the mechanism operating in prokaryotes (*see* OPERON). Control of gene expression is more complicated in eukaryotes, which possess various control mechanisms not seen in prokaryotes. For example, the methylation of cytosine bases of specific genes in eukaryotic DNA (**DNA methylation**) is observed in cells in which the gene is not expressed; if DNA methylation is prevented by the use of inhibitory chemicals, this can cause certain genes to be expressed.

gene imprinting (molecular imprinting) The differential expression of a gene according to whether it is derived from the mother or father. This leads to unequal genetic contributions from the mother and father to their offspring and is essential for normal development. For example, loss of maternal imprinting in mice results in an abnormally large fetus, whereas loss of paternal imprinting leads to a small fetus. Several human diseases are associated with failures of imprinting, including Angelman syndrome and Prader–Willi syndrome.

gene knockout *See* KNOCKOUT.

gene library *See* DNA LIBRARY.

gene manipulation *See* BIOTECHNOLOGY; GENETIC ENGINEERING.

gene mutation *See* POINT MUTATION.

Gene Ontology *See* ONTOLOGY.

gene pool All the *genes and their different alleles that are present in a population of a particular species of organism. *See also* POPULATION GENETICS.

gene probe A single-stranded DNA or RNA fragment used in genetic engineering to search for a particular gene or other DNA sequence. The probe has a base sequence complementary to the target sequence and will thus attach to it by *base pairing. By labelling the probe with a radioactive isotope or fluorescent label it can be identified on subsequent separation and purification. Probes of varying lengths, up to about 100 nucleotides, can be constructed in the laboratory. They are used in the *Southern blotting technique to identify particular DNA fragments, for instance in conjunction with *restriction mapping to diagnose gene abnormalities or to map certain sequences.

general circulation of the atmosphere *See* WIND.

general theory of relativity *See* RELATIVITY.

generation A group of organisms of approximately the same age within a population. Organisms that are crossed to produce offspring in a genetics study are referred to as the **parental generation** and their offspring as the first **filial generation**. *See also* F_1; F_2; P.

generation time **1.** (in physics) The average time that elapses between the creation of a neutron by fission in a nuclear reactor and a fission produced by that neutron. **2.** (in biology) The interval between the beginnings of consecutive cell divisions. It may be as short as 20 minutes in bacteria. *See also* INTERPHASE.

generative nucleus One of the two male gametes in the *pollen tube of angiosperms.

generator Any machine that converts mechanical power into electrical power. Electromagnetic generators are the main source of electricity and may be driven by steam turbines, water turbines, internal-combus-

tion engines, windmills, or by some moving part of any other machine. In power stations, generators produce alternating current and are often called **alternators**.

gene sequencing *See* DNA SEQUENCING.

gene silencing *See* KNOCKOUT; RNA INTERFERENCE.

gene splicing A stage in the processing of messenger *RNA (*see* TRANSCRIPTION), occurring only in eukaryote cells, in which non-coding *introns are removed from the primary mRNA transcript and the coding *exons are spliced together to form the functional mRNA molecule. Splicing is catalysed by a complex of small RNA molecules and proteins called a **spliceosome**. In some organisms, self-splicing of mRNA is known to occur.

gene therapy The application of genetic engineering techniques to alter or replace defective genes. Techniques currently being investigated involve the transfer of normal genes into the genetic material of the cell to replace the defective gene and the use of *knockout techniques to inactivate defective genes in certain tissues. *Retroviruses are often used as *vectors for transferring genes into cells as part of the natural retrovirus life cycle involves the insertion of their own genetic material into the chromosomes of their host. Alternatively *liposomes may be used. Gene therapy is being developed in an attempt to cure and prevent such single-gene diseases as cystic fibrosis.

genetically modified organisms (GMOs) Organisms whose genomes incorporate and express genes from another species. Genetically modified (or **transgenic**) individuals are created by genetic engineering, using suitable *vectors to insert the desired foreign gene into the fertilized egg or early embryo of the host. GMOs offer considerable commercial potential. See Feature (pp 352–353).

genetic code The means by which genetic information in *DNA controls the manufacture of specific proteins by the cell. The code takes the form of a series of triplets of bases in DNA, from which is transcribed a complementary sequence of *codons in messenger *RNA (*see* TRANSCRIPTION). The sequence of these codons determines the sequence of amino acids during *protein synthesis. There are 64 possible codes from the combinations of the four bases present in DNA and messenger RNA and 20 amino acids present in body proteins: some of the amino acids are coded by more than one codon, and some codons have other functions (*see* START CODON; STOP CODON). See illustration.

genetic engineering (recombinant DNA technology) The techniques involved in altering the characters of an organism by inserting genes from another organism into its DNA. This altered DNA (known as **recombinant DNA**) is usually produced by *gene cloning. Genetic engineering has many applications, ranging from the commercial production of hormones, vaccines, etc., to the creation of genetically modified crop plants in agriculture. *See* GENETICALLY MODIFIED ORGANISMS (Feature). *See also* DNA LIBRARY; GENE PROBE.

genetic fingerprinting *See* DNA PROFILING.

genetic mapping *See* CHROMOSOME MAP; LINKAGE MAP; PHYSICAL MAP; RESTRICTION MAPPING.

genetic marker *See* MARKER GENE; MOLECULAR MARKER.

genetics The branch of biology concerned with the study of heredity and variation. **Classical genetics** is based on the work of Gregor Mendel (*see* MENDELISM). During the 20th century genetics expanded to overlap with the fields of ecology and animal behaviour (*see* BEHAVIOURAL GENETICS; POPULATION GENETICS), and important advances in biochemistry and microbiology led to clarification of the chemical nature of *genes and the ways in which they can replicate and be transmitted, creating the field of **molecular genetics**. Since the 1980s, automated DNA sequencing techniques coupled with advances in computerized data handling have enabled rapid determination of the nucleotide sequences of entire genomes. The *bioinformatics revolution has allowed evolutionary relationships to be traced at the genome level and gene function to be analysed at the cellular level. *See also* GENETIC ENGINEERING.

SEE WEB LINKS

- Essential genetic topics described using entertaining animations, produced by the Genetic Science Learning Center of Utah State University

genetic screening The process by which the genome of a human or other organism is analysed for genetic markers that indicate

First base in codon	Second base in codon				Third base in codon
	U	C	A	G	
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA (stop codon)	UGA (stop codon)*	A
	UUG Leu	UCG Ser	UAG (stop codon)	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg†	A
	AUG Met (start codon)	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

*UGA encodes tryptophan in mitochondrial DNA
†AGA is a stop codon in mitochondrial DNA

Genetic code.

the presence of particular genes, especially ones that cause or predispose to certain diseases. Increased knowledge of the human genome (*see* HUMAN GENOME PROJECT) and technological advances have simplified genetic screening in persons with a family history of certain inherited diseases, e.g. certain forms of breast cancer. Clinical gene testing is now used routinely to screen for many different genes, either to assess the risk of disease in susceptible individuals or their offspring or to confirm a diagnosis of inherited disease. Commercial gene test kits are also available to the general population, although claims that these can determine the risk of healthy individuals developing, say, heart disease or cancer should be treated with caution. Such tests have major implications for the insurance industry as well as for medicine. For example, some healthy individuals may be expected to pay a higher premium for life insurance because genetic screening reveals the presence of such genes. *See also* PREIMPLANTATION GENETIC DIAGNOSIS.

genetic variation *See* VARIATION.

gene tracking A method for determining the inheritance of a particular gene in a family. It is used in the diagnosis of genetic diseases, such as cystic fibrosis and Huntington's disease. Molecular markers, such as *single nucleotide polymorphisms or *restriction fragment length polymorphisms (RFLPs) situated in or near the locus of interest, are identified using *gene probes, and suitable markers selected. These can then be traced through members of the family and used to detect the presence or absence of the

GENETICALLY MODIFIED ORGANISMS

Since the early 1980s developments in genetic engineering have made it possible to produce genetically modified organisms. A gene from one organism is isolated and transferred to cells of another organism, where it is incorporated into the recipient's chromosomes and expressed. Such transgenic organisms can exhibit quite novel characteristics. Since the 1990s there has been a dramatic growth in the commercial applications of this new technology, ranging from the production of human hormones in bacteria and vaccines in yeasts to the development of genetically modified (GM) crop plants.

Techniques

Various methods are used to introduce novel genes, depending on the nature of the recipient organism. Much of the work with genetic modification of plants involves *protoplasts, cultured spherical cells from which the cell walls have been removed. The Ti plasmid (see illustration) of *Agrobacterium tumefaciens*, the bacterium that is responsible for the tumorous growths of crown-gall disease in plants, has been used successfully as a *vector with certain dicotyledons, including tobacco, tomato, potato, soyabean, and cotton. It works much less well with grasses, cereals, and other monocots. In these plants various other techniques are available, including:

- electroporation – treatment of cells by exposure to an electric field that renders them transiently permeable to DNA fragments;
- microinjection – injection of DNA directly into the cell nucleus;
- biolistics – 'shooting' a cell with a DNA-coated tungsten microprojectile, which penetrates the cell wall with minimal damage.

To produce a transgenic animal the novel genes are inserted at a very early stage of development, e.g. the early embryo or the pronucleus of a fertilized egg, typically using microinjection. The recombinant embryos are then transferred to the uterus of a foster mother where they complete their development.

Applications

Plants

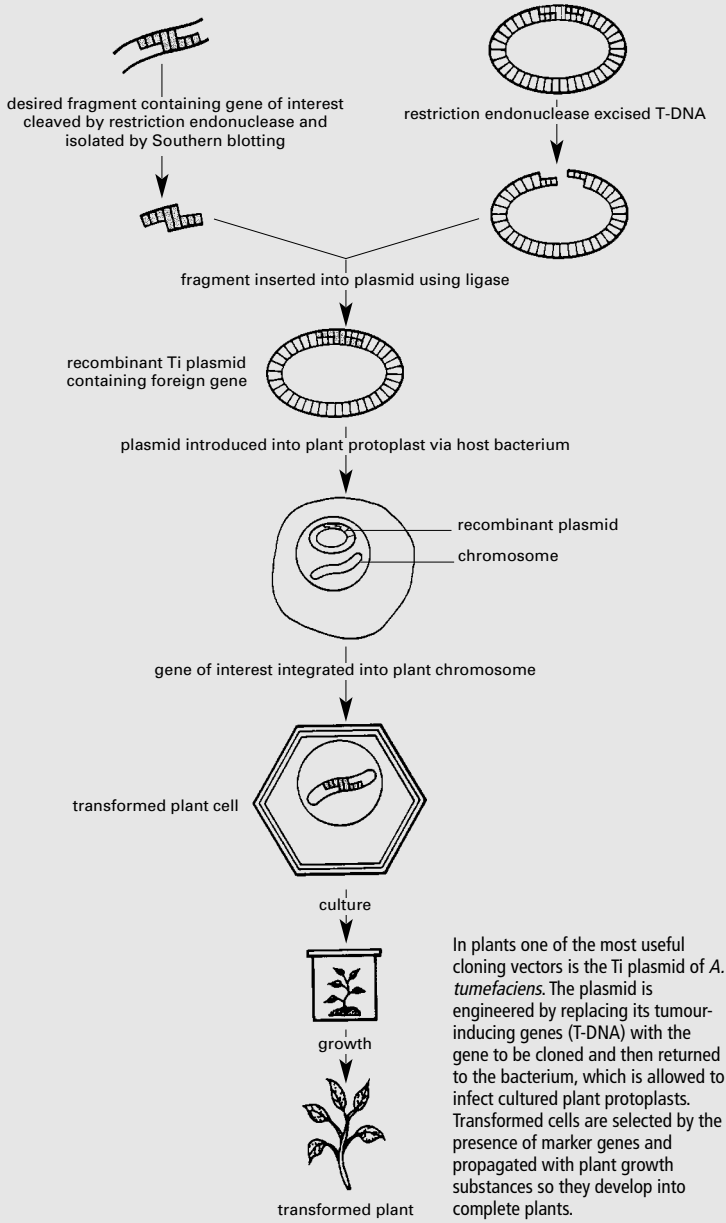
- tolerance to herbicides
- improved insect resistance
- 'vaccination' against specific diseases
- longer 'shelf life' for fruit

Animals

- production of therapeutic proteins in milk
- potential for improved growth rates and milk yields
- potential for production of organs for human transplants

Risks

The use of GM organisms in the environment poses certain potential problems. For example, genes for herbicide or insect resistance may spread from crop plants to wild plants, with possible serious consequences for both agriculture and natural ecosystems. Farmers may be faced with new 'superweeds', while insect populations could decline. Moreover, the products of GM crops have to be fully evaluated to ensure that they are safe to eat. Genetic modification of animals often has unforeseen side-effects and raises ethical issues about such treatments.



In plants one of the most useful cloning vectors is the Ti plasmid of *A. tumefaciens*. The plasmid is engineered by replacing its tumour-inducing genes (T-DNA) with the gene to be cloned and then returned to the bacterium, which is allowed to infect cultured plant protoplasts. Transformed cells are selected by the presence of marker genes and propagated with plant growth substances so they develop into complete plants.

disease locus prenatally in future at-risk pregnancies.

genome All the genes contained in a single set of chromosomes, i.e. in a *haploid nucleus. Each parent, through its reproductive cells, contributes its genome to its offspring.

genome project Any undertaking, whether by a single organization or a consortium of scientific institutions, to map and sequence the entire genome of an organism. The bacterium *Haemophilus influenzae* was the first organism to be sequenced; the first eukaryotic genome to be sequenced was that of the budding yeast *Saccharomyces cerevisiae*. A massive international collaboration resulted in the sequencing of the human genome, completed in 2003 (*see* HUMAN GENOME PROJECT). According to the Genomes OnLine Database (GOLD), by early 2009 there were nearly 4500 genome projects, either completed or ongoing, involving species drawn from all groups of organisms.

genomics The branch of genetics concerned with the study of genomes. It has developed since the 1980s, exploiting automated techniques and computer-based systems to collect and analyse vast amounts of data on nucleotide and amino-acid sequences of various organisms, generated by projects such as the *Human Genome Project. There are several distinct but overlapping areas of genomics. **Structural genomics** is essentially about mapping the genome, and ultimately producing a complete DNA sequence for any particular organism, but is often extended to include determination of three-dimensional molecular structures of nucleic acids and proteins (*see* PROTEOMICS). **Functional genomics** deals with gene expression and how gene products work. This highly complex area, which involves analysis of transcripts of sets of genes (*see* TRANSCRIPTOMICS), seeks to understand how gene expression is controlled and integrated and how gene functions change under different conditions, such as disease states. **Comparative genomics** identifies regions of sequence similarity between genomes of different species. Knowledge of the functional significance of a particular DNA sequence in one species allows predictions about functions of closely matching sequences in other species. In addition, such comparisons permit inferences about mechanisms of gene evolution and give insights into the evolutionary relationships of different organisms. *See also* BIOINFORMATICS; METABOLOMICS.

genotoxicity The condition resulting from the interaction of toxic agents (**genotoxins**) with DNA molecules in genes. Since the genes are passed down to the next generation, the toxicity induced by genotoxins is heritable. Genotoxins can induce mutations in chromosomes (**clastogenesis**) or in a small number of base pairs (**mutagenesis**). Genotoxic agents include X-rays, natural *carcinogens, some man-made products (e.g. acridine and vinyl chloride), and viruses.

genotype The genetic composition of an organism, i.e. the combination of *alleles it possesses. *Compare* PHENOTYPE.

genus (*pl.* **genera**) A category used in the *classification of organisms that consists of a number of similar or closely related species. The common name of an organism (especially a plant) is sometimes similar or identical to that of the genus, e.g. *Lilium* (lily), *Crocus*, *Antirrhinum*. Similar genera are grouped into families. *See also* BINOMIAL NOMENCLATURE.

geocentric universe A conception of the universe in which the earth is regarded as being at its centre. It was espoused by many ancient Greek philosophers and reached its most comprehensive form in the Ptolemaic system (*see* PTOLEMAIC ASTRONOMY), which held sway throughout the Middle Ages. In the 16th century, Copernicus revived the idea that the earth travels around the sun, which had been a minority view in antiquity. A century later Galileo and Kepler finally established the validity of the *heliocentric universe and *Copernican astronomy.

geochemistry The scientific study of the chemical composition of the earth. It includes the study of the abundance of the earth's elements and their isotopes and the distribution of the elements in environments of the earth (lithosphere, atmosphere, biosphere, and hydrosphere).

geochronology *See* VARVE DATING.

geode A globular hollow piece of rock, ranging in size from 2–30 cm across, found in lavas and limestone. The outer shell is made of chalcedony (a type of silica) and the interior hollow is lined with well-formed crystals of quartz, aligned towards the centre.

geodesic (geodesic line) The shortest dis-

tance between two points on a curved surface.

geodesy The science concerned with surveying and mapping the earth's surface to determine, for example, its exact size, shape, and gravitational field. The information supplied by geodesy in the form of locations, distances, directions, elevations, and gravity information is of use in civil engineering, navigation, geophysics, and geography.

geodetic effect The effect, predicted by the general theory of *relativity, in which a mass (e.g. the earth) distorts space–time.

SEE WEB LINKS

- The home page of NASA's Gravity Probe B experiment to investigate the geodetic effect

geodynamics The study of the motions of the earth; it includes those of the crust, mantle, and core, and the earth's rotation.

geographical information system (GIS) A computer-based system for the capture, storage, retrieval, manipulation, analysis, and display of spatial data. Geographical information systems have wide applications, for example, in forestry management, estate management, town planning, public utility management, insurance, transportation, and distribution.

geography The study of the features of the earth's surface, their distribution and interaction, and the interaction of man with them. It is divided between the physical and social sciences. **Human geography** includes economic geography, political geography, historical geography, and urban geography; **physical geography** enccompasses geomorphology, biogeography, climatology, meteorology, pedology, and hydrology. The methods used by geographers include mapmaking (cartography), remote sensing techniques (e.g. aerial photography and satellite imagery), surveying techniques, statistical analysis, and *geographical information systems.

geological time scale A time scale that covers the earth's history from its origin, estimated to be about 4600 million years ago, to the present. The chronology is divided into a hierarchy of time intervals: eons, eras, periods, epochs, ages, and chrons (see Appendix).

geology The study of the origin, structure, and composition of the earth. It is commonly subdivided into **historical geology**, which includes stratigraphy, palaeontology, and geochronology; and **physical geology**, which includes geomorphology, geophysics, geochemistry, mineralogy, petrology, crystallography, and economic geology.

geomagnetism The science concerned with the earth's magnetic field. If a bar magnet is suspended at any point on the earth's surface so that it can move freely in all planes, the north-seeking end of the magnet (N-pole) will point in a broadly northerly direction. The angle (*D*) between the horizontal direction in which it points and the geographic meridian at that point is called the **magnetic declination**. This is taken to be positive to the east of geographic north and negative to the west. The needle will not, however, be horizontal except on the **magnetic equator**. In all other positions it will make an angle (*I*) with the horizontal, called the **inclination** (or **magnetic dip**). At the **magnetic poles** $I = 90°$ (+90° at the N-pole, –90° at the S-pole) and the needle will be vertical. The positions of the poles, which vary with time, were in the 1970s approximately 76.1°N, 100°W (N) and 65.8°S, 139°E (S). The vector intensity $\boldsymbol{F}$ of the geomagnetic field is specified by *I*, *D*, and *F*, where *F* is the local magnetic intensity of the field measured in gauss or tesla (1 gauss = 10^{-4} tesla). *F*, *I*, and *D*, together with the horizontal and vertical components of *F*, and its north and east components, are called the **magnetic elements**. The value of *F* varies from about 0.2 gauss to 0.6 gauss, in general being higher in the region of the poles than at the equator, but values vary irregularly over the earth's surface with no correlation with surface features. There is also a slow unpredictable change in the local values of the magnetic elements called the **secular magnetic variation**. For example, in London between 1576 and 1800 *D* changed from +11° to –24° and *I* varied between 74° and 67°. The study of *palaeomagnetism has extended knowledge of the secular magnetic variation into the geological past and it is clear that the direction of the geomagnetic field has reversed many times. The source of the field and the cause of the variations are not known with any certainty but the source is believed to be associated with *dynamo action in the earth's liquid core.

SEE WEB LINKS

- The website of the USGS National Geomagnetism Program
- Geomagnetic data at the NPL website

geometrical isomerism *See* ISOMERISM.

geometrical optics *See* OPTICS.

geometric distribution The distribution of the number of independent Bernoulli trials before a successful result is obtained; for example, the distribution of the number of times a coin has to be tossed before a head comes up. The probability that the number of trials (x) is k is

$$P(x=k) = q^{k-1}p$$

The mean and variance are $1/p$ and q/p^2 respectively.

geometric mean *See* MEAN.

geometric series A series of numbers or terms in which the ratio of any term to the subsequent term is constant. For example, 1, 4, 16, 64, 256,… has a **common ratio** of 4. In general, a geometric series can be written:

$$a + ar + ar^2 \ldots + ar^{n-1}$$

and the sum of n terms is:

$$a(r^n - 1)/(r - 1).$$

geometrized units A system of units, used principally in general relativity, in which all quantities that have dimensions involving length, mass, and time are given dimensions of a power of length only. This is equivalent to setting the gravitational constant and the speed of light both equal to unity. *See also* GAUSSIAN UNITS; HEAVISIDE–LORENTZ UNITS; NATURAL UNITS; PLANCK UNITS.

geomorphology The study of the origin and development of landforms, excluding the major forms of the earth's surface (e.g. mountain chains and ocean basins).

geo-neutrinos Neutrinos that are emitted as a result of radioactivity inside the earth. Small numbers of geo-neutrinos have been detected in experiments. It is hoped that eventually they can be used to investigate the internal structure of the earth and to elucidate how radioactivity slows down the cooling of the earth.

geophysics The branch of science in which the principles of mathematics and physics are applied to the study of the earth's crust and interior. It includes the study of earthquake waves, geomagnetism, gravitational fields, and electrical conductivity using precise quantitative principles. In applied geophysics the techniques are applied to the discovery and location of economic minerals (e.g. petroleum). Meteorology and physical oceanography can also be considered as geophysical sciences.

geosphere The nonliving part the earth, in contrast to the living biosphere; it includes the *lithosphere, *hydrosphere, and the *earth's atmosphere. The term is also used synonymously with lithosphere.

geostationary orbit *See* SYNCHRONOUS ORBIT.

geosynchronous orbit *See* SYNCHRONOUS ORBIT.

geothermal energy Heat within the earth's interior that is a potential source of energy. Volcanoes, geysers, hot springs, and fumaroles are all sources of geothermal energy. The main areas of the world in which these energy sources are used to generate power include Larderello (Italy), Wairakei (New Zealand), Geysers (California, USA), and Reykjavik (Iceland). High-temperature porous rock also occurs in the top few kilometres of the earth's crust. Thermal energy from these reservoirs can be tapped by drilling into them and extracting their thermal energy by conduction to a fluid. The hot fluid can then be used for direct heating or to raise steam to drive a turbogenerator.

geotropism (gravitropism) The growth of plant organs in response to gravity. A main root is positively geotropic and a main stem negatively geotropic, growing downwards and upwards respectively, irrespective of the positions in which they are placed. For example, if a stem is placed in a horizontal position it will still grow upwards. *Auxins are thought to play a role in geotropism. *See* TROPISM.

geraniol An alcohol, $C_9H_{15}CH_2OH$, present in a number of essential oils.

germanium Symbol Ge. A lustrous hard metalloid element belonging to group 14 (formerly IVB) of the periodic table; a.n. 32; r.a.m. 72.59; r.d. 5.36; m.p. 937°C; b.p. 2830°C. It is found in zinc sulphide and in certain other sulphide ores, and is mainly obtained as a by-product of zinc smelting. It is also present in some coal (up to 1.6%). Small amounts are used in specialized alloys but the main use depends on its semiconductor properties. Chemically, it forms compounds in the +2 and +4 oxidation states, the germanium(IV) compounds being the more stable. The element also forms a large num-

ber of organometallic compounds. Predicted in 1871 as eka-silicon by Dmitri Mendeleev, it was discovered by Winkler in 1886.

SEE WEB LINKS

- Information from the WebElements site

German silver (nickel silver) An alloy of copper, zinc, and nickel, often in the proportions 5:2:2. It resembles silver in appearance and is used in cheap jewellery and cutlery and as a base for silver-plated wire. *See also* ELECTRUM.

germ cell Any cell in the series of cells (the **germ line**) that eventually produces *gametes. In mammals the germinal epithelium of the ovaries and testes contain the germ cells.

germinal epithelium **1.** A layer of epithelial cells on the surface of the ovary that are continuous with the *mesothelium. These cells do not give rise to the ova (they were formerly thought to do this). **2.** The layer of epithelial cells lining the seminiferous tubules of the testis, which gives rise to spermatogonia (*see* SPERMATOGENESIS).

germination **1.** The initial stages in the growth of a seed to form a seedling. The embryonic shoot (plumule) and embryonic root (radicle) emerge and grow upwards and downwards respectively. Food reserves for germination come from *endosperm tissue within the seed and/or from the seed leaves (cotyledons). *See also* EPIGEAL; HYPOGEAL. **2.** The first signs of growth of spores and pollen grains.

germ layers (primary germ layers) The layers of cells in an animal embryo at the *gastrula stage, from which are derived the various organs of the animal's body. There are two or three germ layers: an outer layer (*see* ECTODERM), an inner layer (*see* ENDODERM), and in most animal groups a middle layer (*see* MESODERM). *See also* DEVELOPMENT.

germ plasm *See* WEISMANNISM.

gestation The period in animals bearing live young (especially mammals) from the fertilization of the egg to birth of the young (parturition). In humans gestation is known as **pregnancy** and takes about nine months (40 weeks).

getter A substance used to remove small amounts of other substances from a system by chemical combination. For example, a metal such as magnesium may be used to remove the last traces of air when achieving a high vacuum. Various getters are also employed to remove impurities from semiconductors.

GeV Gigaelectronvolt, i.e. 10^9 eV. In the USA this is often written BeV, billion-electronvolt.

geyser A hot spring that regularly throws up jets of hot water and steam. The steam is formed in the geyser tube underground where groundwater comes into contact with hot rock (magma). Increased pressure may raise the boiling temperature of the water, accounting for the intermittent nature of the eruption. Steam formed below a column of water forces the water out of the vent before the steam can escape.

GFP *See* GREEN FLUORESCENT PROTEIN.

GHB Gammahydroxybutyric acid. *See* 4-HYDROXYBUTANOIC ACID.

ghrelin A peptide hormone that is secreted chiefly by cells in the stomach lining and increases hunger by stimulating the release of *neuropeptide Y from hypothalamus. It also stimulates release of growth hormone by binding to receptors in the anterior pituitary. The concentration of ghrelin in blood rises during the fasting period before a meal, thereby promoting appetite. Paradoxically, it also appears to suppress the mobilization of fat reserves in adipose tissue. Its role in regulating the body's energy balance has prompted interest in ghrelin as a potential target for anti-obesity treatments.

giant fibre A nerve fibre with a very large diameter, found in many types of invertebrate (e.g. earthworms and squids). Its function is to allow extremely rapid transmission of nervous impulses and hence rapid escape movements in emergencies.

giant impact hypothesis A hypothesis concerning the origin of the earth's moon, according to which a Mars-sized planet nicknamed Theia, having formed in the same orbital zone as the earth, was pulled toward it and eventually collided with it; Theia's iron core sank into that of the still-evolving earth, and the bulk of Theia's mantle, along with part of the earth's mantle and crust, was ejected into earth orbit. The debris formed a ring around the earth but soon coalesced to form the moon.

giant magnetoresistance A type of *magnetoresistance that occurs in thin films consisting of alternating layers of ferromag-

netic and nonmagnetic metals. In the presence of an external magnetic field there is a substantial decrease in the electrical resistance due to quantum-mechanical effects associated with the spins of the electrons of the nonmagnetic metal. Giant magnetoresistance is made use of in computer magnetic disk drives. *See also* COLOSSAL MAGNETORESISTANCE; MAGNETORESISTANCE.

giant molecular cloud (GMC) A huge area in space several hundred light-years across, consisting of molecular hydrogen. There are as many as 5000 in the Milky Way, and two of them occur in the constellation Orion. They are the largest objects in the Galaxy, each containing up to 10 million times as much material as the sun. Parts of them have collapsed under gravity and formed star-containing emission nebulae.

giant star A very large star that is highly luminous. Lying above the main sequence on a *Hertzsprung–Russell diagram, giant stars represent a late stage in *stellar evolution. *See also* RED GIANT; SUPERGIANT.

gibberellic acid (GA_3) A plant hormone that is extracted from fungal cultures and is one of the most important commercially available *gibberellins. It was discovered in 1954.

gibberellin Any of a group of plant hormones chemically related to terpenes. Gibberellins promote stem elongation and the mobilization of food reserves in germinating seeds and have a role in inducing flowering and fruit development. Commercially available gibberellins, such as *gibberellic acid, are used to manipulate the onset of sexual maturity in various species, e.g. to induce cone bearing in young conifers.

gibbous *See* PHASES OF THE MOON.

Gibbs, Josiah Willard (1839–1903) US mathematician and physicist, who spent his entire academic career at Yale University. During the 1870s he developed the theory of chemical thermodynamics, devising functions such as Gibbs *free energy; he also derived the *phase rule and was one of the founders of *statistical mechanics. In mathematics he introduced *vector notation.

Gibbs free energy (Gibbs function) *See* FREE ENERGY.

gibbsite A mineral form of hydrated *aluminium hydroxide ($Al(OH)_3$). It is named after the US mineralogist George Gibbs (d. 1833).

gibi- *See* BINARY PREFIXES.

giga- Symbol G. A prefix used in the metric system to denote one thousand million times. For example, 10^9 joules = 1 gigajoule (GJ).

gilbert Symbol Gb. The c.g.s. unit of *magnetomotive force equal to $10/4\pi$ (= 0.795 77) ampere-turn. It is named after William Gilbert.

Gilbert, William (1544–1603) English physician and physicist. He was physician to Queen Elizabeth I, and in 1600 published his famous book about magnetism, in which he likened the earth to a huge bar magnet. He was the first to use the terms 'magnetic pole' and 'electricity'.

gill **1.** (in zoology) A respiratory organ used by aquatic animals to obtain oxygen from the surrounding water. A gill consists essentially of a membrane or outgrowth from the body, with a large surface area and a plentiful blood supply, through which diffusion of oxygen and carbon dioxide between the water and blood occurs. Fishes have **internal gills**, formed as outgrowths from the pharynx wall and contained within *gill slits. Water entering the mouth is pumped out through these slits and over the gills. The gills of most aquatic invertebrates and amphibian larvae are **external gills**, which project from the body so that water passes over them as the animal moves. **2.** (in botany) One of the ridges of tissue that radiate from the centre of the underside of the cap of mushrooms. The spores are produced on these gills.

gill bar A cartilaginous support for the tissue between the gill slits in lower chordates, such as lancelets.

gill slit An opening leading from the pharynx to the exterior in aquatic vertebrates and lancelets. In lancelets they function in *filter feeding. In fish they contain the *gills and are usually in the form of a series of long slits. They are absent in adult tetrapod vertebrates (except for some amphibians) but their presence in some form in the embryos of all vertebrates is a characteristic of the phylum *Chordata.

gimbal A type of mount for an instrument (such as a *gyroscope or compass) in which

the instrument is free to rotate about two perpendicular axes.

gingiva (gum) The part of the epithelial tissue lining the mouth that covers the jaw bones. It is continuous with the sockets surrounding the roots of the teeth.

Giorgi units *See* M.K.S. UNITS.

GIS *See* GEOGRAPHICAL INFORMATION SYSTEM.

gizzard A muscular compartment of the alimentary canal of many animals that is specialized for breaking up food. In birds the gizzard lies between the *proventriculus and the duodenum and contains small stones and grit, which assist in breaking up the food when the gizzard contracts. *See also* GASTRIC MILL.

glacial ethanoic acid *See* ETHANOIC ACID.

gland A group of cells or a single cell in animals or plants that is specialized to secrete a specific substance. In animals there are two types of glands, both of which synthesize their secretions. *Endocrine glands discharge their products directly into the blood vessels; *exocrine glands secrete through a duct or network of ducts into a body cavity or onto the body surface. Secretory cells are characterized by having droplets (**vesicles**) containing their products. *See also* SECRETION.

In plants glands are specialized to secrete certain substances produced by the plant. The secretions may be retained within a single cell, secreted into a special cavity or duct, or secreted to the outside. Examples are the water glands (*hydathodes) of certain leaves, nectaries (*see* NECTAR), and the digestive glands of certain carnivorous plants.

Glaser, Donald Arthur (1926–) US physicist. In 1952, at the University of Michigan, he devised the *bubble chamber for detecting ionizing radiation. For this work he was awarded the 1960 Nobel Prize for physics.

Glashow–Weinberg–Salam model (GWS model) *See* ELECTROWEAK THEORY.

glass Any noncrystalline solid; i.e. a solid in which the atoms are random and have no long-range ordered pattern. Glasses are often regarded as supercooled liquids. Characteristically they have no definite melting point, but soften over a range of temperatures.

The common glass used in windows, bottles, etc., is **soda glass**, which is made by heating a mixture of lime (calcium oxide), soda (sodium carbonate), and sand (silicon(IV) oxide). It is a form of calcium silicate. Borosilicate glasses (e.g. **Pyrex**) are made by incorporating some boron oxide, so that silicon atoms are replaced by boron atoms. They are tougher than soda glass and more resistant to temperature changes, hence their use in cooking utensils and laboratory apparatus. Glasses for special purposes (e.g. optical glass) have other elements added (e.g. barium, lead).

glass electrode A type of *half cell having a glass bulb containing an acidic solution of fixed pH, into which dips a platinum wire. The glass bulb is thin enough for hydrogen ions to diffuse through. If the bulb is placed in a solution containing hydrogen ions, the electrode potential depends on the hydrogen-ion concentration. Glass electrodes are used in pH measurement.

glass fibres Melted glass drawn into thin fibres some 0.005 mm–0.01 mm in diameter. The fibres may be spun into threads and woven into fabrics, which are then impregnated with resins to give a material that is both strong and corrosion resistant for use in car bodies and boat building.

glauberite A mineral consisting of a mixed sulphate of sodium and calcium, $Na_2SO_4.CaSO_4$.

Glauber's salt *Sodium sulphate decahydrate, $Na_2SO_4.10H_2O$, used as a laxative. It is named after Johann Glauber (1604–68).

GLC (gas–liquid chromatography) *See* GAS CHROMATOGRAPHY.

glenoid cavity The socket-shaped cavity in the *scapula (shoulder blade) that holds the head of the *humerus in a ball-and-socket joint.

glia (glial cells; neuroglia) Cells of the nervous system that support the neurons. There are four classes of glial cells: **astrocytes**, **oligodendrocytes**, **ependymal cells**, and **microglia**. Oligodendrocytes form insulating sheaths of *myelin round neurons in the central nervous system, preventing impulses from travelling between adjacent neurons. Other functions of glial cells include providing nutrients for neurons and controlling the biochemical composition of the fluid surrounding the neurons.

glide A symmetry element in a crystal lattice that consists of a combination of a trans-

lation with a reflection about a plane. *See also* SCREW.

global positioning system (GPS) A satellite-based navigational system that, with the use of a GPS receiver, can determine any point on or above the earth's surface with a high degree of accuracy. The system uses a network of 24 satellites, designed and controlled by the US Department of Defense, originally for military use. Uses include marine and terrestrial navigation systems (e.g. satellite navigation systems in vehicles), surveying, and mapping.

SEE WEB LINKS

- FAQ covering the global positioning system provided by the US Federal Aviation Administration

global warming An increase over time of the average air temperature of the earth. Global average surface temperature increased over the 20th century by about 0.6°C, and is predicted to increase by between 1.4°C and 5.8°C during the period 1990–2100. The increase in temperature has been largely attributed to human activity in the form of increased emissions of greenhouse gases (*see* GREENHOUSE EFFECT), especially carbon dioxide, to the atmosphere and the consequent greenhouse effect. It has serious implications, for example, for changes in global climate patterns and in the melting of ice masses, such as the polar ice caps, with consequent raising of sea levels (during the 20th century global average sea level rose between 0.1 and 0.2 m). At an international level, global warming is studied by the Intergovernmental Panel on Climate Change (IPCC). International efforts to control global warming led to the **Kyoto Protocol** (an amendment to the United Nations Framework Convention on Climate Change, which was signed in 1992). The treaty was drawn up in Kyoto, Japan, in 1997, to reduce emissions of greenhouse gases; the treaty took effect in 2005, following ratification by Russia, and will require all ratifying nations to achieve individual emission reduction targets. Among countries not ratifying the treaty, most notable is the USA, the world's largest emitter of greenhouse gases, which withdrew from the Kyoto Protocol in 2001. The term *climate change is used synonymously for global warming in some areas.

globular cluster *See* STAR CLUSTER.

globular protein *See* PROTEIN.

globulin Any of a group of globular proteins that are generally insoluble in water and present in blood, eggs, milk, and as a reserve protein in seeds. Blood serum globulins comprise four types: α_1-, α_2-, and β-globulins, which serve as carrier proteins; and γ-globulins (**gamma globulins**), which include the *immunoglobulins responsible for immune responses.

glomerular filtrate The fluid in the lumen of the Bowman's capsule of the *nephron that has been filtered from the capillaries of the glomerulus (*see* ULTRAFILTRATION). The glomerular filtrate has the same composition as the plasma except that it does not contain any of the larger components, such as plasma proteins or cells.

glomerulus A tangled mass of blood capillaries enclosed by the cup-shaped end (*Bowman's capsule) of a kidney tubule (*see* NEPHRON). Fluid is filtered from these capillaries into the Bowman's capsule and down the nephron (*see* GLOMERULAR FILTRATE).

glottis The opening from the pharynx to the trachea (windpipe). In mammals it also serves as the space for the *vocal cords. *See also* EPIGLOTTIS; LARYNX.

glove box A metal box that has gloves fitted to ports in its walls. It is used to manipulate mildly radioactive materials and in laboratory techniques in which an inert, sterile, dry, or dust-free atmosphere has to be maintained.

glow discharge An electrical discharge that passes through a gas at low pressure and causes the gas to become luminous. The glow is produced by the decay of excited atoms and molecules.

glucagon A hormone, secreted by the *islets of Langerhans in the pancreas, that increases the concentration of glucose in the blood by stimulating the metabolic breakdown of glycogen. It thus antagonizes the effects of *insulin (*see* ANTAGONISM).

glucan Any *polysaccharide composed only of glucose residues, e.g. starch and glycogen.

glucocorticoid *See* CORTICOSTEROID.

gluconeogenesis The synthesis of glucose from noncarbohydrate sources, such as fat and protein. This occurs when the glycogen supplies in the liver are exhausted. The pathway is essentially a reversal of *glycolysis from pyruvate to glucose and it can utilize

many sources, including amino acids, glycerol, and *Krebs cycle intermediates. Large-scale protein and fat catabolism normally occurs only in those suffering from starvation or certain endocrine disorders.

gluconic acid An optically active hydroxycarboxylic acid,

$CH_2(OH)(CHOH)_4COOH$.

It is the carboxylic acid corresponding to the aldose sugar glucose, and can be made by the action of certain moulds.

glucosamine *See* AMINO SUGAR.

glucose (dextrose; **grape sugar)** A white crystalline sugar, $C_6H_{12}O_6$, occurring widely in nature. Like other *monosaccharides, glucose is optically active: most naturally occurring glucose is dextrorotatory. Glucose and its derivatives are crucially important in the energy metabolism of living organisms. It is a major energy source, being transported around the body in blood, lymph, and cerebrospinal fluid to the cells, where energy is released in the process of *glycolysis. Glucose is present in the sap of plants, in fruits, and in honey and is also a constituent of many polysaccharides, most notably of starch and cellulose. These yield glucose when broken down, for example by enzymes during digestion.

glucuronic acid A compound, $OC_6H_9O_6$, derived from the oxidation of glucose. It is an important constituent of *gums and *mucilages. Glucuronic acid can combine with hydroxyl (–OH), carboxyl (–COOH), or amino ($–NH_2$) groups to form a **glucuronide**. The addition of a glucuronide group to a molecule (**glucuronidation**) generally increases the solubility of a compound; hence glucuronidation plays an important role in the excretion of foreign substances (*see* PHASE II METABOLISM).

glucuronide *See* GLUCURONIC ACID.

glueball A hypothetical bound state consisting of two or more gluons (*see* ELEMENTARY PARTICLES). Glueballs are thought to be unstable and decay rapidly into *hadrons. There is some indirect experimental evidence for glueballs.

gluino *See* SUPERSYMMETRY.

gluon *See* ELEMENTARY PARTICLES.

glutamate The anion of the amino acid glutamic acid. It functions as a neurotransmitter at excitatory synapses in the vertebrate central nervous system and at excitatory neuromuscular junctions in insects and crustaceans.

glutamic acid *See* AMINO ACID; GLUTAMATE.

glutamine *See* AMINO ACID.

glutaric acid *See* PENTANEDIOIC ACID.

glutathione A *peptide comprising the amino acids glutamic acid, cysteine, and glycine. It occurs widely in plants, animals, and microorganisms, serving chiefly as an antioxidant. Reduced glutathione reacts with potentially harmful oxidizing agents and is itself oxidized. This is important in ensuring the proper functioning of proteins, haemoglobin, membrane lipids, etc. Glutathione is also involved in amino acid transport across plasma membranes.

gluten A mixture of two proteins, gliadin and glutenin, occurring in the endosperm of wheat grain. Their amino acid composition varies but glutamic acid (33%) and proline (12%) predominate. The composition of wheat glutens determines the 'strength' of the flour and whether or not it is suitable for biscuit or bread making. Sensitivity of the lining of the intestine to gluten occurs in **coeliac disease**, a condition that must be treated by a gluten-free diet.

glycaemic index (GI) An indication of how eating a particular food will affect the concentration of glucose in the blood. GI is determined relative to the effects of a standard test meal of (usually) 50 g of glucose in a fasting individual, which is given the value 100. Foods with a high GI (typically >85), such as bread, rice, and potatoes, cause blood glucose to rise rapidly following ingestion, whereas the increase is lower and more prolonged in foods with a low GI (< 60), such as apples, beans, and yoghurt. Lower GI foods are recommended to optimize control of blood glucose for diabetics.

glycan *See* POLYSACCHARIDE.

glyceraldehyde 3-phosphate (GALP) A triose phosphate, $CHOCH(OH)CH_2OPO_3H_2$, that is an intermediate in the *Calvin cycle (*see also* PHOTOSYNTHESIS) and glycolysis.

glycerate 3-phosphate A phosphorylated three-carbon monosaccharide that is an intermediate in the *Calvin cycle of photosynthesis and also in *glycolysis. It was for-

merly known as **3-phosphoglycerate** or **phosphoglyceric acid** (**PGA**).

glyceride (acylglycerol) A fatty-acid ester of glycerol. Esterification can occur at one, two, or all three hydroxyl groups of the glycerol molecule producing mono-, di-, and triglycerides respectively. *Triglycerides are the major constituent of fats and oils found in living organisms. Alternatively, one of the hydroxyl groups may be esterified with a phosphate group forming a phosphoglyceride (*see* PHOSPHOLIPID) or to a sugar forming a **glycolipid**.

glycerine *See* GLYCEROL.

glycerol (glycerine; propane-1,2,3,-triol) A trihydric alcohol, $HOCH_2CH(OH)CH_2OH$. Glycerol is a colourless sweet-tasting viscous liquid, miscible with water but insoluble in ether. It is widely distributed in all living organisms as a constituent of the *glycerides, which yield glycerol when hydrolysed. Glycerol itself is used as an *antifreeze molecule by certain organisms.

glycerophospholipid *See* PHOSPHOLIPID.

glycine A sweet-tasting *amino acid that, besides being a component of proteins, is the main inhibitory neurotransmitter for fast synapses in the spinal cord of vertebrates.

glycobiology The study of carbohydrates and carbohydrate complexes, especially *glycoproteins.

glycogen (animal starch) A *polysaccharide consisting of a highly branched polymer of glucose occurring in animal tissues, especially in liver and muscle cells. It is the major store of carbohydrate energy in animal cells and is present as granular clusters of minute particles.

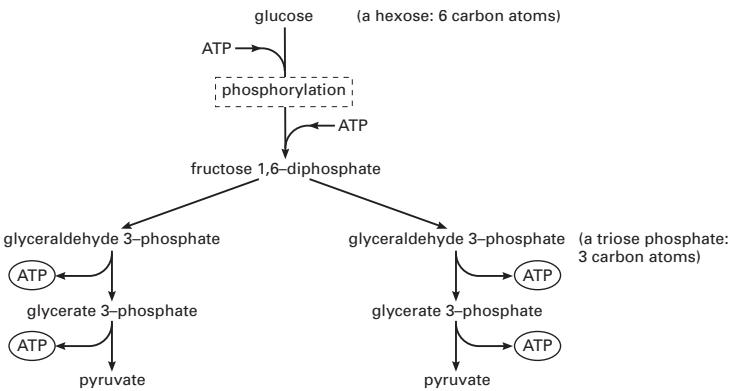
glycogenesis The conversion of glucose to glycogen, which is stimulated by insulin from the pancreas. Glycogenesis occurs in skeletal muscles and to a lesser extent in the liver. Glucose that is taken up by cells is phosphorylated to glucose 6-phosphate; this is converted successively to glucose 1-phosphate, uridine diphosphate glucose, and finally to glycogen. *See also* GLUCONEOGENESIS. *Compare* GLYCOGENOLYSIS.

glycogenolysis The conversion of glycogen to glucose, which occurs in the liver and is stimulated by glucagon from the pancreas and adrenaline from the adrenal medulla. These hormones activate an enzyme that phosphorylates glucose molecules in the glycogen chain to form glucose 1-phosphate, which is converted to glucose 6-phosphate. This is then converted to glucose by a phosphatase enzyme. In skeletal muscle glycogen is degraded to glucose 6-phosphate, which is then converted into pyruvate and used in ATP production during glycolysis and the Krebs cycle. However, pyruvate can also be converted, in the liver, to glucose; thus muscle glycogen is indirectly a source of blood glucose. *Compare* GLYCOGENESIS.

glycol *See* ETHANE-1,2-DIOL.

glycolipid *See* GLYCERIDE.

glycolysis (Embden–Meyerhof pathway) The series of biochemical reactions in which



Glycolysis. The principal stages.

glucose is broken down to pyruvate with the release of usable energy in the form of *ATP (see illustration). One molecule of glucose undergoes two phosphorylation reactions and is then split to form two triose-phosphate molecules. Each of these is converted to pyruvate. The net energy yield is two ATP molecules per glucose molecule. In *aerobic respiration pyruvate then enters the *Krebs cycle. Alternatively, when oxygen is in short supply or absent, the pyruvate is converted to various products by *anaerobic respiration. Other simple sugars, e.g. fructose and galactose, and glycerol (from fats) enter the glycolysis pathway at intermediate stages. *Compare* GLUCONEOGENESIS.

glycoprotein A carbohydrate linked covalently to a protein. Formed in the Golgi apparatus in the process of *glycosylation, glycoproteins are important components of plasma membranes, in which they extend throughout the *lipid bilayer. They are also constituents of body fluids, such as mucus, that are involved in lubrication. Many of the hormone receptors on the surfaces of cells are glycoproteins. Glycoproteins produced by viruses attach themselves to the surface of the host cell, where they act as markers for the receptors of leucocytes. Viral glycoproteins can also act as target molecules and help viruses to detect certain types of host cell; for example, a glycoprotein on the surface of *HIV enables the virus to find and infect white blood cells.

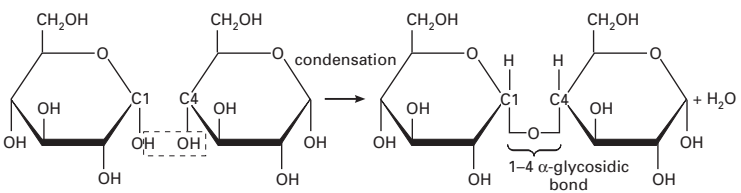
glycosaminoglycan Any one of a group of polysaccharides that contain *amino sugars (such as glucosamine). Formerly known as **mucopolysaccharides**, they include *hyaluronic acid and chondroitin (*see* CARTILAGE), which provide lubrication in joints and form part of the matrix of cartilage. The three-dimensional structure of these molecules enables them to trap water, which forms a gel and gives glycosaminoglycans their elastic properties.

glycoside Any one of a group of compounds consisting of a pyranose sugar residue, such as glucose, linked to a noncarbohydrate residue (R) by a *glycosidic bond: the hydroxyl group (–OH) on carbon-1 of the sugar is replaced by –OR. Glycosides are widely distributed in plants; examples are the *anthocyanin pigments and the **cardiac glycosides**, such as digoxin and ouabain, which are used medicinally for their stimulant effects on the heart.

glycosidic bond (glycosidic link) The type of chemical linkage between the monosaccharide units of disaccharides, oligosaccharides, and polysaccharides, which is formed by the removal of a molecule of water (i.e. a *condensation reaction). The bond is normally formed between the carbon-1 on one sugar and the carbon-4 on the other (see illustration). An α-glycosidic bond is formed when the –OH group on carbon-1 is below the plane of the glucose ring and a β-glycosidic bond is formed when it is above the plane. Cellulose is formed of glucose molecules linked by 1-4 β-glycosidic bonds, whereas starch is composed of 1-4 α-glycosidic bonds.

glycosylation The process in which a carbohydrate is joined to another molecule, such as a protein to form a *glycoprotein or to a lipid to form a glycolipid (*see* GLYCERIDE). Glycosylation occurs in the rough endoplasmic reticulum and the *Golgi apparatus of cells.

glyphosate *N*-(phosphonomethyl)-glycine: a herbicide, marketed as Roundup, that kills a wide range of plants but shows little persistence in soil and has low toxicity to animals. If applied to the leaves it is rapidly translocated to the rest of the plant,



Glycosidic bond formation.

and hence can penetrate the roots of even hardy perennials. It works by blocking the synthesis of aromatic amino acids, so that treated plants are unable to manufacture proteins and other key metabolites. Certain crops, notably soya bean, have been genetically engineered to give them resistance to glyphosate. These 'Roundup-ready' crops, which can be sprayed with the herbicide without being affected, are now widely grown in North America and elsewhere.

Gnathostomata A subphylum or superclass of chordates consisting of all vertebrates that possess jaws. It contains six extant classes: *Chondrichthyes (cartilaginous fishes), *Osteichthyes (bony fishes), *Amphibia, *Reptilia, *Aves (birds), and *Mammalia. *See also* CRANIATA.

gneiss A coarse-grained rock that is characterized by compositional banding of metamorphic origin. It consists chiefly of irregular granular bands of quartz and feldspar alternating with thin undulating bands of micas and amphiboles. Gneisses are formed during high-grade regional metamorphism; those derived from sedimentary origins are known as **paragneisses** and those from igneous origins as **orthogneisses**.

gnotobiotic Designating germ-free conditions, especially those in which experimental animals are inoculated with known strains of microorganisms.

goblet cell A goblet-shaped cell, found in the epithelium of the intestine and respiratory system in mammals and in the epidermis of fish, that secretes *mucus. Goblet cells have a wide top and constricted base and possess glycoprotein-containing vesicles.

Gödel's theorem A fundamental result in mathematics stating that, in a given mathematical structure, some propositions cannot be proved to be true or false, i.e. the propositions are undecidable, using only the axioms of that mathematical structure. The theorem was proved by the Austrian mathematician Kurt Gödel (1906–78) in 1931. The relevance of this result to fundamental physics has been extensively debated.

goethite A yellow-brown mineral, FeO.OH, crystallizing in the orthorhombic system. It is formed as a result of the oxidation and hydration of iron minerals or as a direct precipitate from marine or fresh water (e.g. in swamps and bogs). Most *limonite is composed largely of cryptocrystalline goethite. Goethite is mined as an ore of iron.

gold Symbol Au. A soft yellow malleable metallic *transition element; a.n. 79; r.a.m. 196.967; r.d. 19.32; m.p. 1064.43°C; b.p. 2807±2°C. Gold has a face-centred-cubic crystal structure. It is found as the free metal in gravel or in quartz veins, and is also present in some lead and copper sulphide ores. It also occurs combined with silver in the telluride sylvanite, $(Ag,Au)Te_2$. It is used in jewellery, dentistry, and electronic devices. Chemically, it is unreactive, being unaffected by oxygen. It reacts with chlorine at 200°C to form gold(III) chloride. It forms a number of complexes with gold in the +1 and +3 oxidation states.

SEE WEB LINKS

- Information from the WebElements site

Gold, Thomas *See* HOYLE, SIR FRED.

golden ratio A visually satisfying proportion found by dividing a line in such a way that the ratio of the smaller part to the larger part is the same as that of the larger part to the whole. It is equal to about 8:13 or about 1:1.618034, and can be expressed exactly as $1:\frac{1}{2}(1+\sqrt{5})$. *See also* FIBONACCI NUMBER.

Goldschmidt process A method of extracting metals by reducing the oxide with aluminium powder, e.g.

$$Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3$$

The reaction can also be used to produce molten iron (*see* THERMITE). It was discovered by the German chemist Hans Goldschmidt (1861–1923).

Goldstone's theorem The theorem in relativistic quantum field theory that if there is an exact continuous symmetry of the *Hamiltonian or *Lagrangian defining the system, and this is not a symmetry of the *vacuum state (i.e. there is *broken symmetry), then there must be at least one spin-zero massless particle called a **Goldstone boson**. In the quantum theory of many-body systems Goldstone bosons are *collective excitations. An important exception to Goldstone's theorem is provided in *gauge theories with the Higgs mechanism, whereby the Goldstone bosons gain mass and become *Higgs bosons. The theorem is named after Jeffrey Goldstone.

Golgi, Camillo (1843–1926) Italian cytologist, who experimented with cells and tissues while working as a physician. He later be-

came a professor at Pavia University. He devised a method of staining cells using silver salts, which enabled him to study nerve cells. He is best known for his discovery of the cell organelle now called the *Golgi apparatus. For his work on the structure of the nervous system he shared the 1906 Nobel Prize for physiology or medicine with Santiago Ramón y Cajal (1852–1934).

Golgi apparatus (Golgi complex) An assembly of vesicles and folded membranes within the cytoplasm of eukaryotic *cells that modifies proteins and packages them and other materials (e.g. polysaccharides) for delivery to the plasma membrane for secretion or to destinations within the cell. Proteins arrive in vesicles following their assembly in the *endoplasmic reticulum; after processing in the Golgi apparatus, they are sorted into **Golgi vesicles**, for secretion, storage, or transport to lysosomes. The apparatus is named after its discoverer, Camillo Golgi.

gonad Any of the usually paired organs in animals that produce reproductive cells (gametes). The most important gonads are the male *testis, which produces spermatozoa, and the female *ovary, which produces ova (egg cells). The gonads also produce hormones that control secondary sexual characteristics.

gonadotrophin (gonadotrophic hormone) Any of several hormones, secreted by the mammalian anterior *pituitary gland, that stimulate reproductive activity of the testes or ovaries (the gonads). Pituitary gonadotrophins include *follicle-stimulating hormone and *luteinizing hormone. **Chorionic gonadotrophin** is a hormone produced by the placenta of higher mammals that maintains the *corpus luteum. The presence of large amounts of **human chorionic gonadotrophin** (**hCG**) in the urine of women is an indication of pregnancy.

Gondwanaland *See* CONTINENTAL DRIFT.

Gooch crucible A porcelain dish with a perforated base over which a layer of asbestos is placed, used for filtration in gravimetric analysis. It is named after US chemist Frank Gooch (1852–1929).

Gopher A computer program used on a computer connected to the *Internet that carries out routine tasks of collecting information for the user from services attached to the Internet. Gopher presents the user with a directory of material accessible at a particular point, a set of documents that can be searched using keywords, or a document containing text or other forms of material that the computer can display. Gopher is simpler but rather less flexible than the *World Wide Web.

Gouy balance A method of measuring magnetic susceptibility. The sample is suspended from a balance, with the bottom part of the sample between the poles of an electromagnet. When the magnetic field is switched on, the sample experiences a field gradient which causes an apparent change in weight. In particular, paramagnetic substances show an increase in weight, which, after correction for a smaller diamagnetic contribution, can be used to calculate the paramagnetic part of the susceptibility. This can be used to calculate the number of unimpaired electrons in the sample. Magnetic measurements of this type are widely used to investigate the electronic structures of metal complexes. The **Evans balance** is a portable version of the Gouy balance using permanent magnets and giving a direct readout. Other methods of measuring magnetic susceptibility include magnetic resonance techniques and the use of a SQID (superconducting quantum interference device). The Gouy balance is named after the French scientist Louis Georges Gouy (1854–1926).

governor A device that maintains a motor or engine at a constant speed despite variations in the load, using the principle of negative feedback. A common method uses a set of flying balls that reduce the fuel intake as the speed increases. The balls, attached by flexible steel strips to a collar capable of moving vertically up and down a rotating shaft, move outwards as the speed increases. The collar rises as the balls fly out and is coupled to a lever that controls the fuel intake.

G protein Any one of a group of proteins that relay signals in mammalian cells. They occur on the inner surface of the plasma membrane and transmit signals from receptors on the outer surface of the cell to intracellular components. G proteins are activated by binding to GTP and become inactive when they bind to GDP (*see* GUANOSINE). The cholera toxin exerts its effects by changing the G protein in the epithelial cells of the intestine so that it is continually activated, which causes an abnormal increase in cellular adenylate cyclase levels. One consequence of this is that sodium ions are ac-

tively pumped into the intestine, causing water to follow by osmosis: the result is diarrhoea and dehydration.

G-protein-coupled receptor (GPCR) Any of a superfamily of proteins that are located in cell membranes and act as receptors by relaying signals from the exterior to the interior of the cell via associated G proteins. The latter then activate second messengers, which regulate the activity of the cell. A wide range of substances, including peptide hormones, acetylcholine, noradrenaline, gamma-aminobutyric acid, and glutamate, can bind as ligands to the various types of GPCR, at binding sites in the extracellular region of the receptor molecule. Ligand binding changes the shape of the receptor allowing the G protein to bind to it, which activates the G protein by causing GTP to replace bound GDP.

GPS *See* GLOBAL POSITIONING SYSTEM.

Graafian follicle (ovarian follicle) The fluid-filled cavity that surrounds and protects the developing egg cell in the ovary of a mammal. After the release of the ovum it develops into a *corpus luteum. It is named after the Dutch anatomist Reinier de Graaf (1641–73).

graben A long elongated block of rock or crust that sinks between a pair of parallel near-vertical faults, when they move slightly outwards. The higher bordering areas are called horsts.

grad *See* GRADIENT OPERATOR.

gradient **1.** The slope of a line. In Cartesian coordinates, a straight line $y = mx + c$, has a gradient m. For a curve, $y = f(x)$, the gradient at a point is the derivative dy/dx at that point, i.e. the slope of the tangent to the curve at that point. **2.** *See* GRADIENT OPERATOR.

gradient operator (grad) The *operator

$$\nabla = \boldsymbol{i}\,\partial/\partial x + \boldsymbol{j}\,\partial/\partial y + \boldsymbol{k}\,\partial/\partial z,$$

where $\boldsymbol{i}$, $\boldsymbol{j}$, and $\boldsymbol{k}$ are unit vectors in the x, y, and z directions. Given a scalar function f and a unit vector $\boldsymbol{n}$, the *scalar product $\boldsymbol{n}.\nabla f$ is the rate of change of f in the direction of $\boldsymbol{n}$. *See also* CURL; DIVERGENCE.

graft An isolated portion of living tissue that is joined to another tissue, either in the same or a different organism, the consequent growth resulting in fusion of the tissues. (The word is also used for the process of joining the tissues.) Grafting of plant tissues is a horticultural practice used to propagate plants, especially certain bushes and fruit trees, artificially. A shoot or bud of the desired variety (the **scion**) is grafted onto a rootstock of either a common or a wild related species (the **stock**). The scion retains its desirable characteristics (e.g. flower form or fruit yield) and supplies the stock with food made by photosynthesis. The stock supplies the scion with water and mineral salts and affects only the size and vigour of the scion. Animal and human grafts are used to replace faulty or damaged parts of the body. An **autograft** is taken from one part of the body and transferred to another part of the same individual, e.g. a skin graft used for severe burns. An **allograft** (**homograft**) is taken from one individual (the **donor**) and implanted in another of the same species (the **recipient**), the process being known as **transplantation**, e.g. a heart or kidney transplant. In such cases the graft may be regarded by the body as foreign (a state of **incompatibility**): an *immune response follows and the graft is rejected (*see also* HISTOCOMPATIBILITY).

graft copolymer *See* POLYMER.

graft hybrid A type of plant *chimaera that may be produced when a part of one plant (the scion) is grafted onto another plant of a different genetic constitution (the stock). Shoots growing from the point of union of the graft contain tissues from both the stock and the scion.

Graham, Thomas (1805–69) Scottish chemist, who became professor of chemistry at Glasgow University in 1830, moving to University College, London, in 1837. His 1829 paper on gaseous diffusion introduced *Graham's law. He went on to study diffusion in liquids, leading in 1861 to the definition of *colloids.

Graham's law The rates at which gases diffuse is inversely proportional to the square roots of their densities. This principle is made use of in the diffusion method of separating isotopes. The law was formulated in 1829 by Thomas Graham.

gram Symbol g. One thousandth of a kilogram. The gram is the fundamental unit of mass in *c.g.s. units and was formerly used in such units as the **gram-atom**, **gram-molecule**, and **gram-equivalent**, which have now been replaced by the *mole.

Gram's stain A staining method used to differentiate bacteria. The bacterial sample is smeared on a microscope slide, stained with a violet dye, treated with acetone-alcohol (a decolourizer), and finally counterstained with a red dye. **Gram-positive** bacteria retain the first dye, appearing blue-black under the microscope. In **Gram-negative** bacteria, the acetone-alcohol washes out the violet dye and the counterstain is taken up, the cells appearing red. It is named after the Danish bacteriologist Hans Gram (1853–1938), who first described the technique (since modified) in 1884.

grand unified theory (GUT) A theory that attempts to combine the strong, weak, and electromagnetic interactions into a single *gauge theory with a single symmetry group. There are a number of different theories, most of which postulate that the interactions merge at high energies into a single interaction (the standard model emerges from the GUT as a result of *broken symmetry). The energy above which the interactions are the same is around 10^{15} GeV, which is much higher than those obtainable with existing accelerators.

One prediction of GUTs is the occurrence of *proton decay. Some also predict that the neutrino has nonzero mass. There is no evidence for proton decay at present, although there is some evidence that neutrinos have very small nonzero masses. *See also* SUPERSTRING THEORY.

granite An extremely hard light-coloured acid igneous rock consisting mainly of plagioclase feldspar and quartz (average 25%), with some biotite (mica), hornblende, or other coloured mineral. It generally results from the slow solidification of molten *magma, giving it a coarse grain size. Some granites result from metamorphism of pre-existing rocks.

granulocyte Any white blood cell (*see* LEUCOCYTE) that contains granular material (**secretory vesicles**) and *lysosomes in its cytoplasm. *Neutrophils and *basophils are examples of granulocytes. *Compare* AGRANULOCYTE.

granum (*pl.* **grana**) A stack of platelike bodies (**thylakoids**), many of which are found in plant *chloroplasts (each chloroplast contains about 50 grana). Grana bear the light-receptive pigment chlorophyll and contain the enzymes responsible for the light-dependent reactions of *photosynthesis.

grape sugar *See* GLUCOSE.

graph A diagram that illustrates the relationship between two variables. It usually consists of two perpendicular axes, calibrated in the units of the variables and crossing at a point called the **origin**. Points are plotted in the spaces between the axes and the points are joined to form a curve. *See also* CARTESIAN COORDINATES; POLAR COORDINATES.

graphene A single sheet of carbon atoms arranged in hexagons. Graphene can be regarded as a single plane of graphite and is of interest because it has some unusual and potentially useful electrical properties.

graphite *See* CARBON.

graphite-moderated reactor *See* NUCLEAR REACTOR.

graph theory The area of mathematics that deals with *graphs and their properties. It has important applications in *topology and in the construction of certain types of *algorithms, as used in some computer programs.

graptolites A group of extinct marine colonial animals that were common in the Palaeozoic era. Graptolites are generally regarded as being related to colonial soft-bodied marine invertebrates called pterobranchs. They had chitinous outer skeletons in the form of simple or branched stems, the individual polyps occupying minute cups (**thecae**) along these stems. Fossils of these skeletons are found in Palaeozoic rocks of all continents; they are particularly abundant in Ordovician and Silurian rock strata, for which they are used as *index fossils. At the end of the Silurian many graptolites became extinct but a few groups continued into the early Carboniferous.

grass-green bacteria *See* CYANOBACTERIA.

grassland A major terrestrial *biome in which the dominant plants are species of grass; the rainfall is insufficient to support extensive growth of trees, which are also suppressed by grazing animals. Tropical grassland (**savanna**), which covers much of Africa south of the Sahara, has widely spaced trees, such as acacias and baobabs, and supports large herds of grazing animals and

their predators. Temperate grasslands, such as the **steppes** of Asia, the **prairies** of North America, and the **pampas** of South America, have few trees and are largely used for agriculture.

graticule (in optics) A network of fine wires or a scale in the eyepiece of a telescope or microscope or on the stage of a microscope, or on the screen of a cathode-ray oscilloscope for measuring purposes.

grating *See* DIFFRACTION GRATING.

gravimetric analysis A type of quantitative analysis that depends on weighing. For instance, the amount of silver in a solution of silver salts could be measured by adding excess hydrochloric acid to precipitate silver chloride, filtering the precipitate, washing, drying, and weighing.

gravitation *See* NEWTON'S LAW OF GRAVITATION.

gravitational collapse A phenomenon predicted by the general theory of *relativity in which matter collapses as a consequence of gravitational attraction until it becomes a compact object such as a *white dwarf, *neutron star, or *black hole. The type of object depends on the initial mass. The process of gravitational collapse is important in *astrophysics as it gives rise to such phenomena as *supernova explosions and gamma-ray bursts (*see* GAMMA-RAY ASTRONOMY).

gravitational constant Symbol *G*. The constant that appears in *Newton's law of gravitation; it has the value $6.672\ 59(85) \times 10^{-11}$ N m^2 kg^{-2}. *G* is usually regarded as a universal constant although, in some models of the universe, it is proposed that it decreases with time as the universe expands.

gravitational field The region of space surrounding a body that has the property of *mass. In this region any other body that has mass will experience a force of attraction. The ratio of the force to the mass of the second body is the **gravitational field strength**.

gravitational interaction *See* FUNDAMENTAL INTERACTIONS.

gravitational lens An object that deflects light by gravitation as described by the general theory of *relativity; it is analogous to a lens in *optics. The prediction of a gravitational lensing effect in general relativity theory has been confirmed in observations on *quasars. In 1979 a 'double' quasar was discovered, due to the multiple image of a single quasar caused by gravitational lensing by a galaxy, or cluster of galaxies, along the line of sight between the observer and the quasar. The images obtained by gravitational lensing can be used to obtain information about the mass distribution of the galaxy or cluster of galaxies.

gravitational mass *See* MASS.

gravitational shift *See* REDSHIFT.

gravitational waves **1.** (in physics) Waves propagated through a *gravitational field. The prediction that an accelerating mass will radiate gravitational waves (and lose energy) comes from the general theory of *relativity. Many attempts have been made to detect waves from space directly using large metal detectors. The theory suggests that a pulse of gravitational radiation (as from a supernova explosion or *black hole) causes the detector to vibrate, and the disturbance is detected by a transducer. The interaction is very weak and extreme care is required to avoid external disturbances and the effects of thermal noise in the detecting system. So far, no accepted direct observations have been made. However, indirect evidence of gravitational waves has come from observations of a pulsar in a binary system with another star. **2.** (in oceanography) Water surface waves transmitted primarily because of the weight of the water in the crests, which causes them to collapse. Ocean waves are of this type.

SEE WEB LINKS

- The home page for the Laser Interferometer Gravitational-Wave Observatory (LIGO)

graviton A hypothetical particle or quantum of energy exchanged in a gravitational interaction (*see* FUNDAMENTAL INTERACTIONS). Such a particle has not been observed but is postulated to make the gravitational interaction consistent with quantum mechanics. It would be expected to travel at the speed of light and have zero rest mass and charge, and spin 2.

gravitropism *See* GEOTROPISM.

gravity The phenomenon associated with the gravitational force acting on any object that has mass and is situated within the earth's *gravitational field. The weight of a body (*see* MASS) is equal to the force of gravity acting on the body. According to Newton's second law of motion $F = ma$, where F

is the force producing an acceleration a on a body of mass m. The weight of a body is therefore equal to the product of its mass and the acceleration due to gravity (g), which is now called the *acceleration of free fall. By combining the second law of motion with *Newton's law of gravitation ($F = GM_1M_2/d^2$) it follows that: $g = GM/d^2$, where G is the *gravitational constant, M is the mass of the earth, and d is the distance of the body from the centre of the earth. For a body on the earth's surface $g = 9.806\ 65\ \text{m s}^{-2}$.

A force of gravity also exists on other planets, moons, etc., but because it depends on the mass of the planet and its diameter, the strength of the force is not the same as it is on earth. If F_e is the force acting on a given mass on earth, the force F_p acting on the same mass on another planet will be given by:

$$F_p = F_e d_e^2 M_p / M_e d_p^2,$$

where M_p and d_p are the mass and diameter of the planet, respectively. Substituting values of M_p and d_p for the moon shows that the force of gravity on the moon is only 1/6 of the value on earth.

SEE WEB LINKS

- The home page of the NASA/JPL Gravity Recovery and Climate experiment to make precise measurements of the earth's gravitational field

gray Symbol Gy. The derived SI unit of absorbed *dose of ionizing radiation (*see* RADIATION UNITS). It is named after the British radiobiologist L. H. Gray (1905–65).

grazing The consumption of vegetation, usually on *grassland, by animals, particularly cattle and sheep. Overgrazing can lead to *desertification.

grazing incidence telescope A type of astronomical telescope designed to work at X-ray and gamma-ray wavelengths. Its mirror consists of a paraboidal annulus of metal, which deflects incoming photons striking it at an acute angle. The deflected high-energy photons are detected by a spark chamber.

Great Attractor A huge concentration of mass, equivalent to about a million galaxies, beyond the Hydra and Centaurus constellations. Our own Galaxy and others near to it are heading towards the Great Attractor at a rate of about 600 kilometres per second.

great circle Any circle on a sphere formed by a plane that passes through the centre of the sphere. The equator and the meridians of longitude are all great circles on the earth's surface.

green algae *See* CHLOROPHYTA.

green fluorescent protein (GFP) A naturally fluorescent protein obtained from the jellyfish *Aequorea victoria* and used as a marker for identifying cells containing recombinant DNA or for localizing specific proteins in cells. It absorbs blue light and emits a green fluorescence, and hence the abundance and location of GFP in cells can be visualized microscopically under ultraviolet light. Several colour variants of GFP are now available.

greenhouse effect An effect occurring in the atmosphere because of the presence of certain gases (**greenhouse gases**) that absorb infrared radiation. Light and ultraviolet radiation from the sun are able to penetrate the atmosphere and warm the earth's surface. This energy is re-radiated as infrared radiation, which, because of its longer wavelength, is absorbed by such substances as carbon dioxide. The greenhouse effect is a natural phenomenon, without which the earth's climate would be much more hostile to life. However, emissions of carbon dioxide from human activities (e.g. farming, industry, and transport) have increased markedly in the last 150 years or so. The overall effect is that the average temperature of the earth and its atmosphere is increasing (*see* GLOBAL WARMING). The effect is similar to that occurring in a greenhouse, where light and long-wavelength ultraviolet radiation can pass through the glass into the greenhouse but the infrared radiation is absorbed by the glass and part of it is re-radiated into the greenhouse. The greenhouse effect is seen as a major environmental hazard. Average increases in temperature are likely to change weather patterns and agricultural output. It is already causing the polar ice caps to melt, with a corresponding rise in sea level. Carbon dioxide, from coal-fired power stations and car exhausts, is the main greenhouse gas. Other contributory pollutants are nitrogen oxides, ozone, methane, and *chlorofluorocarbons. Many countries have now agreed targets to limit emissions of greenhouse gases, e.g. by switching to renewable energy sources. *See also* POLLUTION.

greenhouse gas *See* GREENHOUSE EFFECT.

greenockite A mineral form of cadmium sulphide, CdS.

Green's function One of a set of functions that are used for solving *differential equations with *boundary conditions. It was named after the British mathematician George Green (1793–1841).

green vitriol *See* IRON(II) SULPHATE.

Gregorian telescope *See* TELESCOPE.

Greisen–Zatsepin–Kuzmin limit *See* GZK LIMIT.

g

grey matter Part of the tissue that makes up the central nervous system of vertebrates. It is brown-grey in colour, consisting largely of nerve *cell bodies, *synapses, and *dendrites. The grey matter is the site of coordination between nerves of the central nervous system. *Compare* WHITE MATTER.

grid **1.** (in electricity) The system of overhead wires or underground cables by which electrical power is distributed from power stations to users. The grid is at a high voltage, up to 750 kV in some countries. **2.** (in electronics) *See* CONTROL GRID. **3.** (in cartography) A network of horizontal and vertical lines on a map that provide a means of locating a specific point.

Griess test A test for nitrates or nitrites, once widely used to detect the possible existence of gunshot residue.

Grignard reagents A class of organometallic compounds of magnesium, with the general formula RMgX, where R is an organic group and X a halogen atom (e.g. CH_3MgCl, C_2H_5MgBr, etc.). They actually have the structure $R_2Mg.MgCl_2$, and can be made by reacting a haloalkane with magnesium in ether; they are rarely isolated but are extensively used in organic synthesis, when they are made in one reaction mixture. Grignard reagents have a number of reactions that make them useful in organic synthesis. With methanal they give a primary alcohol

$$CH_3MgCl + HCHO \rightarrow CH_3CH_2OH$$

Other aldehydes give a secondary alcohol

$$CH_3CHO + CH_3MgCl \rightarrow (CH_3)_2CHOH$$

With alcohols, hydrocarbons are formed

$$CH_3MgCl + C_2H_5OH \rightarrow C_2H_5CH_3$$

Water also gives a hydrocarbon

$$CH_3MgCl + H_2O \rightarrow CH_4$$

The compounds are named after their discoverer, the French chemist Victor Grignard (1871–1935).

grooming The actions of an animal of rearranging fur or feathers and cleaning the body surface by biting, scratching, licking, etc., which is important for removing parasites and spreading oils over the body surface. In many mammals, especially primates, grooming between individuals (**allogrooming**) has an important role in maintaining social cohesion.

ground state The lowest stable energy state of a system, such as a molecule, atom, or nucleus. *See* ENERGY LEVEL.

ground substance The matrix of connective tissue, in which various cells and fibres are embedded. The ground substance of cartilage consists of *chondrin. *See* EXTRACELLULAR MATRIX.

ground tissues All the plant tissues formed by the *apical meristems except the epidermis and vascular tissue. The principal ground tissues are the *cortex, *pith, and primary *medullary rays, and they consist chiefly of *parenchyma.

Collenchyma is a form of ground tissue less frequently observed. It consists of living cells with additional cellulose thickening in the walls, giving them additional strength, and is most commonly found in the stem cortex.

groundwater **1. (subterranean water)** Water that occurs below the surface of the ground, as opposed to that at the surface. **2. (phreatic water)** Water that occurs below the surface in soil or rocks that are saturated, either in cavities and pores (through which it can flow) or below the water table. Groundwater has an erosive action in permeable rocks, such as limestone, in which it can form underground rivers and caves.

ground wave A radio wave that travels in approximately a straight line between points on the earth's surface. For transmission over longer distances sky waves have to be involved. *See* RADIO TRANSMISSION.

group **1.** (in physics) A set of elements *A, B, C,* etc., for which there exists a law of composition, referred to as 'multiplication'. Any two elements can be combined to give a 'product' *AB.*
(1) Every product of two elements is an element of the set.

(2) The operation is associative, i.e. $A(BC) = (AB)C$.
(3) The set has an element I, called the **identity element**, such that $IA = AI = A$ for all A in the set.
(4) Each element of the set has an **inverse** A^{-1} belonging to the set such that $AA^{-1} = A^{-1}A = I$.

Although the law of combination is called 'multiplication' this does not necessarily have its usual meaning. For example, the set of integers forms a group if the law of composition is addition.

Two elements A, B of a group **commute** if $AB = BA$. If all the elements of a group commute with each other the group is said to be **Abelian**. If this is not the case the group is said to be **non-Abelian**. The distinction between Abelian and non-Abelian groups is of fundamental importance in *gauge theories.

The interest of group theory in physics and chemistry is in analysing symmetry. **Discrete groups** have a finite number of elements, such as the symmetries involved in rotations and reflections of molecules, which give rise to **point groups**. **Continuous groups** have an infinite number of elements where the elements are continuous. An example of a continuous group is the set of rotations about a fixed axis. The **rotation group** thus formed underlies the *quantum theory of *angular momentum, which has many applications to *atoms and *nuclei. More abstract and more general continuous groups describe fundamental interactions by gauge theories.

2. (in chemistry) *See* PERIODIC TABLE.

group 0 elements *See* NOBLE GASES.

group 1 elements A group of elements in the *periodic table: lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs), and Francium (Fr). They are known as the *alkali metals. Formerly, they were classified in group I, which consisted of two subgroups: group IA (the main group) and group IB. Group IB consisted of the *coinage metals, copper, silver, and gold, which comprise group 11 and are usually considered with the *transition elements.

group 2 elements A group of elements in the *periodic table: beryllium (Be), magnesium (Hg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra). They are known as the *alkaline-earth metals. Formerly, they were classified in group II, which consisted of two subgroups: group IIA (the main group, *see* ALKALINE-EARTH METALS) and group IIB. Group IIB consisted of the three metals zinc (Zn), cadmium (Cd), and mercury (Hg), which have two *s*-electrons outside filled *d*-subshells. Moreover, none of their compounds have unfilled *d*-levels, and the metals are regarded as nontransition elements. They now form group 12 and are sometimes called the **zinc group**. Zinc and cadmium are relatively electropositive metals, forming compounds containing divalent ions Zn^{2+} or Cd^{2+}. Mercury is more unreactive and also unusual in forming mercury(I) compounds, which contain the ion Hg_2^{2+}.

groups 3–12 *See* TRANSITION ELEMENTS.

group 13 elements A group of elements in the *periodic table: boron (B), aluminium (Al), gallium (Ga), indium (In), and thallium (Tl), which all have outer electronic configurations ns^2np^1 with no partly filled inner levels. They are the first members of the *p*-block. The group differs from the alkali metals and alkaline-earth metals in displaying a considerable variation in properties as the group is descended. Formerly, they were classified in group III, which consisted of two subgroups: group IIIB (the main group) and group IIIA. Group IIIA consisted of scandium (Sc), yttrium (Yt), and lanthanum (La), which are generally considered with the *lanthanoids, and actinium (Ac), which is classified with the *actinoids. Scandium and yttrium now belong to group 3 (along with lutetium and lawrencium).

Boron has a small atomic radius and a relatively high ionization energy. In consequence its chemistry is largely covalent and it is generally classed as a metalloid. It forms a large number of volatile hydrides, some of which have the uncommon bonding characteristic of *electron-deficient compounds. It also forms a weakly acidic oxide. In some ways, boron resembles silicon (*see* DIAGONAL RELATIONSHIP).

As the group is descended, atomic radii increase and ionization energies are all lower than for boron. There is an increase in polar interactions and the formation of distinct M^{3+} ions. This increase in metallic character is clearly illustrated by the increasing basic character of the hydroxides: boron hydroxide is acidic, aluminium and gallium hydroxides are amphoteric, indium hydroxide is basic, and thallium forms only the oxide. As the elements of group 13 have a vacant *p*-orbital they display many electron-acceptor properties. For example, many boron compounds form adducts with donors such as

ammonia and organic amines (acting as Lewis acids). A large number of complexes of the type $[BF_4]^-$, $[AlCl_4]^-$, $[InCl_4]^-$, $[TlI_4]^-$ are known and the heavier members can expand their coordination numbers to six as in $[AlF_6]^{3-}$ and $[TlCl_6]^{3-}$. This acceptor property is also seen in bridged dimers of the type Al_2Cl_6. Another feature of group 13 is the increasing stability of the monovalent state down the group. The electron configuration ns^2np^1 suggests that only one electron could be lost or shared in forming compounds. In fact, for the lighter members of the group the energy required to promote an electron from the *s*-subshell to a vacant *p*-subshell is small. It is more than compensated for by the resulting energy gain in forming three bonds rather than one. This energy gain is less important for the heavier members of the group. Thus, aluminium forms compounds of the type AlCl in the gas phase at high temperatures. Gallium similarly forms such compounds and gallium(I) oxide (Ga_2O) can be isolated. Indium has a number of known indium(I) compounds (e.g. InCl, In_2O, $In_3^I[In^{III}Cl_6]$). Thallium has stable monovalent compounds. In aqueous solution, thallium(I) compounds are more stable than the corresponding thallium(III) compounds. *See* INERT-PAIR EFFECT.

group 14 elements A group of elements in the *periodic table: carbon (C), silicon (Si), germanium (Ge), tin (Sn), and lead (Pb), which all have outer electronic configurations ns^2np^2 with no partly filled inner levels. Formerly, they were classified in group IV, which consisted of two subgroups: IVB (the main group) and group IVA. Group IVA consisted of titanium (Ti), zirconium (Zr), and hafnium (Hf), which now form group 4 and are generally considered with the *transition elements.

The main valency of the elements is 4, and the members of the group show a variation from nonmetallic to metallic behaviour in moving down the group. Thus, carbon is a nonmetal and forms an acidic oxide (CO_2) and a neutral oxide. Carbon compounds are mostly covalent. One allotrope (diamond) is an insulator, although graphite is a fairly good conductor. Silicon and germanium are metalloids, having semiconductor properties. Tin is a metal, but does have a nonmetallic allotrope (grey tin). Lead is definitely a metal. Another feature of the group is the tendency to form divalent compounds as the size of the atom increases. Thus carbon has only the highly reactive carbenes. Silicon forms analogous silylenes. Germanium has an unstable hydroxide ($Ge(OH)_2$), a sulphide (GeS), and halides. The sulphide and halides disproportionate to germanium and the germanium(IV) compound. Tin has a number of tin(II) compounds, which are moderately reducing, being oxidized to the tin(IV) compound. Lead has a stable lead(II) state. *See* INERT-PAIR EFFECT.

In general, the reactivity of the elements increases down the group from carbon to lead. All react with oxygen on heating. The first four form the dioxide; lead forms the monoxide (i.e. lead(II) oxide, PbO). Similarly, all will react with chlorine to form the tetrachloride (in the case of the first four) or the dichloride (for lead). Carbon is the only one capable of reacting directly with hydrogen. The hydrides all exist from the stable methane (CH_4) to the unstable plumbane (PbH_4).

group 15 elements A group of elements in the *periodic table: nitrogen (N), phosphorus (P), arsenic (As), antimony (Sb), and bismuth (Bi), which all have outer electronic configurations ns^2np^3 with no partly filled inner levels. Formerly, they were classified in group V, which consisted of two subgroups: group VB (the main group) and group VA. Group VA consisted of vanadium (V), niobium (Nb), and tantalum (Ta), which are generally considered with the *transition elements:

The lighter elements (N and P) are nonmetals; the heavier elements are metalloids. The lighter elements are electronegative in character and have fairly large ionization energies. Nitrogen has a valency of 3 and tends to form covalent compounds. The other elements have available *d*-sublevels and can promote an *s*-electron into one of these to form compounds with the V oxidation state. Thus, they have two oxides P_2O_3, P_2O_5, Sb_2O_3, Sb_2O_5, etc. In the case of bismuth, the pentoxide Bi_2O_5 is difficult to prepare and unstable – an example of the increasing stability of the III oxidation state in going from phosphorus to bismuth. The oxides also show how there is increasing metallic (electropositive) character down the group. Nitrogen and phosphorus have oxides that are either neutral (N_2O, NO) or acidic. Bismuth trioxide (Bi_2O_3) is basic. Bismuth is the only member of the group that forms a well-characterized positive ion Bi^{3+}.

group 16 elements A group of elements in the *periodic table: oxygen (O), sulphur (S), selenium (Se), tellurium (Te), and polonium (Po), which all have outer electronic configurations ns^2np^4 with no partly filled inner levels. They are also called the **chalcogens**. Formerly, they were classified in group VI, which consisted of two subgroups: group VIB (the main group) and group VIA. Group VIA consisted of chromium (Cr), molybdenum (Mo), and tungsten (W), which now form group 6 are generally classified with the *transition elements.

The configurations are just two electrons short of the configuration of a noble gas and the elements are characteristically electronegative and almost entirely nonmetallic. Ionization energies are high, (O 1314 to Po 813 kJ mol^{-1}) and monatomic cations are not known. Polyatomic cations do exist, e.g. O_2^+, S_8^{2+}, Se_8^{2+}, Te_4^{2+}. Electronegativity decreases down the group but the nearest approach to metallic character is the occurrence of 'metallic' allotropes of selenium, tellurium, and polonium along with some metalloid properties, in particular, marked photoconductivity. The elements of group 16 combine with a wide range of other elements and the bonding is largely covalent. The elements all form hydrides of the type XH_2. Apart from water, these materials are all toxic foul-smelling gases; they show decreasing thermal stability with increasing relative atomic mass of X. The hydrides dissolve in water to give very weak acids (acidity increases down the group). Oxygen forms the additional hydride H_2O_2 (hydrogen peroxide), but sulphur forms a range of sulphanes, such as H_2S_2, H_2S_4, H_2S_6.

Oxygen forms the fluorides O_2F_2 and OF_2, both powerful fluorinating agents; sulphur forms analogous fluorides along with some higher fluorides, S_2F_2, SF_2, SF_4, SF_6, S_2F_{10}. Selenium and tellurium form only the higher fluorides MF_4 and MF_6; this is in contrast to the formation of lower valence states by heavier elements observed in groups 13, 14, and 15. The chlorides are limited to M_2Cl_2 and MCl_4; the bromides are similar except that sulphur only forms S_2Br_2. All metallic elements form oxides and sulphides and many form selenides.

group 17 elements A group of elements in the *periodic table: fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At). They are known as the *halogens. Formerly, they were classified in group VII, which consisted of two subgroups: group VIIB (the main group) and group VIIA. Group VIIA consisted of the elements manganese (Mn), technetium (Te), and rhenium (Re), which now form group 7 and are usually considered with the transition elements.

group 18 elements A group of elements in the *periodic table: helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Rn). Formerly classified as **group 0 elements**, they are usually referred to as the *noble gases.

Grover's algorithm An algorithm, invented in 1996 by the Indian–American computer scientist Lov Grover (1961–), for searching an unsorted database on a quantum computer. It is a more efficient method of searching than a traditional algorithm, i.e. one for a conventional computer. *See also* SHOR'S ALGORITHM.

growth An increase in the dry weight or volume of an organism through cell division and cell enlargement. Growth may continue throughout the life of the organism, as occurs in woody plants, or it may cease at maturity, as in humans and other mammals. *See also* ALLOMETRIC GROWTH; EXPONENTIAL GROWTH.

growth factor Any of various chemicals, particularly polypeptides, that have a variety of important roles in the stimulation of new cell growth and cell maintenance. They bind to the cell surface on receptors. Specific growth factors can cause new cell proliferation (**epidermal growth factor**, **insulin-like growth factor** (**IGF**), **haemopoietic growth factor** – *see* HAEMOPOIETIC TISSUE) and the migration of cells (**fibroblast growth factor**) and play a role in wound healing (**platelet-derived growth factor; PDGF**). Some growth factors act in the embryonic stage of development; for example, nerve growth factor (*see* NEUROTROPHIN) stimulates the growth of axons and dendrites from developing sensory and sympathetic neurons. Some growth factors or their receptors are involved in the abnormal regulation of growth seen in cancer when produced in excessive amounts or permanently activated.

growth hormone (GH; **somatotrophin)** A hormone, secreted by the mammalian pituitary gland, that stimulates protein synthesis and growth of the long bones in the legs and arms. It also promotes the breakdown and use of fats as an energy source, rather than

glucose. Production of growth hormone is greatest during early life. Its secretion is controlled by the opposing actions of two hormones from the hypothalamus: **growth hormone releasing hormone** (**somatoliberin**), which promotes its release; and *somatostatin, which inhibits it. Overproduction of **human growth hormone** (**hGH**) results in gigantism in childhood and *acromegaly in adults; underproduction results in dwarfism. **Bovine somatotrophin** (**BST**) has been used to increase milk and meat production in cattle.

growth ring (annual ring) Any of the rings that can be seen in a cross-section of a woody stem (e.g. a tree trunk). It represents the *xylem formed in one year as a result of fluctuating activity of the vascular *cambium. In temperate climates pale soft **spring wood**, characterized by large xylem vessels, is formed in spring and early summer. Growth slows down in late summer and a darker dense **autumn wood** with smaller xylem vessels is formed (see illustration). The age of a tree can be determined by counting the rings. Under certain circumstances two or more growth rings may form in one year, giving rise to false annual rings.

growth substance *See* PLANT HORMONE.

GSC (gas–solid chromatography) *See* GAS CHROMATOGRAPHY.

G-series *See* NERVE AGENTS.

GTP (guanosine triphosphate) *See* GUANOSINE.

guanidine A crystalline basic compound $HN{:}C(NH_2)_2$, related to urea.

guanine A *purine derivative. It is one of the major component bases of *nucleotides and the nucleic acids *DNA and *RNA.

guano An accumulation of the droppings of birds, bats, or seals, usually formed by a long-established colony of animals. It is rich in plant nutrients, and some deposits are extracted for use as fertilizer.

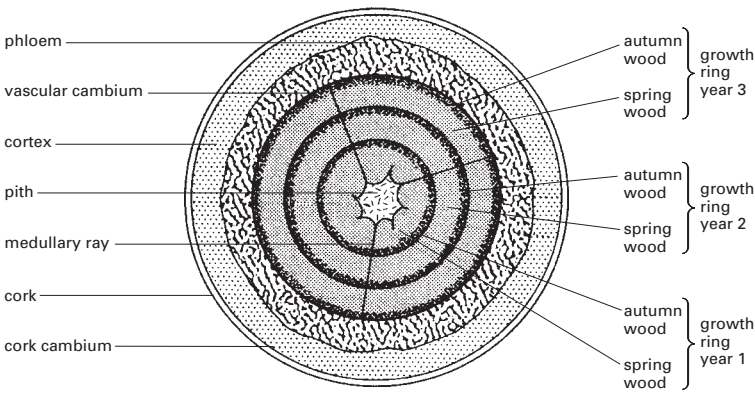
guanosine A nucleoside consisting of one guanine molecule linked to a D-ribose sugar molecule. The derived nucleotides, guanosine mono-, di-, and triphosphate (GMP, GDP, and GTP, respectively), participate in various metabolic reactions.

guard cell *See* STOMA.

guild (in ecology) A group of species within a community that exploit the same resources in a similar way. Thus, for example, different species of snakes and lizards may belong to a guild by virtue of occupying the same types of underground shelters, and different species of seed-eating birds may constitute a guild.

gullet *See* OESOPHAGUS.

gum **1.** Any of a variety of substances obtained from plants. Typically they are insoluble in organic solvents but form gelatinous or sticky solutions with water. Most gums are complex polysaccharides. Commercially im-



Growth ring. Transverse section through a three-year-old woody stem to show the growth rings.

portant examples are gum arabic and gum tragacanth. **Gum arabic** (or **gum acacia**) is obtained from various acacia trees; it is used in the manufacture of confectionery, cosmetics, linctuses and other medicinal products, and gummed labels. **Gum tragacanth**, extracted from trees of the genus *Astragalus*, forms a thick *mucilage in water; it is used in the manufacture of pills and confectionery and as a sauce thickener. Gum resins are mixtures of gums and natural resins.

Gums are produced by the young xylem vessels of some plants (mainly trees) in response to wounding or pruning. The exudate hardens when it reaches the plant surface and thus provides a temporary protective seal while the cells below divide to form a permanent repair. Excessive gum formation is a symptom of some plant diseases.
2. *See* GINGIVA.

guncotton *See* CELLULOSE NITRATE.

gun metal A type of bronze usually containing 88–90% copper, 8–10% tin, and 2–4% zinc. Admiralty gunmetal, which is used in shipbuilding, contains 88% copper, 10% tin, and 2% zinc. Because it was easy to cast it was originally used to make cannons; it is still used for bearings and other parts that require high resistance to wear and corrosion.

gunpowder An explosive consisting of a mixture of potassium nitrate, sulphur, and charcoal. It was invented by the Chinese, probably in the 10th century, although the English monk Roger Bacon (1214–92) is often credited with its discovery. For many centuries it was the explosive used in firearms; it is no longer used for this purpose, although it is the basis of many fireworks.

gut *See* ALIMENTARY CANAL.

GUT *See* GRAND UNIFIED THEORY.

guttation *See* HYDATHODE.

guyot (tablemount) A flat-topped circular underwater mountain. Guyots occur in deep water (usually below 2000 m) and are thought to be conical volcanic peaks levelled off by the action of water currents. They consist mainly of *basalt and tend to occur in groups, similar to island arcs.

GWS model Glashow–Weinberg–Salam model. *See* ELECTROWEAK THEORY.

gymnosperm Any plant whose ovules and the seeds into which they develop are borne unprotected, rather than enclosed in ovaries, as are those of the flowering plants (the term gymnosperm means naked seed). In traditional systems of classification such plants were classified as the Gymnospermae, a class of the Spermatophyta, but they are now divided into separate phyla: *Coniferophyta (conifers), *Cycadophyta (cycads), Ginkgophyta (ginkgo), and Gnetophyta (e.g. *Welwitschia*).

gynoecium (gynaecium) The female sex organs (*carpels) of a flower. *Compare* ANDROECIUM.

gypsum A monoclinic mineral form of hydrated *calcium sulphate, $CaSO_4.2H_2O$. It occurs in five varieties: **rock gypsum**, which is often red stained and granular; **gypsite**, an impure earthy form occurring as a surface deposit; **alabaster**, a pure fine-grained translucent form; **satin spar**, which is fibrous and silky; and **selenite**, which occurs as transparent crystals in muds and clays. It is used in the building industry and in the manufacture of cement, rubber, paper, and plaster of Paris.

gyrocompass A *gyroscope that is driven continuously so that it can be used as a non-magnetic compass. When the earth rotates the gyroscope experiences no torque if its spin axis is parallel to the earth's axis; if these axes are not parallel, however, the gyroscope experiences a sequence of restoring torques that tend to make it align itself with the earth's axis. The gyrocompass is therefore an accurate north-seeking device that is uninfluenced by metallic or magnetic objects and it is also more consistent than the magnetic compass. It is therefore widely used on ships, aircraft, missiles, etc.

gyromagnetic ratio Symbol γ. The ratio of the angular momentum of an atomic system to its magnetic moment. The inverse of the gyromagnetic ratio is called the **magnetomechanical ratio**.

gyroscope A disk with a heavy rim mounted in a double *gimbal so that its axis can adopt any orientation in space. When the disk is set spinning the whole contrivance has two useful properties: (1) Gyroscopic inertia, i.e. the direction of the axis of spin resists change so that if the gimbals are turned the spinning disk maintains the same orientation in space. This property forms the basis of the *gyrocompass and other navigational devices. (2) Precession, i.e. when a gy-

roscope is subjected to a torque that tends to alter the direction of its axis, the gyroscope turns about an axis at right angles both to the axis about which the torque was applied and to its main axis of spin. This is a consequence of the need to conserve *angular momentum.

In the gyrostabilizer for stabilizing a ship, aircraft, or platform, three gyroscopes are kept spinning about mutually perpendicular axes so that any torque tending to alter the orientation of the whole device affects one of the gyroscopes and thereby activates a servomechanism that restores the original orientation.

GZK limit (Greisen–Zatsepin–Kuzmin limit) A limit on the energy of cosmic rays imposed by the interaction between the cosmic rays and the cosmic microwave background radiation. This limit, found by Kenneth Greisen, Vadim Kuzmin, and Georgiy Zatsepin in 1966 using the theory of the *inverse Compton effect, is about 6×10^{19} eV. Cosmic rays with higher energies have been detected but it has been established that these come from relatively near sources and so have not had a chance to be slowed down by interaction with the background radiation.