P

P (parental generation) The individuals that are selected to begin a breeding experiment, crosses between which yield the *F_1 generation. Only pure-breeding (homozygous) individuals are selected for the P generation.

pacemaker 1. (sinoatrial node) A small mass of specialized muscle cells in the mammalian heart, found in the wall of the right atrium near the opening for the vena cava. The cells initiate and maintain the heart beat: by their rhythmic and spontaneous contractions they stimulate contraction of the atria (*see also* ATRIOVENTRICULAR NODE). The cells themselves are controlled by the autonomic nervous system, which determines the heart rate. Similar pacemakers occur in the hearts of other vertebrates. **2.** An electronic or nuclear battery-charged device that can be implanted surgically into the chest to produce and maintain the heart beat. These devices are used when the heart's own pacemaker is defective or diseased.

pachytene The period in the first prophase of *meiosis when paired *homologous chromosomes are fully contracted and twisted around each other.

packing density 1. The number of devices (such as *logic circuits) or integrated circuits per unit area of a *silicon chip. **2.** The quantity of information stored in a specified space of a storage system associated with a computer, e.g. *bits per inch of magnetic tape.

packing fraction The algebraic difference between the relative atomic mass of an isotope and its mass number, divided by the mass number.

paedogenesis Reproduction by an animal that is still in the larval or pre-adult form. Paedogenesis is a form of *neoteny and is particularly marked in the axolotl, a larval form of the salamander, which retains its larval features owing to a thyroid deficiency but can breed, producing individuals like itself. If the thyroid hormone thyroxine is given, metamorphosis occurs.

pahoehoe *See* LAVA.

pairing (synapsis) The close association between *homologous chromosomes that develops during the first prophase of *meiosis. The two chromosomes move together and an exact pairing of corresponding points along their lengths occurs as they lie side by side. The resulting structure is called a **bivalent**.

pair production The creation of an electron and a positron from a photon in a strong electric field, such as that surrounding an atomic nucleus. The electron and the positron each have a mass of about 9×10^{-31} kg, which is equivalent on the basis of the mass–energy equation ($E = mc^2$) to a total of 16×10^{-14} J. The frequency, ν, associated with a photon of this energy (according to $E = h\nu$) is 2.5×10^{20} Hz. Pair production thus requires photons of high quantum energy (Bremsstrahlung or gamma rays). Any excess energy is taken up as kinetic energy of the products.

palaeobotany The branch of *palaeontology concerned with the study of plants through geological time, as revealed by their *fossil remains (*see also* PALYNOLOGY). It overlaps with other aspects of plant study, including anatomy, ecology, evolution, and taxonomy.

Palaeocene The earliest geological epoch of the *Palaeogene period. It began about 65 million years ago, following the Cretaceous period, and extended for about 10 million years to the beginning of the *Eocene (the Palaeocene is sometimes included in the Eocene). It was named by the palaeobotanist W. P. Schimper in 1874. A major floral and faunal discontinuity occurred between the end of the Cretaceous and the beginning of the Palaeocene: following the extinction of many reptiles the mammals became abundant on land. By the end of the epoch primates and rodents had evolved.

palaeoclimatology The study of climates of earlier geological periods. This is based largely on the study of sediments that were laid down during these periods and of fos-

sils. The changes in the positions of the continents as a result of *continental drift and *plate tectonics complicate the study.

palaeoecology The study of the relationships of *fossil organisms to each other and to their environments. It involves the study both of the fossils and of the surrounding rocks in which they are found. Trace fossils may provide information on the behaviour of the organism.

Palaeogene The older of the two geological periods of the *Cenozoic era, consisting of the *Palaeocene, *Eocene, and *Oligocene epochs. The Palaeogene began 65 million years ago and lasted until the start of the *Neogene period, 23 million years ago. It thus corresponds approximately to the first two-thirds of the *Tertiary period, a division that is no longer officially recognized.

Palaeolithic The Old Stone Age, lasting in Europe from about 2.5 million to 9000 years ago, during which humans used primitive stone tools made by chipping stones and flints.

palaeomagnetism The study of magnetism in rocks, which provides information on variations in the direction and intensity of the earth's magnetic field with time. During the formation of an igneous or sedimentary rock containing magnetic minerals the polarity of the earth's magnetic field at that time becomes 'frozen' into the rock. Studies of this fossil magnetism in samples of rocks have enabled the former positions of magnetic poles at various geological times to be located. It has also revealed that periodic reversals in the geomagnetic field have taken place (i.e. the N-pole becomes the S-pole and vice versa). This information has been important in plate tectonics in establishing the movements of lithospheric plates over the earth's surface. The magnetic reversals provided crucial evidence for the sea-floor spreading hypothesis proposed in the early 1960s.

palaeontology The study of extinct organisms, including their structure, environment, evolution, and distribution, as revealed by their *fossil remains. Palaeontological work also makes important contributions to geology in revealing stratigraphic relationships between rock strata and determining the physical appearance and climate of the earth during past geological ages. *See also* PALAEOBOTANY; PALAEOECOLOGY; PALAEOZOOLOGY.

Palaeozoic The first era of *Phanerozoic time. It follows the *Precambrian and is subdivided into the Lower Palaeozoic, comprising the *Cambrian, *Ordovician, and *Silurian periods, and the Upper Palaeozoic, comprising the *Devonian, *Carboniferous, and *Permian periods. It extended from about 542 million years ago to about 251 million years ago, when it was succeeded by the *Mesozoic era.

palaeozoology The branch of *palaeontology concerned with the study of animals throughout geological time, as revealed by their *fossil remains.

palate The roof of the mouth cavity of vertebrates, which separates the *buccal and nasal cavities. In mammals it is divided into two zones, the bony **hard palate** and the **soft palate**, and completely separates the buccal cavity from the air passage to enable simultaneous eating and breathing.

palisade mesophyll *See* MESOPHYLL.

palladium Symbol Pd. A soft white ductile *transition element (*see also* PLATINUM METALS); a.n. 46; r.a.m. 106.4; r.d. 12.02; m.p. 1552°C; b.p. 3140±1°C. It occurs in some copper and nickel ores and is used in jewellery and as a catalyst for hydrogenation reactions. Chemically, it does not react with oxygen at normal temperatures. It dissolves slowly in hydrochloric acid. Palladium is capable of occluding 900 times its own volume of hydrogen. It forms few simple salts, most compounds being complexes of palladium(II) with some palladium(IV). It was discovered by William Woolaston (1766–1828) in 1803.

SEE WEB LINKS

- Information from the WebElements site

pallium *See* CEREBRAL CORTEX.

palmitate (hexadecanoate) A salt or ester of palmitic acid.

palmitic acid (hexadecanoic acid) A 16-carbon saturated fatty acid, $CH_3(CH_2)_{14}COOH$; r.d. 0.85; m.p. 63°C; b.p. 390°C. Glycerides of palmitic acid occur widely in plant and animal oils and fats.

palp An elongated sensory organ, usually near the mouth, in many invertebrates. Examples are the tactile head appendages of polychaete worms, the ciliated flap of tissue

that produces feeding currents in bivalve molluscs, the distal part of the *mandibles of crustaceans, and the olfactory parts of the first and second *maxillae of some insects.

palynology (micropalaeontology) The study of fossil pollen and spores (**pollen analysis**) and various other *microfossils, such as coccoliths and dinoflagellates. Palynology is used in stratigraphy, palaeoclimatology, and archaeology. Pollen and spores are very resistant to decay and therefore their fossils are found in sedimentary rocks. They may be extracted by various methods, including boiling with potassium hydroxide solution, washing with strong oxidizing mixtures, and centrifuging repeatedly. Spores and pollen are classified according to shape, form of aperture, and both internal and external details of the exine (outer coat). They indicate the nature of the dominant flora, and therefore the climate and conditions of the period in which they lived.

pancreas A gland in vertebrates lying between the duodenum and the spleen. Under the influence of the hormone *secretin it secretes **pancreatic juice** containing digestive enzymes or their precursors (mainly *trypsin, *chymotrypsin, *amylase, and *lipase) into the duodenum via the pancreatic duct. It also contains groups of cells – the *islets of Langerhans – that function as an *endocrine gland, producing the hormones *insulin and *glucagon, which regulate blood sugar levels.

pancreozymin *See* CHOLECYSTOKININ.

panicle A type of flowering shoot common in the grass family. The primary axis bears groups of *racemes and is itself racemose, as the youngest groups of flowers are at the top (e.g. oat). The term may be used loosely for any form of branched *racemose inflorescence; for example, the horse chestnut is a raceme of cymes. Both these arrangements are seen in the family Polygonaceae (docks and sorrels).

pantothenic acid A vitamin of the *vitamin B complex. It is a constituent of *coenzyme A, which performs a crucial role in the oxidation of fats, carbohydrates, and certain amino acids. Deficiency rarely occurs because the vitamin occurs in many foods, especially cereal grains, peas, egg yolk, liver, and yeast.

papain A protein-digesting enzyme (*see* PROTEASE) occurring in the fruit of the West Indian papaya tree (*Carica papaya*). It is used as a digestant and in the manufacture of meat tenderizers.

paper chromatography A technique for analysing mixtures by *chromatography, in which the stationary phase is absorbent paper. A spot of the mixture to be investigated is placed near one edge of the paper and the sheet is suspended vertically in a solvent, which rises through the paper by capillary action carrying the components with it. The components move at different rates, partly because they absorb to different extents on the cellulose and partly because of partition between the solvent and the moisture in the paper. The paper is removed and dried, and the different components form a line of spots along the paper. Colourless substances are detected by using ultraviolet radiation or by spraying with a substance that reacts to give a coloured spot (e.g. ninhydrin gives a blue coloration with amino acids). The components can be identified by the distance they move in a given time.

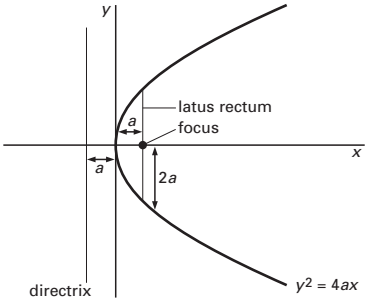
papilla Any cone-shaped protuberance projecting from the surface of an organ or organism. Papillae occur, for example, on the tongue, in the kidneys, and, in plants, on the surface of many petals.

papovavirus One of a group of DNA-containing viruses that produce tumours in their hosts. **Papillomaviruses** produce non-malignant tumours (such as warts) in all vertebrates and certain cancers (e.g. cervical cancer) in humans. **Polyomaviruses** produce malignant tumours in certain classes of vertebrates (not including humans).

pappus A group of modified *sepals, often in the form of a ring of silky hairs. For example, when the fruit of the dandelion matures a pappus of hairs persists at the top of a thin stalk forming a parachute-like structure, which serves to disperse the fruit.

para- **1.** Prefix designating a benzene compound in which two substituents are in the 1,4 positions, i.e. directly opposite each other, on the benzene ring. The abbreviation *p*- is used; for example, *p*-xylene is 1,4-dimethylbenzene. *Compare* ORTHO-; META-. **2.** Prefix denoting the form of diatomic molecules in which the nuclei have opposite spins, e.g. parahydrogen. *Compare* ORTHO-.

parabola A *conic with eccentricity $e = 1$. It is the locus of a point that moves so that its distance from the **focus** is equal to its per-



Parabola.

pendicular distance from the **directrix**. A chord through the focus, perpendicular to the axis, is called the **latus rectum**. For a parabola with its vertex at the origin, lying symmetrically about the x-axis, the equation is $y^2 = 4ax$, where a is the distance from the vertex to the focus. The directrix is the line $x = -a$, and the latus rectum is $4a$. See illustration.

parabolic reflector (paraboloidal reflector) A reflector having a section that is a parabola. A concave parabolic reflector will reflect a parallel beam of radiation through its focus and, conversely, will produce a parallel beam if the source of the radiation is placed at its focus. Parabolic mirrors are used in reflecting optical *telescopes to collect the light and in some light sources that require a parallel beam of light. In radio telescopes a dish aerial may also consist of a parabolic reflector.

paraboloid A solid formed by rotating a parabola about its axis of symmetry.

paraffin *See* PETROLEUM.

paraffins *See* ALKANES.

paraffin wax *See* PETROLEUM.

paraformaldehyde *See* METHANAL.

parahydrogen *See* HYDROGEN.

paraldehyde *See* ETHANAL.

parallax **1.** An apparent displacement of a distant object (with respect to a more distant background) when viewed from two different positions. If such an object is viewed from two points at either end of a base line, the angle between the lines joining the object to the ends of the base line is the **angle of parallax**. If the base line is the distance between the two eyes of an observer the angle is called the **binocular parallax**. **2.** The angular displacement in the apparent position of a celestial body when observed from two different points. **Diurnal parallax** results from the earth's daily rotation, the celestial body being viewed from the surface of the earth rather than from its centre. **Annual parallax** is caused by the earth's motion round the sun, the celestial body being viewed from the earth rather than from the centre of the sun. **Secular parallax** is caused by the motion of the solar system relative to the fixed stars.

parallel circuits A circuit in which the circuit elements are connected so that the current divides between them. For resistors in parallel, the total resistance, R, is given by $1/R = 1/r_1 + 1/r_2 + 1/r_3 \ldots$, where r_1, r_2, and r_3 are the resistances of the individual elements. For capacitors in parallel, the total capacitance, C, is given by $C = c_1 + c_2 + c_3 \ldots$.

parallelepiped (parallelopiped) A solid with six faces, all of which are parallelograms.

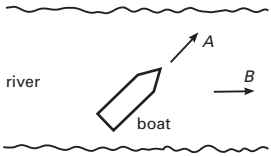
parallel evolution The development of related organisms along similar evolutionary paths due to strong selection pressures acting on all of them in the same way. It is debatable if the phenomenon really exists: many argue that all evolution is ultimately *convergent or divergent (*see* ADAPTIVE RADIATION).

parallelogram of forces *See* PARALLELOGRAM OF VECTORS.

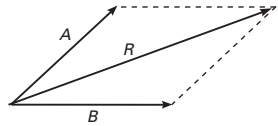
parallelogram of vectors A method of determining the *resultant of two *vector quantities. The two vector quantities are represented by two adjacent sides of a parallelogram and the resultant is then the diagonal through their point of intersection. The magnitude and direction of the resultant is found by scale drawing or by trigonometry. The method is used for such vectors as forces (**parallelogram of forces**) and velocities (**parallelogram of velocities**). See illustration overleaf.

parallelogram of velocities *See* PARALLELOGRAM OF VECTORS.

parallel processing A technique that allows more than one process – stream of activity – to be running at any given moment in a computer system, hence processes can be



A is the velocity of the boat with respect to the water; *B* is the velocity of the water with respect to the bank



R is the resultant velocity of the boat with respect to the bank

Parallelogram of velocities.

executed in parallel. This means that two or more processors are active among a group of processes at any instant.

parallel spins Neighbouring spinning electrons in which the *spins, and hence the magnetic moments, of the electrons are aligned in the same direction. The interaction between the magnetic moments of electrons in atoms is dominated by exchange interactions (*see* EXCHANGE FORCE). Under some circumstances the exchange interactions between magnetic moments favour parallel spins, while under other conditions they favour *antiparallel spins. The case of ferromagnetism (*see* MAGNETISM) is an example of a system with parallel spins.

paramagnetism *See* MAGNETISM.

parametric equation An equation of a curve expressed in the form of the parameters that locate points on the curve. The parametric equations of a straight line are $x = a + bt$, $y = c + dt$. For a circle, they are $x = a\cos\theta$, $y = a\sin\theta$.

paraphyletic *See* MONOPHYLETIC.

parapositronium *See* POSITRONIUM.

parasitic capture The absorption of a neutron by a nuclide that does not result in either fission or a useful artificial element.

parasitism An association in which one organism (the **parasite**) lives on (**ectoparasitism**) or in (**endoparasitism**) the body of another (the *host), from which it obtains its nutrients. Some parasites inflict comparatively little damage on their host, but many cause characteristic diseases (these are, however, never immediately fatal, as killing the host would destroy the parasite's source of food). Parasites are usually highly specialized for their way of life, which may involve one host or several (if the *life cycle requires it). They typically produce vast numbers of eggs, very few of which survive to find their way to another suitable host. **Obligate parasites** can only survive and reproduce as parasites; **facultative parasites** can also live as *saprotrophs. The parasites of humans include fleas and lice (which are ectoparasites), various bacteria, protozoans, and fungi (endoparasites causing characteristic diseases), and tapeworms (e.g. *Taenia solium*, which lives in the gut).

SEE WEB LINKS

- Comprehensive descriptions of human parasites feature in this diagnostic website from the US Centers for Disease Control and Prevention

parasympathetic nervous system Part of the *autonomic nervous system. Its nerve endings release acetylcholine as a *neurotransmitter and its actions tend to antagonize those of the *sympathetic nervous system. For example, the parasympathetic nervous system increases salivary gland secretion, decreases heart rate, and promotes digestion (by increasing *peristalsis). While the sympathetic nervous system has opposite effects.

parathyroid glands Two pairs of *endocrine glands situated behind, or embedded within, the thyroid gland in higher vertebrates. They produce *parathyroid hormone, which controls the amount of calcium in the blood. *See also* C CELL.

parathyroid hormone (PTH; parathormone; parathyrin) A peptide hormone secreted by the *parathyroid gland in response to low levels of calcium in the blood. It acts to maintain normal blood levels of calcium by (1) increasing the number of osteoclasts, cells that break down the bone matrix and release calcium into the blood; (2) increasing the reabsorption of calcium and magnesium ions in the kidney tubules, so that their concentration is maintained in the blood; (3) converting *vitamin D to its active form,

which increases calcium absorption in the intestine. Parathyroid hormone acts in opposition to *calcitonin.

paraxial ray A ray of light that falls on a reflecting or refracting surface close to and almost parallel to the axis. It is for such rays that simple lens theory can be developed, by means of making small angle approximations.

parenchyma **1.** A plant tissue consisting of roughly spherical relatively undifferentiated cells, frequently with air spaces between them. The cortex and pith are composed of parenchyma cells (*see* GROUND TISSUES). **2.** Loose *connective tissue formed of large cells. Its function is to pack the spaces between organs in some simple acoelomate animals, such as flatworms (Platyhelminthes).

parent **1.** (in biology) **a.** Either male or female partner that together produce offspring in the process of sexual reproduction. *See also* P. **b.** Denoting an organism or cell that gives rise to new organisms or cells, as by asexual reproduction or cell division. **2.** (in physics) *See* DAUGHTER.

parity Symbol *P*. The property of a *wave function that determines its behaviour when all its spatial coordinates are reversed in direction, i.e. when x,y,z are replaced by $-x,-y,-z$. If a wave function ψ satisfies the equation $\psi(x,y,z) = \psi(-x,-y,-z)$ it is said to have even parity, if it satisfies $\psi(x,y,z) = -\psi(-x,-y,-z)$ it has odd parity. In general,

$$\psi(x,y,z) = P\psi(-x,-y,-z),$$

where P is a quantum number called parity that can have the value +1 or –1. The principle of **conservation of parity** (or **space-reflection symmetry**) would hold if all physical laws could be stated in a coordinate system independent of left- or right-handedness. If parity was conserved there would therefore be no fundamental way of distinguishing between left and right. In electromagnetic and strong interactions, parity is, in fact, conserved. In 1956, however, it was shown that parity is not conserved in weak interactions. In the beta decay of cobalt–60, for example, the electrons from the decay are emitted preferentially in a direction opposite to that of the cobalt spin. This experiment provides a fundamental distinction between left and right.

parsec A unit of length used to express astronomical distance. The distance at which the mean radius of the earth's orbit subtends an angle of one second of arc. One parsec is equal to 3.0857×10^{16} metres or 3.2616 light years.

parsimony *See* PRINCIPLE OF PARSIMONY.

parthenocarpy The formation of fruit without prior fertilization of the flower by pollen. The resulting fruits are seedless and therefore do not contribute to the reproduction of the plant; examples are bananas and pineapples. *Plant hormones may have a role in this phenomenon, which can be induced by auxins in the commercial production of tomatoes and other fruits.

parthenogenesis The development of an organism from an unfertilized egg. This occurs sporadically in many plants (e.g. dandelions and hawkweeds) and in a few animals, but in some species it is the main and sometimes only method of reproduction. For example, in some species of aphid, males are absent or very rare. The eggs formed by the females contain the full (diploid) number of chromosomes and are genetically identical. Variation is consequently very limited in species that reproduce parthenogenetically.

partial A simple component of a complex tone. When a musical instrument produces a note, say, middle C, it will produce a complex tone in which the fundamental frequency is mixed with a number of partials. Some of these partials, for example, if the note is produced by bowing a taut string, will be *harmonics, i.e. integral multiples of the fundamental. If the string is struck, however, some of the partials can be inexact multiples of the fundamental. Partials are not therefore identical with harmonics.

partial derivative The infinitesimal change in a function consisting of two or more variables when one of the variable changes and the others remain constant. If $z = f(x,y)$, $\partial z/\partial x$ is the partial derivative of z with respect to x, while y remains unchanged. A **partial differential equation**, such as the *Laplace equation, is an equation containing partial derivatives of a function.

partial eclipse *See* ECLIPSE.

partial pressure *See* DALTON'S LAW.

particle **1.** (in physics) One of the fundamental components of matter. *See* ELEMENTARY PARTICLES. **2.** (in mechanics) A hypothetical body that has mass but no physical extension. As it is regarded as hav-

ing no volume, a particle is incapable of rotation and therefore can only have translational motion. Thus a real body may often, for translational purposes, be regarded as a particle located at the body's centre of mass and having a mass equal to that of the whole body.

particle physics The study of *elementary particles.

particulate inheritance The transmission from parent to offspring of separate units that determine characteristics. Gregor Mendel observed that *recessive characteristics, absent in the offspring of a cross in which only one parent possessed them, reappeared repeatedly in the progeny of subsequent crosses. This led him to formulate his theory of inherited 'factors' (now called *alleles) that retain their identity through succeeding generations (*see* MENDEL'S LAWS). *Compare* BLENDING INHERITANCE.

partition If a substance is in contact with two different phases then, in general, it will have a different affinity for each phase. Part of the substance will be absorbed or dissolved by one and part by the other, the relative amounts depending on the relative affinities. The substance is said to be **partitioned** between the two phases. For example, if two immiscible liquids are taken and a third compound is shaken up with them, then an equilibrium is reached in which the concentration in one solvent differs from that in the other. The ratio of the concentrations is the **partition coefficient** of the system. The **partition law** states that this ratio is a constant for given liquids.

partition coefficient *See* PARTITION.

partition function The quantity Z defined by $Z = \Sigma \exp(-E_i/kT)$, where the sum is taken over all states i of the system. E_i is the energy of the ith state, k is the *Boltzmann constant, and T is the thermodynamic *temperature. Z is a quantity of fundamental importance in equilibrium *statistical mechanics. For a system in which there are non-trivial interactions, it is very difficult to calculate the partition function exactly. For such systems it is necessary to use *approximation techniques and/or *model systems. The partition function links results at the atomic level to *thermodynamics, since Z is related to the Helmholtz *free energy F by $F = kT\ln Z$.

parton A pointlike, almost free, particle postulated as a component of nucleons. The parton model enabled the results of very high-energy experiments on nucleons to be understood. *See* QUANTUM CHROMODYNAMICS.

parturition The act of giving birth to young at the end of the *gestation period. Fetal hormones cause the process to start.

pascal The *SI unit of pressure equal to one newton per square metre.

Pascal, Blaise (1623–62) French mathematician and physicist. An infant prodigy, he had already made a mechanical calculating machine by 1642. In physics he formulated *Pascal's law concerning fluid pressure and the principle behind the hydraulic press. The SI unit of pressure is named after him.

Pascal's distribution (negative binomial distribution) The distribution of the number of independent *Bernoulli trials performed up to and including the r^{th} success. The probability that the number of trials, x, is equal to k is given by

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

The mean and variance are r/p and rq/p^2 respectively. *See also* GEOMETRIC DISTRIBUTION.

Pascal's law In a confined fluid, externally applied pressure is transmitted uniformly in all directions. In a static fluid, force is transmitted at the speed of sound throughout the fluid and acts at right angles to any surface in or bounding the fluid. This principle is made use of in the hydraulic jack, the pneumatic tyre, and similar devices. The law was discovered in 1647 by Blaise Pascal.

Pascal's triangle A triangular array of numbers in which each number is the sum of the two numbers immediately above it (except for the 1s):

1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1
1 6 15 20 15 6 1
1 7 21 35 35 21 7 1

and so on. The numbers in each row are the coefficients of the expansion of the binomial $(x + y)^n$ (*see* BINOMIAL THEOREM). It is named after Blaise Pascal.

Paschen–Back effect An effect in atomic line *spectra that occurs when the atoms are placed in a strong magnetic field. Spectral

lines that give the anomalous *Zeeman effect when the atoms are placed in a weaker magnetic field have a different splitting pattern in a very strong magnetic field in which the spectral lines go back to the pattern of the normal Zeeman effect. The Paschen–Back effect is named after the German physicists Louis Paschen (1865–1947) and Ernest Back (1881–1959), who discovered it in 1912.

Paschen series *See* HYDROGEN SPECTRUM.

passive Describing a solid that has reacted with another substance to form a protective layer, so that further reaction stops. The solid is said to have been 'rendered passive'. For example, aluminium reacts spontaneously with oxygen in air to form a thin layer of *aluminium oxide, which prevents further oxidation. Similarly, pure iron forms a protective oxide layer with concentrated nitric acid and is not dissolved further.

passive device **1.** An electronic component, such as a capacitor or resistor, that is incapable of amplification. **2.** An artificial *satellite that reflects an incoming signal without amplification. **3.** A solar-power device that makes use of an existing structure to collect and utilize solar energy without the use of pumps, fans, etc. **4.** A radar device that provides information for navigation, guidance, surveillance, etc., by receiving the microwave radiation. Such a passive device emits no microwave energy itself and therefore does not disclose its position. **5.** A system that detects an object by the radiation that it emits, rather than by reflecting radiation off it, as in a passive infrared detector (**PIT detector**). *Compare* ACTIVE DEVICE.

passive immunity *See* IMMUNITY.

passive transport *See* DIFFUSION.

Pasteur, Louis (1822–95) French chemist and microbiologist, who held appointments in Strasbourg (1849–54) and Lille (1854–57), before returning to Paris to the Ecole Normale and the Sorbonne. From 1888 to his death he was director of the Pasteur Institute. In 1848 he discovered *optical activity, in 1860 relating it to molecular structure. In 1856 he began work on *fermentation, and by 1862 was able to disprove the existence of *spontaneous generation. He introduced *pasteurization (originally for wine) in 1863. He went on to study disease and developed vaccines against cholera (1880), anthrax (1882), and rabies (1885).

pasteurization The treatment of milk to destroy disease-causing bacteria, such as those of tuberculosis, typhoid, and brucellosis. Milk is heated to 65°C for 30 minutes or to 72°C for 15 minutes followed by rapid cooling to below 10°C. The method was devised by the French microbiologist Louis Pasteur (1822–95).

patella (kneecap) A small rounded movable bone that is situated in a tendon in front of the knee joint in most mammals (including humans). The function of the patella is to protect the knee.

path integral formulation A formulation of quantum mechanics put forward by Richard Feynman in 1942 in which all the possible paths a particle in a quantum mechanical system can take, weighted by the probability of each path occurring, are added up. Path integrals have been used extensively, both in analysing the foundations of quantum mechanics and in solving certain types of problem.

pathogen Any disease-causing microorganism. Pathogens include viruses, rickettsiae, and many bacteria, fungi, and protozoans. *See* INFECTION.

pathology The study of the changes in organs and tissues that are caused by or give rise to disease. This involves the examination of tissue samples, X-ray photographs, or other evidence taken from living patients or from cadavers. **Clinical pathology** applies these findings to clinical cases, particularly in the development of diagnostic tests and treatments. In **experimental pathology**, disease processes are studied using experimental animals, cell cultures, or other means.

patristic Denoting similarity between organisms resulting from common ancestry. *Compare* HOMOPLASY.

Pauli, Wolfgang Ernst (1900–58) Austrian-born Swiss physicist. After studying with Niels *Bohr and Max Born, he taught at Heidelberg and, finally Zurich. His formulation in 1925 of the *Pauli exclusion principle explained the electronic make-up of atoms. For this work he was awarded the 1945 Nobel Prize for physics. In 1930 he predicted the existence of the *neutrino, which was finally discovered in 1956 by Clyde Cowan (1919–74) and Frederick Reines (1918–98).

Pauli exclusion principle The quantum-mechanical principle, applying to fermions

but not to bosons, that no two identical particles in a system, such as electrons in an atom or quarks in a hadron, can possess an identical set of quantum numbers. It was first formulated by Wolfgang Pauli in 1925. The origin of the Pauli exclusion principle lies in the *spin–statistics theorem of relativistic quantum field theory.

Pauling, Linus Carl (1901–94) US chemist. After spending two years in Europe, he became a professor at the Californian Institute of Technology. His original work was on chemical bonding; in the mid-1930s he turned to the structure of proteins, for which he was awarded the 1954 Nobel Prize for chemistry. He was also an active campaigner against nuclear weapons and in 1962 was awarded the Nobel Peace Prize.

Paul trap *See* ION TRAP.

Pavlov, Ivan Petrovich (1849–1936) Russian physiologist, who became professor of physiology in St Petersburg in 1886. While working on the physiology of digestion he discovered that the mere sight of food stimulates the production of digestive juices. For this work he was awarded the 1904 Nobel Prize for physiology or medicine. Pavlov went on to demonstrate operant *conditioning in dogs and other animals. *See also* LEARNING (Feature).

***p*-block elements** The block of elements in the periodic table consisting of the main groups 13 (B to Tl), 14 (C to Pb), 15 (N to Bi), 16 (O to Po), 17 (F to At) and 18 (He to Rn). The outer electronic configurations of these elements all have the form ns^2np^x where x = 1 to 6. Members at the top and on the right of the *p*-block are nonmetals (C, N, P, O, F, S, Cl, Br, I, At). Those on the left and at the bottom are metals (Al, Ga, In, Tl, Sn, Pb, Sb, Bi, Po). Between the two, from the top left to bottom right, lie an ill-defined group of metalloid elements (B, Si, Ge, As, Te).

PC *See* PERSONAL COMPUTER.

PCB *See* POLYCHLORINATED BIPHENYL.

PCP *See* PHENCYCLIDINE.

PCR *See* POLYMERASE CHAIN REACTION.

p.d. (potential difference) *See* ELECTRIC POTENTIAL.

PDGF *See* GROWTH FACTOR.

peacock ore *See* BORNITE.

peak oil The point at which global oil production reaches a maximum and then begins to decline because of diminishing reserves. Thereafter, the oil extracted from new sources cannot keep pace with depletion of existing oilfields, and demand is forecast to exceed supply, so causing the price of oil and its derivatives to rise inexorably. This in turn, it is argued, will have dramatic economic and social consequences. The timing of peak oil is controversial, with many estimates lying between 2010 and 2015. However, this depends on continued high demand for oil, which may ease if alternatives, such as *renewable energy sources, become more widely adopted.

pearl ash *See* POTASSIUM CARBONATE.

pearlite *See* STEEL.

Pearson symbol A symbolic notation devised by W. B. Pearson for indicating the structure of a crystal. There are three parts:
(1) A lower case letter denoting one of six crystal systems: a = anorthic (triclinic); m = monoclinic; o = orthorhombic; t = tetragonal; h = hexagonal or rhombohedral; c = cubic.
(2) An upper-case letter denoting the lattice type: P = primitive; I = body-centred; F = face-centred (full); C = face-centred (side); R = rhombohedral.
(3) A number giving the number of atoms in the unit cell.
For example, sodium chloride has a cubic, face-centred structure with 8 atoms in the unit cell, so has Pearson symbol cF8. The first two letters of a Pearson symbol give the *Bravais lattice.

peat A mass of dark-brown or black fibrous plant debris produced by the partial disintegration of vegetation in wet places. It may accumulate in depressions. When subjected to burial and hence pressure and heat it may be converted to *coal. Peat is used to improve soil and as a fuel, especially in Ireland and Sweden.

pebi- *See* BINARY PREFIXES.

peck order *See* DOMINANT.

pecten Any of various comblike structures in animals. The pecten in the eyes of birds consists essentially of a network of blood vessels attached to the optic nerve and projecting into the vitreous humour. Its function is uncertain, but it may be involved in supplying the retina with nutrients and oxy-

gen. A simple form of this structure is found in the eyes of reptiles.

pectin (pectic substance) A mixture of polysaccharides made up primarily of a sugar acid (galacturonic acid). Pectin is an important constituent of plant cell walls and the *middle lamella between adjacent cell walls; it is also found in certain plant juices. Normally present in an insoluble form, in ripening fruits and in tissues affected by certain diseases it changes into a soluble form, which is evidenced by softening of the tissues. It is used in making jam as it forms a gel with sucrose.

pectoral fins *See* FINS.

pectoral girdle (shoulder girdle) The bony or cartilaginous structure in vertebrates to which the anterior limbs (pectoral fins, forelegs, or arms) are attached. In mammals it consists of two dorsal *scapulae (shoulder blades) attached to the backbone and two ventral *clavicles (collar bones) attached to the sternum (breastbone).

pedicel The stalk attaching a flower to the main floral axis (*see* PEDUNCLE). Some flowers, described as **sessile**, do not have a pedicel and arise directly from the peduncle.

pedology The science of the study of soils, including their origin and characteristics and their utilization.

peduncle The main stalk of a plant that bears the flowers, which may be solitary or grouped in an *inflorescence. *Compare* PEDICEL.

pegmatite Very coarse-grained igneous rock. Granite pegmatite, the commonest type, consists chiefly of alkali feldspar and quartz; accessory minerals, such as mica, tourmaline, topaz, beryl, fluorite, cassiterite, and garnet, may also be present. Many pegmatites are thus economically important as sources of these minerals. The individual crystals may be extremely large; for example, mica and quartz crystals over 3 m in length have been found.

pelagic Describing organisms that swim or drift in a sea or a lake, as distinct from those that live on the bottom (*see* BENTHOS). Pelagic organisms are divided into *plankton and *nekton.

pelargonic acid *See* NONANOIC ACID.

Pelecypoda *See* BIVALVIA.

pellagra A disease resulting from a deficiency of *nicotinic acid, which is characterized by dermatitis and mental disorder.

pellicle The thin outer covering, composed of protein, that protects and maintains the shape of certain unicellular organisms, e.g. *Euglena*. It is transparent and in ciliated organisms, e.g. *Paramecium*, contains small pores through which the cilia emerge.

Peltier effect The change in temperature produced at a junction between two dissimilar metals or semiconductors when an electric current passes through the junction. The direction of the current determines whether the temperature rises or falls. The first metals to be investigated were bismuth and copper; if the current flows from bismuth to copper the temperature rises. If the current is reversed the temperature falls. The effect was discovered in 1834 by the French physicist Jean Peltier (1785–1845) and has been used recently for small-scale refrigeration. *Compare* SEEBECK EFFECT.

pelvic fins *See* FINS.

pelvic girdle (pelvis; hip girdle) The bony or cartilaginous structure in vertebrates to which the posterior limbs (pelvic fins or legs) are attached. The pelvic girdle articulates dorsally with the backbone; it is made up of two halves, each produced by the fusion of the *ilium, *ischium, and *pubis.

pelvis **1.** *See* PELVIC GIRDLE. **2.** The lower part of the abdomen in the region of the pelvic girdle. **3.** A conical chamber in the *kidney into which urine drains from the kidney tubules before passing to the *ureter.

pen drive *See* USB DRIVE.

pendulum Any rigid body that swings about a fixed point. The **ideal simple pendulum** consists of a bob of small mass oscillating back and forth through a small angle at the end of a string or wire of negligible mass. Such a device has a period $2\pi\sqrt{(l/g)}$, where l is the length of the string or wire and g is the *acceleration of free fall. This type of pendulum moves with *simple harmonic motion.

The **compound pendulum** consists of a rigid body swinging about a point within it. The period of such a pendulum is given by

$$T = 2\pi\sqrt{[(h^2 + k^2)/hg]},$$

where k is the radius of gyration about an axis through the centre of mass and h is the distance from the pivot to the centre of mass. *See also* KATER'S PENDULUM.

penicillin An *antibiotic derived from the mould *Penicillium notatum*; specifically it is known as **penicillin G** (benzylpenicillin) or **penicillin V** (phenoxymethylpenicillin), which belong to a class of similar substances called penicillins. They are all active against a wide variety of bacteria, producing their effects by disrupting synthesis of the bacterial cell wall, and are used to treat a variety of infections caused by these bacteria.

penis The male reproductive organ of mammals (and also of some birds and reptiles) used to introduce sperm into the female reproductive tract to ensure internal fertilization. It contains a duct (the *urethra) through which the sperms pass. The penis becomes erect during precopulatory activity, either by filling with blood or haemolymph or by the action of muscles, and can be inserted into the vagina (or cloaca). In mammals the urine also leaves the body through the penis.

Penning gauge A type of cold-cathode *ionization gauge in which a discharge is maintained between two electrodes with a potential difference of a few kilovolts. An axial magnetic field is also applied to cause electrons to move in spiral paths and increase the ionization current and sensitivity. This type of gauge is used in the range 10^{-3}–10^{-5} torr. It was invented in 1936 by the Dutch physicist Frans Penning (1894–1953).

Penning trap *See* ION TRAP.

Penrose, Sir Roger (1931–) British mathematician and physicist. Penrose was the first to point out that singularities are inevitable features of the general theory of relativity. He has made other important contributions to the theory of relativity and its quantization, including his work on *twistor theory. He also discovered Penrose patterns, which are a two-dimensional analogue of quasicrystals. *See also* HAWKING, STEPHEN WILLIAM.

Penrose process A process by which the rotational energy of a rotating black hole can be extracted. An object close to the event horizon may split into two particles. One, with negative energy, falls into the black hole, causing the rotation rate to decrease. The other, with positive rotation, moves away. The result is that energy is extracted at the expense of rotational energy of the black hole. This process was suggested by Sir Roger Penrose in 1969. *See also* BLANDFORD–ZNAJEK PROCESS.

pentadactyl limb A limb with five digits, characteristic of tetrapod vertebrates (amphibians, reptiles, birds, and mammals). It evolved from the paired fins of primitive fish as an adaptation to locomotion on land and is not found in modern fish. The limb has three parts (see illustration): the upper arm or thigh containing one long bone, the forearm or shank containing two long bones, and the hand or foot, which contains a number of small bones. This basic design is modified in many species, according to the function of the limb, particularly by the loss or fusion of the terminal bones.

pentaerythritol A white crystalline compound, $C(CH_2OH)_4$; m.p. 260°C; b.p. 276°C (30 mmHg). It is used in making the explosive pentaerythritol trinitrate and in producing resins and other organic products.

pentaerythritol tetranitrate (PETN) A powerful high explosive made from pentaerythritol, $C(CH_2ONO_2)_4$.

pentahydrate A crystalline hydrate that has five moles of water per mole of compound.

pentane A straight-chain alkane hydrocarbon, C_5H_{12}; r.d. 0.63; m.p. –129.7°C; b.p. 36.1°C. It is obtained by distillation of petroleum.

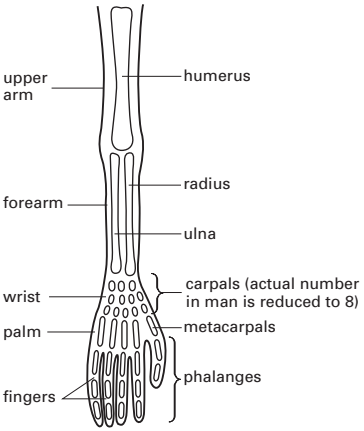
pentanedioic acid (glutaric acid) A simple dicarboxylic acid, $HOOC(CH_2)_3COOH$; m.p. 96°C; b.p. 200°C. It is used in the production of certain polymers.

pentanoic acid (valeric acid) A colourless liquid *carboxylic acid, $CH_3(CH_2)_3COOH$; r.d. 0.9; m.p. –34°C; b.p. 186.05°C. It is used in the perfume industry.

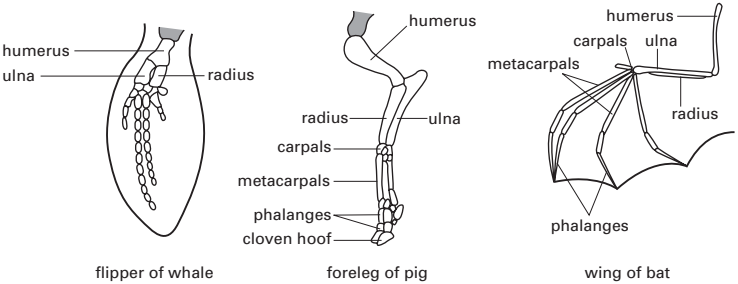
pentaquark A long-lived particle consisting of five quarks with a mass of just over 1500 MeV, which has been predicted to exist. There is no evidence for the existence of this particle.

pentavalent (quinquevalent) Having a valency of five.

pentlandite A mineral consisting of a mixed iron–nickel sulphide, $(Fe,Ni)_9S_8$, crystallizing in the cubic system; the chief ore of nickel. It is yellowish-bronze in colour with a metallic lustre. The chief occurrence of the mineral is at Sudbury in Ontario, Canada.



A basic pentadactyl forelimb, as exemplified by the human arm



The modified pentadactyl forelimb of various vertebrates

Pentadactyl limb.

pentode A *thermionic valve with a **suppressor grid** between the anode and the screen grid of a tetrode. Its purpose is to suppress the loss of electrons from the anode as a result of secondary emission. The suppressor grid is maintained at a negative potential relative to the anode and to the screen grid.

pentose A sugar that has five carbon atoms per molecule. *See* MONOSACCHARIDE.

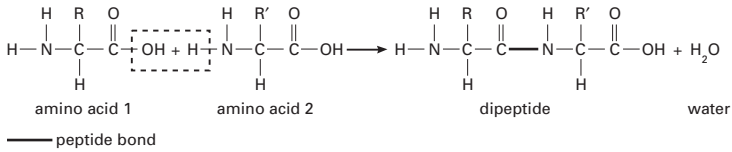
pentose phosphate pathway (pentose shunt) A series of biochemical reactions that results in the conversion of glucose 6-phosphate to ribose 5-phosphate and generates NADPH, which provides reducing power for other metabolic reactions, such as synthesis of fatty acids. Ribose 5-phosphate and its derivatives are components of such molecules as ATP, coenzyme A, NAD, FAD, DNA, and RNA. In plants the pentose phosphate pathway also plays a role in the synthesis of sugars from carbon dioxide. In animals the pathway occurs at various sites, including the liver and adipose tissue.

pentyl group (pentyl radical) The organic group $CH_3CH_2CH_2CH_2CH_2^-$, derived from pentane.

penumbra *See* SHADOW.

pepo *See* BERRY.

pepsin An enzyme that catalyses the



Peptide. Formation of a peptide bond.

breakdown of proteins to polypeptides in the vertebrate stomach. It is secreted as an inactive precursor, *pepsinogen.

pepsinogen The inactive precursor of the enzyme *pepsin. Pepsinogen is secreted by the lining of the vertebrate stomach into the lumen, where it is converted to pepsin by hydrochloric acid and also by the action of pepsin itself.

peptidase *See* ENDOPEPTIDASE; EXOPEPTIDASE; PROTEASE.

peptide Any of a group of organic compounds comprising two or more amino acids linked by **peptide bonds**. These bonds are formed by the reaction between adjacent carboxyl (–COOH) and amino ($–NH_2$) groups with the elimination of water (see illustration). **Dipeptides** contain two amino acids, **tripeptides** three, and so on. *Polypeptides contain more than 20 and usually 100–300. Naturally occurring **oligopeptides** (of less than 20 amino acids) include the tripeptide glutathione and the pituitary hormones antidiuretic hormone and oxytocin, which are octapeptides. Peptides also result from protein breakdown, e.g. during digestion.

SEE WEB LINKS

- Information about IUPAC nomenclature of peptides

per- Prefix indicating that a chemical compound contains an excess of an element, e.g. a peroxide.

percentile For a random variable in *statistics, any of the 99 values that divide its distribution such that an integral percentage of the collection lies below that value. For example, the 85th percentile is the value of a variable that has 85% of the collection below that value. The 25th percentile is called the lower **quartile**, the 50th percentile is the **median**, and the 75th percentile is the upper quartile.

perchlorate *See* CHLORATES.

perchloric acid *See* CHLORIC(VII) ACID.

Percus–Yevick approximation An approximation used in *statistical mechanics to calculate the radial distribution function of a system. This approximation, which was devised by Jerome Percus and George Yevick in 1958, has been used extensively in the theory of liquids.

perdisulphuric acid *See* PEROXOSULPHURIC(VI) ACID.

perennation The survival of biennial or perennial plants from one year to the next by vegetative means. In biennials and herbaceous perennials the aerial parts of the plant die down and the plants survive by means of underground storage roots (e.g. carrot), *rhizomes (e.g. couch grass, Solomon's seal), *tubers (e.g. dahlia), *bulbs (e.g. daffodil, snowdrop), or *corms (e.g. crocus, gladiolus). These **perennating organs** are also frequently responsible for *vegetative propagation. Woody perennials survive the winter by reducing their metabolic activity (e.g. by leaf loss in deciduous trees and shrubs).

perennial A plant that lives for a number of years. Woody perennials (trees and shrubs) have a permanent aerial form, which continues to grow year after year. Herbaceous (i.e. nonwoody) perennials have aerial shoots that die down each autumn and are replaced in spring by new shoots from an underground structure (*see* PERENNATION). Lupin and rhubarb are examples of herbaceous perennials. *Compare* ANNUAL; BIENNIAL; EPHEMERAL.

perfect gas *See* IDEAL GAS; GAS.

perfect pitch *See* ABSOLUTE PITCH.

perfect solution *See* RAOULT'S LAW.

perianth The part of a flower situated outside the stamens and carpels. In dicotyledons it consists of two distinct whorls, the outer of sepals (*see* CALYX) and the inner of petals (*see* COROLLA). In monocotyledons the two whorls are similar and often brightly coloured. In wind-pollinated flowers both

whorls may be reduced or absent. In many horticultural varieties the number of perianth parts is multiplied, but the resulting 'double' flowers are often sterile.

periastron *See* APASTRON.

pericardial cavity The cavity in vertebrates that contains the heart and is bounded by a membrane (the *pericardium). It is part of the *coelom.

pericardium (pericardial membrane) The membrane that encloses the pericardial cavity, containing the vertebrate heart. The pericardium holds the heart in position while allowing it to relax and contract. It consists of two main parts: a tough outer fibrous layer (**fibrous pericardium**) and the more delicate **serous pericardium**, which consists of a double layer of *serous membrane, the inner layer being in close contact with the heart.

pericarp (fruit wall) The part of a fruit that develops from the ovary wall of a flower. The type of fruit that develops depends on whether the pericarp becomes dry and hard or soft and fleshy. The pericarp can be made up of three layers. The outer skin (**epicarp** or **exocarp**) may be tough and hard; the middle layer (**mesocarp**) may be succulent as in peach, hard as in almond, or fibrous as in coconut; and the inner layer (**endocarp**) may be hard and stony as in many *drupes, membranous as in citrus fruits, or indistinguishable from the mesocarp, as in many *berries.

pericycle A plant tissue comprising the outermost layer of the root vascular tissue, lying immediately beneath the *endodermis. Lateral roots originate from the pericycle.

pericynthion The point in the orbit around the moon of a satellite launched from the earth that is nearest to the moon. For a satellite launched from the moon the equivalent point is the **perilune**. *Compare* APOCYNTHION.

periderm *See* CORK CAMBIUM.

perigee The point in the orbit of the moon or an artificial earth satellite when it is closest to the earth. *See* APOGEE.

perihelion The point in the solar orbit of a planet, comet, or other solar system object, natural or artificial, at which it is nearest to the sun. At the beginning of the 21st century, the earth is at perihelion on or about 3 January. Its distance from the sun at that point is about 0.9833 astronomical unit. *Compare* APHELION.

perilymph The fluid of the *inner ear that fills the space between the bony labyrinth and the membranous labyrinth. *Compare* ENDOLYMPH.

period **1.** The time taken for one complete cycle of an oscillating system or wave. **2.** *See* PERIODIC TABLE. **3.** *See* MENSTRUAL CYCLE. **4.** *See* GEOLOGICAL TIME SCALE.

period doubling A mechanism for describing the transition to *chaos in certain dynamical systems. If the force on a body produces a regular orbit with a specific *period a sudden increase in the force can suddenly double the period of the orbit and the motion becomes more complex. The original simple motion is called a **one-cycle**, while the more complicated motion after the period doubling is called a **two-cycle**. The process of period doubling can continue until a motion called an **n-cycle** is produced. As n increases to infinity the motion becomes non-periodic. The period-doubling route to chaos occurs in many systems involving nonlinearity, including lasers and certain chaotic chemical reactions. The period-doubling route to chaos was postulated and investigated by the US physicist Mitchell Feigenbaum in the early 1980s. Routes to chaos other than period doubling also exist.

periodic acid *See* IODIC(VII) ACID.

periodic law The principle that the physical and chemical properties of elements are a periodic function of their proton number. The concept was first proposed in 1869 by Dimitri Mendeleev, using relative atomic mass rather than proton number, as a culmination of efforts to rationalize chemical properties by Johann Döbereiner (1817), John Newlands (1863), and Lothar Meyer (1864). One of the major successes of the periodic law was its ability to predict chemical and physical properties of undiscovered elements and unknown compounds that were later confirmed experimentally. *See* PERIODIC TABLE.

periodic motion Any motion of a system that is continuously and identically repeated. The time T that it takes to complete one cycle of an oscillation or wave motion is called the *period, which is the reciprocal of the *frequency. *See* PENDULUM; SIMPLE HARMONIC MOTION.

periodic table A table of elements arranged in order of increasing proton number to show the similarities of chemical elements with related electronic configurations. (The original form was proposed by Dimitri Mendeleev in 1869 using relative atomic masses.) In the modern **short form**, the *lanthanoids and *actinoids are not shown. The elements fall into vertical columns, known as **groups**. Going down a group, the atoms of the elements all have the same outer shell structure, but an increasing number of inner shells. Traditionally, the alkali metals were shown on the left of the table and the groups were numbered IA to VIIA, IB to VIIB, and 0 (for the noble gases). All the elements in the middle of the table are classified as *transition elements and the nontransition elements are regarded as **main-group** elements. Because of confusion in the past regarding the numbering of groups and the designations of subgroups, modern practice is to number the groups across the table from 1 to 18 (see Appendix). Horizontal rows in the table are **periods**. The first three are called **short periods**; the next four (which include transition elements) are **long periods**. Within a period, the atoms of all the elements have the same number of shells, but with a steadily increasing number of electrons in the outer shell. The periodic table can also be divided into four **blocks** depending on the type of shell being filled: the **s*-block, the **p*-block, the **d*-block, and the **f*-block.

There are certain general features of chemical behaviour shown in the periodic table. In moving down a group, there is an increase in metallic character because of the increased size of the atom. In going across a period, there is a change from metallic (electropositive) behaviour to nonmetallic (electronegative) because of the increasing number of electrons in the outer shell. Consequently, metallic elements tend to be those on the left and towards the bottom of the table; nonmetallic elements are towards the top and the right.

There is also a significant difference between the elements of the second short period (lithium to fluorine) and the other elements in their respective groups. This is because the atoms in the second period are smaller and their valence electrons are shielded by a small $1s^2$ inner shell. Atoms in the other periods have inner *s*- and *p*-electrons shielding the outer electrons from the nucleus. Moreover, those in the second period only have *s*- and *p*-orbitals available for bonding. Heavier atoms can also promote electrons to vacant *d*-orbitals in their outer shell and use these for bonding. *See also* DIAGONAL RELATIONSHIP; INERT-PAIR EFFECT.

SEE WEB LINKS

- The WebElements table produced by Mark Winter at the University of Sheffield
- Over 50 different forms of the periodic table in the Chemogenesis web book by Mark R. Leach

periodontal membrane The membrane of connective tissue that surrounds the root of a *tooth and anchors it to its socket in the jawbone. Fibres of the periodontal membrane pass into the *cement covering the root, which provides a firm attachment.

periosteum The outer membrane that surrounds a bone. It contains connective tissue, capillaries, nerves, and a number of types of bone cell. The periosteum plays an important role in bone repair and growth.

peripheral device Any device, such as an input or output device, connected to the central processing unit of a *computer. Backing store is also usually regarded as a peripheral.

peripheral nervous system All parts of the nervous system excluding the *central nervous system. It consists of all the *cranial and *spinal nerves and their branches, which link the *receptors and *effectors with the central nervous system. *See also* AUTONOMIC NERVOUS SYSTEM.

periscope An optical device that enables an observer to see over or around opaque objects. The simplest type consists of a long tube with mirrors at each end set at 45° to the direction to be viewed. A better type uses internally reflecting prisms instead of plane mirrors. Periscopes are used in tanks (to enable the observer to see over obstacles without being shot at) and in submarines (when the vessel is submerged). Such periscopes are usually quite complicated instruments and include telescopes.

Perissodactyla An order of mammals having hoofed feet with an odd number of toes. They are all herbivores and include the tapirs, rhinoceros, and horse. The teeth are large and specialized for grinding. Cellulose digestion occurs in the caecum and large intestine. Fossils of the Eocene epoch, 60 million years ago, show that these animals were

at that time already distinct from the cloven-hoofed *Artiodactyla.

peristalsis Waves of involuntary muscular contraction and relaxation that pass along the alimentary canal, forcing food contents along. It is brought about by contraction of the circular muscles of the gut wall in sequence.

peristome **1.** A ring of toothlike structures around the opening of a moss *capsule. The teeth tend to bend and twist in dry weather, so opening the mouth of the capsule and allowing the spores to escape. In wet weather they close over the opening of the capsule. **2.** The area around the mouth in many invertebrates and some protists. It sometimes assists in food collecting. Examples are the spirally ciliated groove around the mouth of some ciliate protozoans and the first segment of the earthworm.

peritoneum The thin layer of tissue (*see* SEROUS MEMBRANE) that lines the abdominal cavity of vertebrates and covers the abdominal organs. *See also* MESENTERY.

Perkin, Sir William Henry (1838–1907) British chemist, who while still a student accidentally produced mauvine, the first aniline dye and the first dyestuff to be synthesized. Perkin built a factory to produce it, and made a fortune.

permaculture A permanent agriculture based on cropping from perennial plants and trees and often incorporating livestock. Such systems, inspired by natural ecosystems, are typically designed to be diverse, stable, and resilient, with minimal need for energy or artificial fertilizers and pesticides. However, they are generally relatively small in scale and are geared to fulfilling local needs or self-sufficiency for the farmer, as opposed to the large-scale cash cropping of conventional agriculture.

permafrost Permanently frozen soil and subsoil that occurs in arctic, subarctic, and alpine regions. It ranges from 30 cm to over 1000 m thick and covers nearly a fifth of the land surface of the earth. In summer the top few centimetres may thaw, forming pools of meltwater (which cannot drain through the frozen soil beneath).

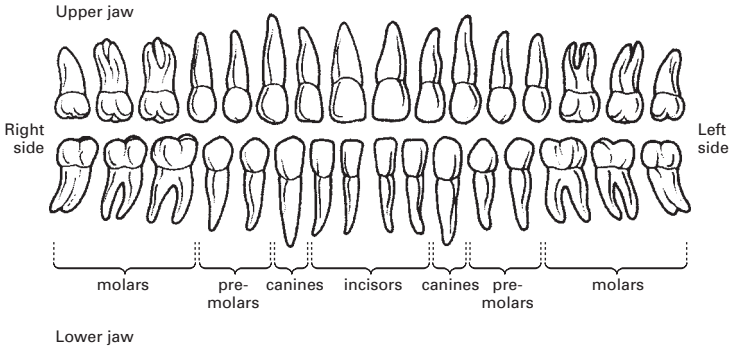
Permalloys A group of alloys of high magnetic permeability consisting of iron and nickel (usually 40–80%) often with small amounts of other elements (e.g. 3–5% molybdenum, copper, chromium, or tungsten). They are used in thin foils in electronic transformers, for magnetic shielding, and in computer memories.

permanent gas A gas, such as oxygen or nitrogen, that was formerly thought to be impossible to liquefy. A permanent gas is now regarded as one that cannot be liquefied by pressure alone at normal temperatures (i.e. a gas that has a critical temperature below room temperature).

permanent hardness *See* HARDNESS OF WATER.

permanent magnet *See* MAGNET.

permanent teeth The second and final set of teeth that mammals produce after shedding the *deciduous teeth. An adult



Permanent teeth.

human normally has 32 permanent teeth, consisting of incisors, canines, molars, and premolars (see illustration). These usually appear between the ages of approximately 6 and 21 years. *See also* DENTAL FORMULA; DIPHYODONT.

permanganate *See* MANGANATE(VII).

permeability (magnetic permeability) Symbol μ. The ratio of the magnetic flux density, *B*, in a substance to the external field strength, *H*; i.e. $\mu = B/H$. The permeability of free space, μ_0, is also called the **magnetic constant** and has the value $4\pi \times 10^{-7}$ H m^{-1} in *SI units. The relative permeability of a substance, μ_r, is given by μ/μ_0 and is therefore dimensionless. *See* MAGNETISM.

Permian The last geological period in the Palaeozoic era. It extended from the end of the Carboniferous period, about 299 million years ago, to the beginning of the Mesozoic era, about 251 million years ago. It was named by the British geologist Roderick Murchison (1792–1871) in 1841 after the Perm province in Russia. In some areas continental conditions prevailed, which continued into the following period, the Triassic. These conditions resulted in the deposition of the New Red Sandstone. During the period a number of animal groups became extinct, including the trilobites, tabulate and rugose corals, and blastoids (*see* MASS EXTINCTION). Amphibians and reptiles continued to be the dominant land animals and gymnosperms replaced ferns, clubmosses, and horsetails as the dominant plants.

permittivity Symbol ε. The ratio of the *electric displacement in a medium to the intensity of the electric field producing it. It is important for electrical insulators used as *dielectrics.

If two charges Q_1 and Q_2 are separated by a distance *r* in a vacuum, the force *F* between the charges is given by:

$$F = Q_1 Q_2 / r^2 4\pi\varepsilon_0$$

In this statement of *Coulomb's law using *SI units, ε_0 is called the absolute permittivity of free space, which is now known as the **electric constant**. It has the value 8.854×10^{-12} F m^{-1}.

If the medium between the charges is anything other than a vacuum the equation becomes:

$$F = Q_1 Q_2 / r^2 4\pi\varepsilon$$

and the force between the charges is reduced. ε is the **absolute permittivity** of the new medium. The **relative permittivity** (ε_r) of a medium, formerly called the **dielectric constant**, is given by $\varepsilon_r = \varepsilon/\varepsilon_0$.

permonosulphuric(VI) acid *See* PEROXOSULPHURIC(VI) ACID.

permutations and combinations A combination is any subset of a particular set of objects, regardless of the order of selection. If the set consists of *n* objects, *r* objects can be selected giving $n!/r!(n-r)!$ different combinations. This can be written ${}_nC_r$.

A permutation is an ordered subset (i.e. attention is paid to the order of selection or arrangement) of a particular set of objects. If the set consists of *n* objects, *r* such objects can be selected to give $n!/(n-r)!$ permutations. This is written ${}_nP_r$.

Permutit Trade name for a *zeolite used for water softening.

peroxides **1.** A group of inorganic compounds that contain the O_2^{2-} ion. They are notionally derived from hydrogen peroxide, H_2O_2, but these ions do not exist in aqueous solution due to extremely rapid hydrolysis to OH^-. **2.** A class of organic compounds that contain the –O–O– group. Organic peroxides tend to be unstable and some are explosive. They can be used to initiate free-radical reactions.

SEE WEB LINKS

- Information about IUPAC nomenclature

peroxisome An organelle, found in the cytoplasm of virtually all plant and animal cells, that contains several enzymes involved in oxidation processes. Peroxisomes are bound by a single membrane; the enzymes they contain include urate oxidase and catalase (which catalyses the breakdown of hydrogen peroxide, produced as a by-product of the activity of the other enzymes). Peroxisomes are active in the process of *detoxification, being particularly abundant in the liver and in the *proximal convoluted tubules of the kidney. In plant cells they are the main site of *fatty-acid oxidation.

peroxodisulphuric acid *See* PEROXOSULPHURIC(VI) ACID.

peroxomonosulphuric(VI) acid *See* PEROXOSULPHURIC(VI) ACID.

peroxosulphuric(VI) acid The term commonly refers to **peroxomonosulphuric(VI) acid**, H_2SO_5, which is also called **permonosulphuric(VI) acid** and **Caro's acid**.

It is a crystalline compound made by the action of hydrogen peroxide on concentrated sulphuric acid. It decomposes in water and the crystals decompose, with melting, above 45°C. The compound **peroxodisulphuric acid**, $H_2S_2O_8$, also exists (formerly called **perdisulphuric acid**). It is made by the high-current electrolysis of sulphate solutions. It decomposes at 65°C (with melting) and is hydrolysed in water to give the mono acid and sulphuric acid. Both peroxo acids are very powerful oxidizing agents. *See also* SULPHURIC ACID (for structural formulas).

perpetual motion **1.** Perpetual motion of the first kind. Motion in which a mechanism, once started, would continue indefinitely to perform useful work without being supplied with energy from an outside source. Such a device would contravene the first law of *thermodynamics and is therefore not feasible. Many historical attempts, exercising great ingenuity, were constructed before the concept of energy and its conservation were understood. Some attempts have been made, since the first law of thermodynamics became generally accepted, by inventors seeking to establish loopholes in the laws of nature. **2.** Perpetual motion of the second kind. Motion in which a mechanism extracts heat from a source and converts all of it into some other form of energy. An example of such a mechanism would be a ship that utilized the internal energy of the oceans for propulsion. Such a device does not contravene the first law of thermodynamics but it does contravene the second law. In the case of the ship, the sea would have to be at a higher temperature than the ship to establish a useful flow of heat. This could not occur without an external energy source. **3.** Perpetual motion of the third kind. A form of motion that continues indefinitely but without doing any useful work. An example is the random molecular motion in a substance. This type postulates the complete elimination of friction. A mechanism consisting of frictionless bearings maintained in a vacuum could turn indefinitely, once started, without contravening the first or second laws of thermodynamics, provided it did no external work. Experience indicates that on the macroscopic scale such a condition cannot be achieved. On the microscopic scale, however, a superconducting ring of wire will apparently sustain a perpetual current flow without the application of an external force. This could be considered a form of perpetual motion of the third kind, if the energy required to cool the wire to superconducting temperatures is ignored.

persistent organic pollutant (POP) A toxic substance that is not biodegradable and persists in the environment. POPs can concentrate as they move up the food chain and are generally deleterious to health. In 2001, an international conference in Sweden resulted in an agreement (the **Stockholm Convention**) to reduce or eliminate the 12 POPs of greatest concern, and to add other chemicals to the list in the future. The 12 chemicals were the pesticides aldrin, chlordane, *DDT, dieldrin, endrin, heptachlor, mirex, and toxaphene, together with the industrial chemical hexachlorobenzene and the groups *polychlorinated biphenyls, *dioxins, and *furans.

SEE WEB LINKS

- Official Stockholm Convention site

personal computer A general-purpose *microcomputer designed for use by one person at a time. The original Personal Computer (or PC) was a highly successful product from IBM. An **IBM-compatible** computer is functionally identical to an IBM PC and able to accept all hardware and software intended for it. The abbreviation 'PC' is now most often used to mean an IBM-compatible computer as opposed to other systems. Personal computers range widely in capability and cost. They may take the form of desktop computers or be portable versions, such as laptop, notebook, or subnotebook computers.

Perspex Trade name for a form of *polymethylmethacrylate.

perturbation A departure by a celestial body from the trajectory or orbit it would follow if it moved only under the influence of a single central force. According to *Kepler's law, for example, a single planet orbiting the sun would move in an elliptical orbit. In fact, planets are perturbed from elliptical orbits by the gravitational forces exerted on them by other planets. Similarly, the moon's orbit round the earth is perturbed by the gravitational effect of the sun and the trajectories of comets are perturbed when they pass close to planets.

perturbation theory A method used in calculations in both classical physics (e.g. planetary orbits) and quantum mechanics (e.g. atomic structure), in which the system

is divided into a part that is exactly calculable and a small term, which prevents the whole system from being exactly calculable. The technique of perturbation theory enables the effects of the small term to be calculated by an infinite series (which in general is an asymptotic series). Each term in the series is a 'correction term' to the solutions of the exactly calculable system. In classical physics, perturbation theory can be used for calculating planetary orbits. In quantum mechanics, it can be used to calculate the energy levels in molecules. In the many-body problem in quantum mechanics and in relativistic quantum field theory, the terms in perturbation theory may be represented pictorially by Feynman diagrams (*see* QUANTUM ELECTRODYNAMICS).

pervasive computing *See* UBIQUITOUS COMPUTING.

perversion *See* LATERAL INVERSION.

pest Any of various organisms, such as fungi, insects, rodents, and plants, that harm crops or livestock or otherwise interfere with the wellbeing of human beings. **Weeds** are plant pests that grow where they are not wanted – often on cultivated land, where they compete with crop plants for space, light, nutrients, etc. Pests are controlled by the use of *pesticides and *biological control methods.

p

pesticide Any chemical compound used to kill pests that destroy agricultural production or are in some way harmful to humans. Pesticides include **herbicides** (such as *2,4-D and Paraquat), which kill unwanted plants or weeds; **insecticides** (such as *pyrethrum), which kill insect pests; **fungicides**, which kill fungi; and **rodenticides** (such as *warfarin), which kill rodents. The problems associated with pesticides are that they are very often nonspecific and may therefore be toxic to organisms that are not pests; they may also be nonbiodegradable, so that they persist in the environment and may accumulate in living organisms (*see* BIOACCUMULATION). Organophosphorus insecticides, such as malathion and parathion, are biodegradable but can also damage the respiratory and nervous systems in humans as well as killing useful insects, such as bees. They act as *anticholinesterases. Organochlorine insecticides, such as dieldrin, aldrin, and *DDT, are very persistent and not easily biodegradable.

PET *See* POSITRON EMISSION TOMOGRAPHY.

peta- Symbol P. A prefix used in the metric system to denote one thousand million million times. For example, 10^{15} metres = 1 petametre (Pm).

petal One of the parts of the flower that make up the *corolla. Petals of insect-pollinated plants are usually brightly coloured and often scented. Those of wind-pollinated plants are usually reduced or absent. Petals are considered to be modified leaves but their structure is simpler. Epidermal hairs may be present and the cuticle is often covered by lines or dots known as **honey guides**, which direct insects to the *nectar.

Peters' projection *See* MAP PROJECTIONS.

petiole The stalk that attaches a *leaf blade to the stem. Leaves without petioles are described as **sessile**.

Petri dish A shallow circular flat-bottomed dish made of glass or plastic and having a fitting lid. It is used in laboratories chiefly for culturing bacteria and other microorganisms. It was invented by the German bacteriologist Julius Petri (1852–1921).

petrification *See* FOSSIL.

petrochemicals Organic chemicals obtained from petroleum or natural gas.

petrolatum *See* PETROLEUM JELLY.

petroleum A naturally occurring oil that consists chiefly of hydrocarbons with some other elements, such as sulphur, oxygen, and nitrogen. In its unrefined form petroleum is known as **crude oil** (sometimes **rock oil**). Petroleum is believed to have been formed from the remains of living organisms that were deposited, together with rock particles and biochemical and chemical precipitates, in shallow depressions, chiefly in marine conditions. Under burial and compaction the organic matter went through a series of processes before being transformed into petroleum, which migrated from the source rock to become trapped in large underground reservoirs beneath a layer of impermeable rock. The petroleum often floats above a layer of water and is held under pressure beneath a layer of *natural gas.

Petroleum reservoirs are discovered through geological exploration: commercially important oil reserves are detected by exploratory narrow-bore drilling. The major known reserves of petroleum are in Saudi Arabia, Russia, China, Kuwait, Iran, Iraq,

Mexico, USA, United Arab Emirates, Libya, Venezuela, and beneath the North Sea. The oil is actually obtained by the sinking of an oil well. Before it can be used it is separated by fractional distillation in oil refineries. The main fractions obtained are:
(1) **Refinery gas** A mixture of methane, ethane, butane, and propane used as a fuel and for making other organic chemicals.
(2) **Gasoline** A mixture of hydrocarbons containing 5 to 8 carbon atoms, boiling in the range 40–180°C. It is used for motor fuels and for making other chemicals.
(3) **Kerosine** (or **paraffin oil**) A mixture of hydrocarbons having 11 or 12 carbon atoms, boiling in the range 160–250°C. Kerosine is a fuel for jet aircraft and for oil-fired domestic heating. It is also cracked to produce smaller hydrocarbons for use in motor fuels.
(4) **Diesel oil** (or **gas oil**) A mixture of hydrocarbons having 13 to 25 carbon atoms, boiling in the range 220–350°C. It is a fuel for diesel engines.

The residue is a mixture of higher hydrocarbons. The liquid components are obtained by vacuum distillation and used in lubricating oils. The solid components (**paraffin wax**) are obtained by solvent extraction. The final residue is a black tar containing free carbon (**asphalt** or **bitumen**).

petroleum ether A colourless volatile flammable mixture of hydrocarbons (not an ether), mainly pentane and hexane. It boils in the range 30–70°C and is used as a solvent.

petroleum jelly (petrolatum) A semi-solid mixture of hydrocarbons extracted from petroleum. It is used in skincare products and cosmetics, and as a lubricant. Petroleum is widely available under the tradename **Vaseline**.

pewter An alloy of lead and tin. It usually contains 63% tin; pewter tankards and food containers should have less than 35% of lead so that the lead remains in solid solution with the tin in the presence of weak acids in the food and drink. Copper is sometimes added to increase ductility and antimony is added if a hard alloy is required.

peyote *See* MESCALINE.

Pfund series *See* HYDROGEN SPECTRUM.

PGD *See* PREIMPLANTATION GENETIC DIAGNOSIS.

pH *See* pH SCALE.

PHA *See* PHYTOHAEMAGGLUTININ.

Phaeophyta (brown algae) A phylum of *algae in which the green chlorophyll pigments are usually masked by the brown pigment fucoxanthin. Brown algae are usually marine (being abundant in cold water) and many species, such as the wracks (*Fucus*), inhabit intertidal zones. They vary in size from small branched filaments to ribbon-like bodies (known as kelps) many metres long.

phage *See* BACTERIOPHAGE.

phagocyte A cell that is able to engulf and break down foreign particles, cell debris, and disease-producing microorganisms (*see* PHAGOCYTOSIS). Some protists and certain mammalian cells (e.g. *macrophages and *monocytes) are phagocytes. Phagocytes are important elements in the natural defence mechanism of most animals.

phagocytosis The process by which foreign particles invading the body or minute food particles are engulfed and broken down by certain animal cells (known as *phagocytes). The plasma membrane of the phagocyte invaginates to capture the particle and then closes around it to form a vesicle. This then coalesces with a *lysosome, which contains enzymes that break down the particle. *See* ENDOCYTOSIS. *Compare* PINOCYTOSIS.

phalanges The bones that make up the *digits of the hand or foot in vertebrates. They articulate with the *metacarpals of the hand or with the *metatarsals of the foot. In the basic *pentadactyl limb there are two phalanges for the first digit (the thumb or big toe in humans) and three for each of the others.

phane *See* CYCLOPHANE.

Phanerozoic The most recent eon of geological time, represented by rock strata containing clearly recognizable fossils. It comprises the *Palaeozoic, *Mesozoic, and *Cenozoic eras and has extended for about 542 million years from the beginning of the Cambrian period. *Compare* PROTEROZOIC.

pharmacogenomics (pharmacogenetics) The study of how genes affect the actions of drugs. The enormous growth in knowledge about human genetics arising from the *Human Genome Project, coupled with the rapid advance of computer systems to analyse the vast amounts of data, has revolutionized drug discovery and development. This approach, which combines *genomics and pharmacology, improves un-

derstanding of drug actions, suggests new potential drug molecules, and enables computer-based searches for likely drug targets. It also raises the prospect of drugs being tailor-made to suit the genetic make-up of particular patients or groups of patients. This more precise targeting of drugs should make drugs more effective, with less risk of adverse side effects.

pharmacokinetics The movement of foreign substances, particularly drugs, throughout the body of an animal. Processes that influence the pharmacokinetics of a compound include uptake, distribution throughout the body tissues, the length of time the compound remains in the body, and its rate of clearance (e.g. by metabolism or excretion).

pharmacology The study of the properties of drugs and their effects on living organisms. Clinical pharmacology is concerned with the effects of drugs in treating disease.

pharynx **1.** The cavity in vertebrates between the mouth and the *oesophagus and windpipe (*trachea), which serves for the passage of both food and respiratory gases. The presence of food in the pharynx stimulates swallowing (*see* DEGLUTITION). In fish and aquatic amphibians the pharynx is perforated by *gill slits. **2.** The corresponding region in invertebrates.

phase **1.** A homogeneous part of a heterogeneous system that is separated from other parts by a distinguishable boundary. A mixture of ice and water is a two-phase system. A solution of salt in water is a single-phase system. **2.** A description of the stage that a periodic motion has reached, usually by comparison with another such motion of the same frequency. Two varying quantities are said to be **in phase** if their maximum and minimum values occur at the same instants; otherwise, there is said to be a **phase difference**. *See also* PHASE ANGLE. **3.** One of the circuits in an electrical system or device in which there are two or more alternating currents that are not in phase with each other. In a three-phase system the displacement between the currents is one third of a period. **4.** *See* PHASES OF THE MOON.

phase angle The difference in *phase between two sinusoidally varying quantities. The displacement x_1 of one quantity at time t is given by $x_1 = a\sin\omega t$, where ω is the angular frequency and a is the amplitude. The displacement x_2 of a similar wave that reaches the end of its period T, a fraction β of the period before the first is said to **lead** the first quantity by a time βT; if it reaches the end of its period, a fraction β of the period after the first quantity it **lags** by a time βT. The value of x_2 is then given by $x_2 = a\sin(\omega t + \phi)$. ϕ is called the phase angle and it is equal to $2\pi\beta$.

phase-contrast microscope A type of *microscope that is widely used for examining such specimens as biological cells and tissues. It makes visible the changes in phase that occur when nonuniformly transparent specimens are illuminated. In passing through an object the light is slowed down and becomes out of phase with the original light. With transparent specimens having some structure *diffraction occurs, causing a larger phase change in light outside the central maximum of the pattern. The phase-contrast microscope provides a means of combining this light with that of the central maximum by means of an annular diaphragm and a **phase-contrast plate**, which produces a matching phase change in the light of the central maximum only. This gives greater contrast to the final image, due to constructive interference between the two sets of light waves. This is **bright contrast**; in **dark contrast** a different phase-contrast plate is used to make the same structure appear dark, by destructive interference of the same waves.

phase diagram A graph showing the relationship between solid, liquid, and gaseous *phases over a range of conditions (e.g. temperature and pressure). *See* STEEL.

phase I metabolism The first stage in the conversion of a foreign compound, such as a drug or toxin, into a form that can be eliminated by the body. Common reactions during this phase are oxidation, reduction, and hydrolysis; the resulting metabolites are chemically more reactive than the parent compound, enabling them to undergo the reactions of the second stage (*see* PHASE II METABOLISM).

phase II metabolism The second stage in adapting foreign compounds for elimination from the body (*compare* PHASE I METABOLISM). Phase II metabolism involves the addition of chemical groups (e.g. glycine or acetate), which usually makes the com-

pound less toxic to body tissues and easier to excrete.

phase modulation *See* MODULATION.

phase rule For any system at equilibrium, $P + F = C + 2$, where P is the number of distinct phases, C the number of components, and F the number of degrees of freedom of the system. The relationship, derived by Josiah Willard Gibbs in 1876, is often called the **Gibbs phase rule**.

phases of the moon The shapes of the illuminated surface of the moon as seen from the earth. The shape changes as a result of the relative positions of the earth, sun, and moon.

New moon occurs when the nearside is totally unilluminated by the sun. As the moon moves eastwards in its orbit the sunrise *terminator crosses the nearside from east to west producing a **crescent moon**. The moon is half illuminated at **first quarter**. When it is more than half-phase but less than full phase it is said to be a **gibbous moon**. When the moon is at *opposition the nearside is fully illuminated producing a **full moon**. The sunset terminator then follows to produce a waning gibbous moon, **last quarter**, a waning crescent moon, and eventually the next new moon.

phase space For a system with n degrees of freedom, the $2n$-dimensional space with coordinates (q_1, q_2, …, q_n, p_1, p_2, …, p_n), where the qs describe the degrees of freedom of the system and the ps are the corresponding momenta. Each point represents a state of the system. In a gas of N point particles, each particle has three positional coordinates and three corresponding momentum coordinates, so that the phase space has $6N$-dimensions. If the particles have internal degrees of freedom, such as the vibrations and rotations of molecules, then these must be included in the phase space, which is consequently of higher dimension than that for point particles. As the system changes with time the representative points trace out a curve in phase space known as a **trajectory**. *See also* ATTRACTOR; CONFIGURATION SPACE; STATISTICAL MECHANICS.

phase speed (phase velocity) Symbol V_p. The speed of propagation of a pure sine wave. $V_p = \lambda f$, where λ is the wavelength and f is the frequency. The value of the phase speed depends on the nature of the medium through which it is travelling and may also depend on the mode of propagation. For electromagnetic waves travelling through space the phase speed c is given by $c^2 = 1/\varepsilon_0\mu_0$, where ε_0 and μ_0 are the electric constant and the magnetic constant respectively.

phase transition A change in a feature that characterizes a system. Examples of phase transitions are changes from solid to liquid, liquid to gas, and the reverse changes. Other examples of phase transitions include the transition from a paramagnet to a ferromagnet (*see* MAGNETISM) and the transition from a normally conducting metal to a superconductor. Phase transitions can occur by altering such variables as temperature and pressure.

Phase transitions can be classified by their **order**. If there is non-zero *latent heat at the transition it is said to be a **first-order transition**. If the latent heat is zero it is said to be a **second-order transition**.

Some *models describing phase transitions, particularly in *low-dimensional systems, are amenable to exact mathematical solutions. An effective technique for understanding phase transitions is the *renormalization group since it can deal with problems involving different length-scales, including the feature of **universality**, in which very different physical systems behave in the same way near a phase transition. *See also* ORDER PARAMETER; RENORMALIZATION GROUP; TRANSITION POINT; BROKEN SYMMETRY; EARLY UNIVERSE.

phasor A rotating *vector that represents a sinusoidally varying quantity. Its length represents the amplitude of the quantity and it is imagined to rotate with angular velocity equal to the angular frequency of the quantity, so that the instantaneous value of the quantity is represented by its projection upon a fixed axis. The concept is convenient for representing the *phase angle between two quantities; it is shown on a diagram as the angle between their phasors.

phellem *See* CORK.

phelloderm *See* CORK CAMBIUM.

phellogen *See* CORK CAMBIUM.

phencyclidine (PCP) A hallucinogenic drug, originally used as a veterinary anaesthetic. It is usually used as a powder (known as 'angel dust').

phenetic Describing a system of *classification of organisms based on similarities and differences in as many observable characteristics as possible. A phenetic system does not aim to reflect evolutionary descent, although it may well do so. *Compare* PHYLOGENETIC.

phenol (carbolic acid) A white crystalline solid, C_6H_5OH; r.d. 1.1; m.p. 43°C; b.p. 182°C. It is made by the *cumene process or by the *Raschig process and is used to make a variety of other organic chemicals. *See also* PHENOLS.

phenol–formaldehyde resin A class of resins produced by polymerizing phenols with formaldehyde (methanol) using acid or basic catalysts. They are generally cross-linked thermosetting materials. *Bakelite is the original example.

phenolic resins Synthetic resins made by copolymerizing phenols with aldehydes. *Phenol–formaldehyde resins are the commonest type.

phenolphthalein A dye used as an acid-base *indicator. It is colourless below pH 8 and red above pH 9.6. It is used in titrations involving weak acids and strong bases. It is also used as a laxative.

phenolphthalein test *See* KASTLE MEYER TEST.

phenols Organic compounds that contain a hydroxyl group (–OH) bound directly to a carbon atom in a benzene ring. Unlike normal alcohols, phenols are acidic because of the influence of the aromatic ring. Thus, phenol itself (C_6H_5OH) ionizes in water:

$$C_6H_5OH \rightarrow C_6H_5O^- + H^+$$

Phenols are made by fusing a sulphonic acid salt with sodium hydroxide to form the sodium salt of the phenol. The free phenol is liberated by adding sulphuric acid.

phenotype The observable characteristics of an organism. These are determined by its genes (*see* GENOTYPE), the dominance relationships between the *alleles, and by the interaction of the genes with the environment.

phenylalanine *See* AMINO ACID.

phenylamine (aniline; aminobenzene) A colourless oily liquid aromatic *amine, $C_6H_5NH_2$, with an 'earthy' smell; r.d. 1.0217; m.p. –6.3°C; b.p. 184.1°C. The compound turns brown on exposure to sunlight. It is basic, forming the **phenylammonium** (or **anilinium**) **ion**, $C_6H_5NH_3^+$, with strong acids. It is manufactured by the reduction of nitrobenzene or by the addition of ammonia to chlorobenzene using a copper(II) salt catalyst at 200°C and 55 atm. The compound is used extensively in the rubber industry and in the manufacture of drugs and dyes.

phenylammonium ion The ion $C_6H_5NH_3^+$, derived from *phenylamine.

***N*-phenylethanamide** *See* ACETANILIDE.

phenylethene (styrene) A liquid hydrocarbon, $C_6H_5CH{:}CH_2$; r.d. 0.9; m.p. –31°C; b.p. 145°C. It can be made by dehydrogenating ethylbenzene and is used in making polystyrene.

phenyl group The organic group C_6H_5–, present in benzene.

phenylhydrazine A toxic colourless dense liquid, $C_6H_8N_2$, b.p. 240°C, which turns brown on exposure to air. It is a powerful reducing agent, made from *diazonium salts of benzene. It is used to identify aldehydes and ketones, with which it forms condensation products called *hydrazones. With glucose and similar sugars it forms osazones. For such tests, the nitro derivative 2,4-dinitrophenylhydrazine (DNP) is often preferred as this generally forms crystalline derivatives that can be identified by their melting points. Phenylhydrazine is also used to make dyes and derivatives of *indole.

phenylhydrazones *See* HYDRAZONES.

phenylketonuria A genetic disorder in which there is disordered metabolism of the amino acid phenylalanine, leading to severe mental retardation of affected children. The disease is caused by the absence or deficiency of the enzyme phenylalanine hydroxylase, which results in the accumulation of phenylalanine in all body fluids. There are also high levels of the ketone phenylpyruvate in the urine, hence the name of the disease. The disease occurs in individuals who are homozygous for the defective recessive allele on chromosome 12; both parents of such individuals are thus heterozygous carriers of the allele. The advent of *gene probes has greatly aided accurate diagnosis, of both phenylketonurics and carriers.

phenylmethanol (benzyl alcohol) A liquid aromatic alcohol, $C_6H_5CH_2OH$; r.d. 1.04; m.p. –15.3°C; b.p. 205.4°C. It is used mainly as a solvent.

phenylmethylamine *See* BENZYLAMINE.

3-phenylpropenoic acid *See* CINNAMIC ACID.

pheromone (ectohormone) A chemical substance emitted by an organism into the environment as a specific signal to another organism, usually of the same species. Pheromones play an important role in the social behaviour of certain animals, especially insects and mammals. They are used to attract mates, to mark trails, and to promote social cohesion and coordination in colonies. Pheromones are usually highly volatile organic acids or alcohols and can be effective at minute concentrations.

Phillips process A process for making high-density polyethene by polymerizing ethene at high pressure (30 atmospheres) and 150°C. The catalyst is chromium(III) oxide supported on silica and alumina.

phloem (bast) A tissue that conducts food materials in vascular plants from regions where they are produced (notably the leaves) to regions, such as growing points, where they are needed. It consists of hollow tubes (sieve tubes) that run parallel to the long axis of the plant organ and are formed from elongated cells (*sieve elements) joined end to end. The end walls of these cells are broken down to a greater or lesser extent to allow passage of materials. In young plants and in newly formed tissues of mature plants the phloem is formed by the activity of the *apical meristem. In most plants secondary phloem is later differentiated by the vascular *cambium and this replaces the earlier formed phloem in older regions. *See also* COMPANION CELL. *Compare* XYLEM.

phlogiston theory A former theory of combustion in which all flammable objects were supposed to contain a substance called **phlogiston**, which was released when the object burned. The existence of this hypothetical substance was proposed in 1669 by Johann Becher, who called it 'combustible earth' (*terra pinguis*: literally 'fat earth'). For example, according to Becher, the conversion of wood to ashes by burning was explained on the assumption that the original wood consisted of ash and *terra pinguis*, which was released on burning. In the early 18th century Georg Stahl renamed the substance phlogiston (from the Greek for 'burned') and extended the theory to include the calcination (and corrosion) of metals. Thus, metals were thought to be composed of **calx** (a powdery residue) and phlogiston; when a metal was heated, phlogiston was set free and the calx remained. The process could be reversed by heating the metal over charcoal (a substance believed to be rich in phlogiston, because combustion almost totally consumed it). The calx would absorb the phlogiston released by the burning charcoal and become metallic again.

The theory was finally demolished by Antoine Lavoisier, who showed by careful experiments with reactions in closed containers that there was no *absolute* gain in mass – the gain in mass of the substance was matched by a corresponding loss in mass of the air used in combustion. After experiments with Priestley's dephlogisticated air, Lavoisier realized that this gas, which he named oxygen, was taken up to form a calx (now called an oxide). The role of oxygen in the new theory was almost exactly the opposite of phlogiston's role in the old. In combustion and corrosion phlogiston was released; in the modern theory, oxygen is taken up to form an oxide.

phloroglucinol A red dye (usually acidified with hydrochloric acid) that stains lignin in plant cells red.

phon A unit of loudness of sound that measures the intensity of a sound relative to a reference tone of defined intensity and frequency. The reference tone usually used has a frequency of 1 kilohertz and a root-mean-square sound pressure of 2×10^{-5} pascal. The observer listens with both ears to the reference tone and the sound to be measured alternately. The reference tone is then increased until the observer judges it to be of equal intensity to the sound to be measured. If the intensity of the reference tone has been increased by n *decibels to achieve this, the sound being measured is said to have an intensity of n phons. The decibel and phon scales are not identical as the phon scale is subjective and relies on the sensitivity of the ear to detect changes of intensity with frequency.

phonochemistry *See* SONOCHEMISTRY.

phonon A quantum of *crystal-lattice vibrational energy having a magnitude hf, where h is the *Planck constant and f is the frequency of the vibration. Phonons are analogous to the quanta of light, i.e. *photons. The concept of phonons is useful in the treatment of the thermal conductivity of

nonmetallic solids and, through consideration of electron–phonon interactions, the temperature dependence of the electrical conductivity of metals.

phosgene *See* CARBONYL CHLORIDE.

phosphagen A compound in animal tissues that provides a reserve of chemical energy in the form of high-energy phosphate bonds. The most common phosphagens are *creatine phosphate, occurring in vertebrate muscle and nerves, and arginine phosphate, found in most invertebrates. During tissue activity (e.g. in muscle contraction) phosphagens give up their phosphate groups, thereby generating *ATP from ADP. The phosphagens are then reformed when ATP is available.

phosphatase An enzyme that catalyses the removal of a phosphate group from an organic compound.

phosphates Salts based formally on phosphorus(V) oxoacids and in particular salts of *phosphoric(V) acid, H_3PO_4. A large number of polymeric phosphates also exist, containing P–O–P bridges. These are formed by heating the free acid and its salts under a variety of conditions; as well as linear polyphosphates, cyclic polyphosphates and cross-linked polyphosphates or ultraphosphates are known.

phosphatide *See* PHOSPHOLIPID.

phosphatidylcholine *See* LECITHIN.

phosphide A binary compound of phosphorus with a more electropositive element. Phosphides show a wide range of properties. Alkali and alkaline earth metals form ionic phosphides, such as Na_3P and Ca_3P_2, which are readily hydrolysed by water. The other transition-metal phosphides are inert metallic-looking solids with high melting points and electrical conductivities.

phosphine A colourless highly toxic gas, PH_3; m.p. –133°C; b.p. –87.7°C; slightly soluble in water. Phosphine may be prepared by reacting water or dilute acids with calcium phosphide or by reaction between yellow phosphorus and concentrated alkali. Solutions of phosphine are neutral but phosphine does react with some acids to give phosphonium salts containing PH_4^+ ions, analogous to the ammonium ions. Phosphine prepared in the laboratory is usually contaminated with diphosphine and is spontaneously flammable but the pure compound is not so. Phosphine can function as a ligand in binding to transition-metal ions. Dilute gas mixtures of very pure phosphine and the rare gases are used for doping semiconductors.

phosphinic acid (hypophosphorus acid) A white crystallline solid, H_3PO_2; r.d. 1.493; m.p. 26.5°C; decomposes above 130°C. It is soluble in water, ethanol, and ethoxyethane. Salts of phosphinic acid may be prepared by boiling white phosphorus with the hydroxides of group 1 or group 2 metals. The free acid is made by the oxidation of phosphine with iodine. It is a weak monobasic acid in which it is the –O–H group that is ionized to give the ion $H_2PO_2^-$. The acid and its salts are readily oxidized to the orthophosphate and consequently are good reducing agents.

phosphite *See* PHOSPHONIC ACID.

phospholipid (phosphatide) One of a group of lipids having both a phosphate group and one or more fatty acids. **Glycerophospholipids** (or **phosphoglycerides**) are based on *glycerol; the three hydroxyl groups are esterified with two fatty acids and a phosphate group, which may itself be bound to one of a variety of simple organic groups (e.g. in *lecithin (phosphatidylcholine) it is choline). **Sphingolipids** are based on the alcohol sphingosine and contain only one fatty acid linked to an amino group. With their hydrophilic polar phosphate groups and long hydrophobic hydrocarbon 'tails', phospholipids readily form membrane-like structures in water. They are a major component of plasma membranes (*see* LIPID BILAYER).

phosphonate *See* PHOSPHONIC ACID.

phosphonic acid (phosphorous acid; orthophosphorous acid) A colourless to pale-yellow deliquescent crystalline solid, H_3PO_3; r.d. 1.65; m.p. 73.6°C; decomposes at 200°C; very soluble in water and soluble in alcohol. Phosphonic acid may be crystallized from the solution obtained by adding ice-cold water to phosphorus(III) oxide or phosphorus trichloride. The structure of this material is unusual in that it contains one direct P–H bond and is more correctly written $(HO)_2HPO$. The acid is dibasic, giving rise to the ions $H_2PO_3^-$ and HPO_3^{2-} (**phosphonates**; formerly **phosphites**), and has moderate reducing properties. On heating it gives phosphine and phosphoric(V) acid.

phosphonium ion The ion PH_4^+, or the

corresponding organic derivatives of the type R_3PH^+, RPH_3^+. The phosphonium ion PH_4^+ is formally analogous to the ammonium ion NH_4^+ but PH_3 has a much lower proton affinity than NH_3 and reaction of PH_3 with acids is necessary for the production of phosphonium salts.

phosphor A substance that is capable of *luminescence (including phosphorescence). Phosphors that release their energy after a short delay of between 10^{-10} and 10^{-4} second are sometimes called **scintillators**.

phosphor bronze An alloy of copper containing 4% to 10% of tin and 0.05% to 1% of phosphorus as a deoxidizing agent. It is used particularly for marine purposes and where it is exposed to heavy wear, as in gear wheels. *See also* BRONZE.

phosphorescence *See* LUMINESCENCE.

phosphoric(V) acid (orthophosphoric acid) A white rhombic solid, H_3PO_4; r.d. 1.834; m.p. 42.35°C; loses water at 213°C; very soluble in water and soluble in ethanol. Phosphoric(V) acid is very deliquescent and is generally supplied as a concentrated aqueous solution. It is the most commercially important derivative of phosphorus, accounting for over 90% of the phosphate rock mined. It is manufactured by two methods; the **wet process**, in which the product contains some of the impurities originally present in the rock and applications are largely in the fertilizer industry, and the **thermal process**, which produces a much purer product suitable for the foodstuffs and detergent industries. In the wet process the phosphate rock, $Ca_3(PO_4)_2$, is treated with sulphuric acid and the calcium sulphate removed either as gypsum or the hemihydrate. In the thermal process, molten phosphorus is sprayed and burned in a mixture of air and steam. Phosphoric(V) acid is a weak tribasic acid, which is best visualized as $(HO)_3PO$. Its full systematic name is **tetraoxo-phosphoric(V) acid**. It gives rise to three series of salts containing **phosphate(V)** ions based on the anions $[(HO)_2PO_2]^-$, $[(HO)PO_3]^{2-}$, and PO_4^{3-}. These salts are acidic, neutral, and alkaline in character respectively and phosphate ions often feature in buffer systems. There is also a wide range of higher acids and acid anions in which there is some P–O–P chain formation. The simplest of these is **pyrophosphoric acid** (technically **heptaoxodiphosphoric(V) acid**), $H_4P_2O_7$, produced by heating phosphoric(V) acid (solid) and phosphorus(III) chloride oxide. **Metaphosphoric acid** is a glassy polymeric solid $(HPO_2)_x$.

phosphorous acid *See* PHOSPHONIC ACID.

phosphorus Symbol P. A nonmetallic element belonging to *group 15 (formerly VB) of the periodic table; a.n. 15; r.a.m. 30.9738; r.d. 1.82 (white), 2.34 (red); m.p. 44.1°C (α-white); b.p. 280°C (α-white). It occurs in various phosphate rocks, from which it is extracted by heating with carbon (coke) and silicon(IV) oxide in an electric furnace (1500°C). Calcium silicate and carbon monoxide are also produced. Phosphorus has a number of allotropic forms. The α-white form consists of P_4 tetrahedra (there is also a β-white form stable below –77°C). If α-white phosphorus is dissolved in lead and heated at 500°C a violet form is obtained. Red phosphorus, which is a combination of violet and white phosphorus, is obtained by heating α-white phosphorus at 250°C with air excluded. There is also a black allotrope, which has a graphite-like structure, made by heating white phosphorus at 300°C with a mercury catalyst. The element is highly reactive. It forms metal *phosphides and covalently bonded phosphorus(III) and phosphorus(V) compounds. Phosphorus is an *essential element for living organisms. It is an important constituent of tissues (especially bones and teeth) and of cells, being required for the formation of nucleic acids and energy-carrying molecules (e.g. ATP) and also involved in various metabolic reactions. The element was discovered by Hennig Brand (*c.* 1630–92) in 1669.

SEE WEB LINKS

- Information from the WebElements site

phosphorus(III) bromide (phosphorus tribromide) A colourless fuming liquid, PBr_3; r.d. 2.85; m.p. –40°C; b.p. 173°C. It is prepared by passing bromine vapour over phosphorus but avoiding an excess, which would lead to the phosphorus(V) bromide. Like the other phosphorus(III) halides, PBr_3 is pyramidal in the gas phase. In the liquid phase the P–Br bonds are labile; for example, PBr_3 will react with PCl_3 to give a mixture of products in which the halogen atoms have been redistributed. Phosphorus(III) bromide is rapidly hydrolysed by water to give phosphonic acid and hydrogen bromide. It reacts readily with many organic hydroxyl groups and is used as a reagent for introducing bromine atoms into organic molecules.

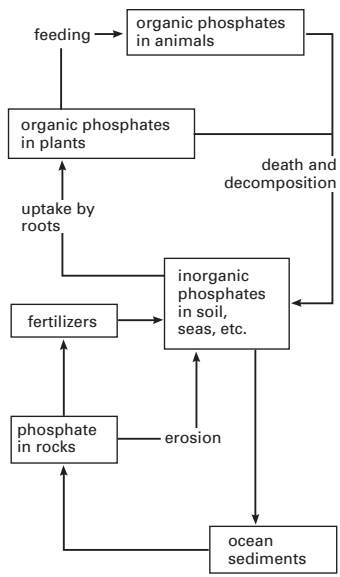
phosphorus(V) bromide (phosphorus pentabromide) A yellow readily sublimable solid, PBr_5, which decomposes below 100°C and is soluble in benzene and carbon tetrachloride (tetrachloromethane). It may be prepared by the reaction of phosphorus(III) bromide with bromine or the direct reaction of phosphorus with excess bromine. It is very readily hydrolysed to give hydrogen bromide and phosphoric(V) acid. An interesting feature of this material is that in the solid state it has the structure $[PBr_4]^+Br^-$. It is used in organic chemistry as a brominating agent.

phosphorus(III) chloride (phosphorus trichloride) A colourless fuming liquid, PCl_3; r.d. 1.57; m.p. –112°C; b.p. 75.5°C. It is soluble in ether and in carbon tetrachloride but reacts with water and with ethanol. It may be prepared by passing chlorine over excess phosphorus (excess chlorine contaminates the product with phosphorus(V) chloride). The molecule is pyramidal in the gas phase and possesses weak electron-pair donor properties. It is hydrolysed violently by water to phosphonic acid and hydrogen chloride. Phosphorus(III) chloride is an important starting point for the synthesis of a variety of inorganic and organic derivatives of phosphorus.

phosphorus(V) chloride (phosphorus pentachloride) A yellow-white rhombic solid, PCl_5, which fumes in air; r.d. 4.65; m.p. 166.8°C (under pressure); sublimes at 160–162°C. It is decomposed by water to give hydrogen chloride and phosphoric(V) acid. It is soluble in organic solvents. The compound may be prepared by the reaction of chlorine with phosphorus(III) chloride. Phosphorus(V) chloride is structurally interesting in that in the gas phase it has the expected trigonal bipyramidal form but in the solid phase it consists of the ions $[PCl_4]^+[PCl_6]^-$. The same ions are detected when phosphorus(V) chloride is dissolved in polar solvents. It is used in organic chemisty as a chlorinating agent.

phosphorus(III) chloride oxide (phosphorus oxychloride; phosphoryl chloride) A colourless fuming liquid, $POCl_3$; r.d. 1.67; m.p. 2°C; b.p. 105.3°C. It may be prepared by the reaction of phosphorus(III) chloride with oxygen or by the reaction of phosphorus(V) oxide with phosphorus(V) chloride. Its reactions are very similar to those of phosphorus(III) chloride. Hydrolysis with water gives phosphoric(V) acid. Phosphorus(III) chloride oxide has a distorted tetrahedral shape and can act as a donor towards metal ions, thus giving rise to a series of complexes.

phosphorus cycle The cycling of *phosphorus between the biotic and abiotic components of the environment (*see* BIOGEOCHEMICAL CYCLE). Inorganic phosphates (PO_4^{3-}, HPO_4^{2-}, or $H_2PO_4^-$) are absorbed by plants from the soil and bodies of water and eventually pass into animals through food chains. Within living organisms phosphates are built up into nucleic acids and other organic molecules. When plants and animals die, phosphates are released and returned to the abiotic environment through the action of bacteria. On a geological time scale, phosphates in aquatic environments eventually become incorporated into and form part of rocks; through a gradual process of erosion, these phosphates are returned to the soil, seas, rivers, and lakes. Phosphorus-containing rocks are mined for the manufacture of fertilizers, which provide an additional supply of inorganic phosphate to the abiotic environment.



Phosphorus cycle.

phosphorus(III) oxide (phosphorus trioxide) A white or colourless waxy solid,

P_4O_6; r.d. 2.13; m.p. 23.8°C; b.p. 173.8°C. It is soluble in ether, chloroform, and benzene but reacts with cold water to give phosphonic acid, H_3PO_3, and with hot water to give phosphine and phosphoric(V) acid. The compound is formed when phosphorus is burned in an oxygen-deficient atmosphere (about 50% yield). As it is difficult to separate from white phosphorus by distillation, the mixture is irradiated with ultraviolet radiation to convert excess white phosphorus into the red form, after which the oxide can be separated by dissolution in organic solvents. Although called a trioxide for historical reasons, phosphorus(III) oxide consists of P_4O_6 molecules of tetrahedral symmetry in which each phosphorus atom is linked to the three others by an oxygen bridge. The chemistry is very complex. Above 210°C it decomposes into red phosphorus and polymeric oxides. It reacts with chlorine and bromine to give oxo-halides and with alkalis to give phosphonates (*see* PHOSPHONIC ACID).

phosphorus(V) oxide (phosphorus pentoxide; **phosphoric anhydride)** A white powdery and extremely deliquescent solid, P_4O_{10}; r.d. 2.39; m.p. 580°C (under pressure); sublimes at 300°C. It reacts violently with water to give phosphoric(V) acid. It is prepared by burning elemental phosphorus in a plentiful supply of oxygen, then purified by sublimation. The hexagonal crystalline form consists of P_4O_{10} molecular units; these have the phosphorus atoms arranged tetrahedrally, each P atom linked to three others by oxygen bridges and having in addition one terminal oxygen atom. The compound is used as a drying agent and as a dehydrating agent; for example, amides are converted into nitrites and sulphuric acid is converted to sulphur trioxide.

phosphorus oxychloride *See* PHOSPHORUS(III) CHLORIDE OXIDE.

phosphorus pentabromide *See* PHOSPHORUS(V) BROMIDE.

phosphorus pentachloride *See* PHOSPHORUS(V) CHLORIDE.

phosphorus tribromide *See* PHOSPHORUS(III) BROMIDE.

phosphorus trichloride *See* PHOSPHORUS(III) CHLORIDE.

phosphorus trioxide *See* PHOSPHORUS(III) OXIDE.

phosphorylase *See* PHOSPHORYLATION.

phosphorylation The introduction of a phosphate group (PO_4^{3-}) to a biomolecule in a reaction that is normally controlled by a **phosphorylase** enzyme. Phosphate is able to combine easily with inert organic compounds, making them chemically active. The first stage in many biochemical reactions is phosphorylation. The conversion of AMP and ADP to *ATP occurs by phosphorylation reactions in two main metabolic pathways, *oxidative phosphorylation and *photophosphorylation. The formation of other nucleotides also involves a phosphorylation reaction. The activity of many enzymes is controlled by phosphorylation: certain enzymes are activated when they are phosphorylated (*see* KINASE), while others are deactivated. Phosphorylation of these enzymes is under the control of hormones and other messengers.

phosphoryl chloride *See* PHOSPHORUS(III) CHLORIDE OXIDE.

phot A unit of illuminance equal to 10^4 lux or one lumen per square centimetre.

photic zone The upper layer of a sea or a lake, in which there is sufficient light for photosynthesis. The limit of the photic zone varies from less than a metre to more than 200 metres, depending on the turbidity of the water.

photino *See* SUPERSYMMETRY.

photoautotroph An autotrophic organism, such as a green plant or a phototrophic bacterium, that synthesizes its organic materials using energy derived from the sun (solar energy) in the process of photosynthesis. *See* AUTOTROPHIC NUTRITION.

photocathode A *cathode that emits electrons when light falls upon it, as a result of the *photoelectric effect. *See* PHOTOELECTRIC CELL.

photocell *See* PHOTOELECTRIC CELL.

photochemical reaction A chemical reaction caused by light or ultraviolet radiation. The incident photons are absorbed by reactant molecules to give excited molecules or free radicals, which undergo further reaction.

photochemical smog A noxious smog produced by the reaction of nitrogen oxides with hydrocarbons in the presence of ultraviolet light from the sun. The reaction is very complex and one of the products is ozone.

photochemistry The branch of chemistry concerned with *photochemical reactions.

photochromism A change of colour occurring in certain substances when exposed to light. Photochromic materials are used in sunglasses that darken in bright sunlight.

photoconductive effect *See* PHOTOELECTRIC EFFECT.

photodiode A semiconductor *diode used to detect the presence of light or to measure its intensity. It usually consists of a *p–n* junction device in a container that focuses any light in the environment close to the junction. The device is usually biased in reverse so that in the dark the current is small; when it is illuminated the current is proportional to the amount of light falling on it. *See* PHOTOELECTRIC EFFECT.

photodisintegration The decay of a nuclide as a result of the absorption of a gamma-ray photon.

photoelasticity An effect in which certain materials exhibit double refraction when subjected to stress. It is used in a technique for detecting strains in transparent materials (e.g. Perspex, celluloid, and glass). When polarized white light is passed through a stressed sample, the birefringence causes coloured patterns to be seen on the viewing screen of a suitable *polarimeter. If monochromatic polarized light is used, a complex pattern of light and dark fringes is produced.

photoelectric cell (photocell) Any of several devices that produce an electric signal in response to exposure to electromagnetic radiation. The original photocells utilized photoemission from a photosensitive cathode (**photocathode**). The electrons emitted are attracted to an anode. A positive potential on the anode enables a current to flow through an external circuit, the current being proportional to the intensity of the illumination on the cathode. The electrodes are enclosed in an evacuated glass tube (*see also* PHOTOMULTIPLIER).

More modern light-sensitive devices utilize the photoconductive effect and the photovoltaic effect (*see* PHOTOELECTRIC EFFECT; PHOTODIODE; PHOTOTRANSISTOR; SOLAR CELL).

photoelectric effect The liberation of electrons (*see* PHOTOELECTRON) from a substance exposed to electromagnetic radiation. The number of electrons emitted depends on the intensity of the radiation. The kinetic energy of the electrons emitted depends on the frequency of the radiation. The effect is a quantum process in which the radiation is regarded as a stream of *photons, each having an energy hf, where h is the Planck constant and f is the frequency of the radiation. A photon can only eject an electron if the photon energy exceeds the *work function, ϕ, of the solid, i.e. if $hf_0 = \phi$ an electron will be ejected; f_0 is the minimum frequency (or **threshold frequency**) at which ejection will occur. For many solids the photoelectric effect occurs at ultraviolet frequencies or above, but for some materials (having low work functions) it occurs with light. The maximum kinetic energy, E_m, of the photoelectron is given by the *Einstein equation: $E_m = hf - \phi$ (*see also* PHOTOIONIZATION).

Apart from the liberation of electrons from atoms, other phenomena are also referred to as photoelectric effects. These are the **photoconductive effect** and the **photovoltaic effect**. In the photoconductive effect, an increase in the electrical conductivity of a semiconductor is caused by radiation as a result of the excitation of additional free charge carriers by the incident photons. **Photoconductive cells**, using such photosensitive materials as cadmium sulphide, are widely used as radiation detectors and light switches (e.g. to switch on street lighting).

In the photovoltaic effect, an e.m.f. is produced between two layers of different materials as a result of irradiation. The effect is made use of in **photovoltaic cells**, most of which consist of *p–n* *semiconductor junctions (*see also* PHOTODIODE; PHOTOTRANSISTOR). When photons are absorbed near a *p–n* junction new free charge carriers are produced (as in photoconductivity); however, in the photovoltaic effect the electric field in the junction region causes the new charge carriers to move, creating a flow of current in an external circuit without the need for a battery. *See also* PHOTOELECTRIC CELL.

photoelectron An electron emitted from a substance by irradiation as a result of the *photoelectric effect or *photoionization.

photoelectron spectroscopy A technique for determining the *ionization potentials of molecules. The sample is a gas or vapour irradiated with a narrow beam of ultraviolet radiation (usually from a helium source at 58.4 nm, 21.21 eV photon energy). The photoelectrons produced in accordance with the *Einstein equation are passed through a slit into a vacuum region, where

they are deflected by magnetic or electrostatic fields to give an energy spectrum. The photoelectron spectrum obtained has peaks corresponding to the ionization potentials of the molecule (and hence the orbital energies). The technique also gives information on the vibrational energy levels of the ions formed. **ESCA** (electron spectroscopy for chemical analysis) is a similar analytical technique in which a beam of X-rays is used. In this case, the electrons ejected are from the inner shells of the atoms. Peaks in the electron spectrum for a particular element show characteristic chemical shifts, which depend on the presence of other atoms in the molecule.

photoemission The process in which electrons are emitted by a substance as a result of irradiation. *See* PHOTOELECTRIC EFFECT; PHOTOIONIZATION.

photofission A *nuclear fission that is caused by a gamma-ray photon.

photographic density A measure of the opacity of a photographic emulsion (negative or transparency). *See* DENSITOMETER.

photography The process of forming a permanent record of an image. Traditionally photography uses specially treated film or paper. In normal black-and-white photography a *camera is used to expose a film or plate to a focused image of the scene for a specified time. The film or plate is coated with an emulsion containing silver salts and the exposure to light causes the silver salts to break down into silver atoms; where the light is bright dark areas of silver are formed on the film after development (by a mild reducing agent) and fixing. The negative so formed is printed, either by a contact process or by projection. In either case light passing through the negative film falls on a sheet of paper also coated with emulsion. Where the negative is dark, less light passes through and the resulting positive is light in this area, corresponding with a light area in the original scene. As photographic emulsions are sensitive to ultraviolet and X-rays, they are widely used in studies involving these forms of electromagnetic radiation. *See also* COLOUR PHOTOGRAPHY.

photoionization The *ionization of an atom or molecule as a result of irradiation by electromagnetic radiation. For a photoionization to occur the incident photon of the radiation must have an energy in excess of the *ionization potential of the species being irradiated. The ejected photoelectron will have an energy, E, given by $E = hf - I$, where h is the Planck constant, f is the frequency of the incident radiation, and I is the ionization potential of the irradiated species.

photolithography A technique used in the manufacture of semiconductor components, integrated circuits, etc. It depends on the principle of masking selected areas of a surface and exposing the unmasked areas to such processes as the introduction of impurities, deposition of thin films, removal of material by etching, etc. The technique has been developed for use on tiny structures (typically measured in micrometres), which can only be examined by means of an electron microscope.

photoluminescence *See* LUMINESCENCE.

photolysis A chemical reaction produced by exposure to light or ultraviolet radiation. Photolytic reactions often involve free radicals, the first step being homolytic fission of a chemical bond. (*See* FLASH PHOTOLYSIS.) The photolysis of water, using energy from sunlight absorbed by chlorophyll, produces gaseous oxygen, electrons, and hydrogen ions and is a key reaction in *photosynthesis.

photometer An instrument used to measure *luminous intensity, illumination, and other photometric quantities. The older types rely on visual techniques to compare a source of light with a standard source. More modern photometers use *photoelectric cells, of the photoconductive, photoemissive, or photovoltaic types. The photovoltaic types do not require an external power source and are therefore very convenient to use but are relatively insensitive. The photoemissive type usually incorporates a *photomultiplier, especially for use in astronomy and with other weak sources. Photoconductive units require only low-voltage supplies, which makes them convenient for commercial illumination meters and photographers' exposure meters.

photometric brightness *See* LUMINANCE.

photometry The study of visual radiation, especially the calculations and measurements of *luminous intensity, *luminous flux, etc. In some cases photometric calculations and measurements extend into the near infrared and the near ultraviolet.

In photometry, two types of measurement are used: those that measure **luminous**

quantities rely on the use of the human eye (for example, to compare the illuminance of two surfaces); those called **radiant** quantities rely on the use of photoelectric devices to measure electromagnetic energy. *See also* PHOTOMETER.

SEE WEB LINKS

- Photometric data available at the NPL website

photomicrography The use of photography to obtain a permanent record (a **photomicrograph**) of the image of an object as viewed through a microscope.

photomorphogenesis The development of plants under the influence of light. All the processes crucial to the growth and development of plants are triggered by light, including seed germination, stem elongation, chloroplast formation, and flowering. These light responses are mediated by various photoreceptor systems, including light-sensitive molecules, principally *phytochrome. The photoreceptors interact with cell signalling networks to regulate the expression of genes involved in development and also influence the production of plant hormone.

photomultiplier A sensitive type of *photoelectric cell in which electrons emitted from a photocathode are accelerated to a second electrode where several electrons are liberated by each original photoelectron, as a result of *secondary emission. The whole process is repeated as many times as necessary to produce a useful electric current by secondary emission from the last electrode. A photomultiplier is thus a photocathode with the output amplified by an electron multiplier. The initial photocurrent can be amplified by a factor of 10^8. Photomultipliers are thus useful when it is necessary to detect low intensities of light, as in stellar photometry, star and planet tracking in guidance systems, and more mundanely in process control.

photon A particle with zero rest mass consisting of a *quantum of electromagnetic radiation. The photon may also be regarded as a unit of energy equal to hf, where h is the *Planck constant and f is the frequency of the radiation in hertz. Photons travel at the speed of light. They are required to explain the photoelectric effect and other phenomena that require light to have particle character.

photoneutron A neutron emitted by an atomic nucleus undergoing a *photonuclear reaction.

photonics The study of devices analogous to those used in electronics, but with the electrons replaced by photons. Thus, photonics is concerned with devices involving the transmission, modulation, reflection, refraction, amplification, detection, and guidance of light. Examples are *lasers and *optical fibres. Photonics is used extensively in *telecommunications.

photonuclear reaction A *nuclear reaction that is initiated by a (gamma-ray) photon.

photoperiodism The response of an organism to changes in day length (**photoperiod**). It enables organisms to exploit favourable conditions associated with seasonal changes in climate and vegetation, for example to produce flowers when pollinating insects are abundant. Generally, the organism must experience a particular ratio of light to dark in the 24-hour period for the physiological switch from say, nonflowering to flowering, to take place. This ratio is the **critical photoperiod** (or **critical day length**), which varies between species: some actions are triggered when the photoperiod falls below the critical threshold (*see* SHORT-DAY PLANT); others are prompted when day length exceeds the critical photoperiod (*see* LONG-DAY PLANT). Plants have various photoreceptor molecules that are sensitive to light, including *phytochrome. In animals, photoperiodic control of breeding is controlled by *melatonin.

photophosphorylation The formation of ATP from ADP and inorganic phosphate using light energy in *photosynthesis (*compare* OXIDATIVE PHOSPHORYLATION). There are two pathways: noncyclic photophosphorylation and cyclic photophosphorylation. In **noncyclic photophosphorylation** electrons derived from the *photolysis of water pass from a complex of chlorophyll molecules along a series of carrier molecules to $NADP^+$. As they do so some of their energy is coupled to the formation of ATP from ADP and inorganic phosphate. $NADP^+$ is reduced to NADPH, which provides reducing power for the light-independent reactions of photosynthesis. In **cyclic photophosphorylation** the electrons are recycled through the electron carrier system back to the chlorophyll complex, resulting in further ATP formation (but no NADPH).

photopic vision The type of vision that occurs when the cones in the eye are the principal receptors, i.e. when the level of illumination is high. Colours can be identified with photopic vision. *Compare* SCOTOPIC VISION.

photoprotection Protection of a plant's photosynthetic apparatus from the harmful effects of light. During periods of peak light intensity plants are able to utilize less than half the incoming energy. The surplus energy poses the risk of photooxidation, and the formation of highly reactive superoxide radicals that can destroy the cell's chlorophyll and many other cellular components. Much of the excess energy is trapped and dissipated as heat by *carotenoids.

photoreceptor A sensory cell or group of cells that reacts to the presence of light. It usually contains a pigment that undergoes a chemical change when light is absorbed, thus stimulating a nerve. *See* EYE.

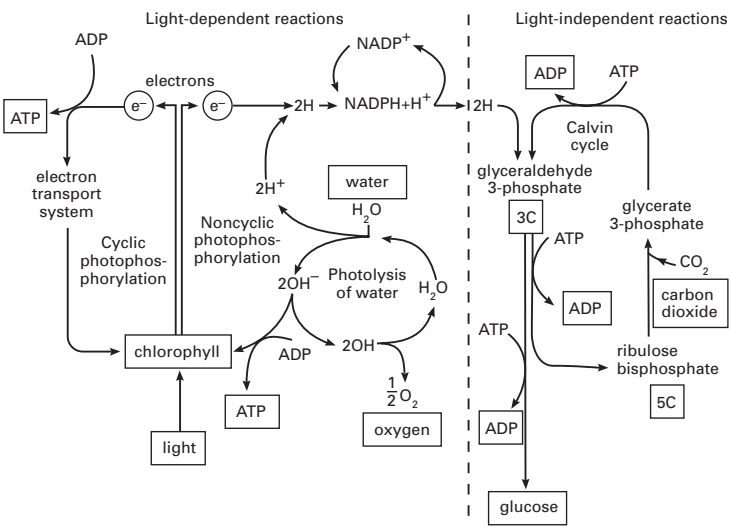
photosensitive substance **1.** Any substance that when exposed to electromagnetic radiation produces a photoconductive, photoelectric, or photovoltaic effect. **2.** Any substance, such as the emulsion of a photographic film, in which electromagnetic radiation produces a chemical change.

photosphere The visible surface of the *sun or other star and the source of its continuous spectrum. It is a gaseous layer several hundreds of kilometres thick with an average temperature of 5780 K. Where the photosphere merges with the *chromosphere the temperature is 4000 K.

photosynthesis The chemical process by which green plants, algae, and certain bacteria synthesize organic compounds from carbon dioxide and water in the presence of sunlight. It occurs in the *chloroplasts and there are two principal types of reaction. In the **light-dependent reactions**, which require the presence of light, energy from sunlight is absorbed by *photosynthetic pigments (chiefly the green pigment *chlorophyll) and used to bring about the *photolysis of water:

$$H_2O \rightarrow 2H^+ + 2e^- + \tfrac{1}{2}O_2.$$

The electrons released by this reaction pass along a series of electron carriers (*see* ELECTRON TRANSPORT CHAIN); as they do so they lose their energy, which is used to convert ADP to ATP in the process of *photophosphorylation. The electrons and protons pro-



Photosynthesis.

duced by the photolysis of water are used to reduce NADP:

$$2H^+ + 2e^- + NADP^+ \rightarrow NADPH + H^+.$$

The ATP and NADPH produced during the light-dependent reactions provide energy and reducing power, respectively, for the ensuing **light-independent reactions** (formerly called the dark reaction), which do not require the presence of light. During these reactions carbon dioxide is reduced to carbohydrate in a metabolic pathway known as the *Calvin cycle. Photosynthesis can be summarized by the equation:

$$CO_2 + 2H_2O \rightarrow [CH_2O] + H_2O + O_2.$$

Since virtually all other forms of life are directly or indirectly dependent on plants for food, photosynthesis is the basis for all life on earth. Furthermore virtually all the atmospheric oxygen has originated from oxygen released during photosynthesis.

SEE WEB LINKS

- Summary of photosynthesis, with illustrations and animations, compiled by the Royal Society of Chemistry

photosynthetic pigments The pigments responsible for the capture of light energy during the light-dependent reactions of *photosynthesis. In plants, algae, and cyanobacteria the green pigment *chlorophyll *a* is the principal light receptor, absorbing blue and red light. However *carotenoids also absorb light energy and pass this on to the chlorophyll molecules.

phototaxis The movement of a cell (e.g. a gamete) or a unicellular organism in response to light. For example, certain algae (e.g. *Chlamydomonas*) can perceive light by means of a sensitive eyespot and move to regions of higher light concentration to enhance photosynthesis. *See* TAXIS.

phototransistor A junction *transistor that is photosensitive. When radiation falls on the emitter-base junction, new free charge carriers are created in the base region and the collector current is increased. Phototransistors are similar to *photodiodes except that the primary photoelectric current is amplified internally and it is therefore more sensitive to light than the photodiode. Some types can be used as switching or bistable devices, a small intensity of radiation switching them from a low to high current state.

phototropism (heliotropism) The growth of plant organs in response to light. Aerial shoots usually grow towards light, while some aerial roots grow away from light. The phototropic response is triggered by photosensitive molecules and brought about by *auxin. *See* TROPISM.

photovoltaic effect *See* PHOTOELECTRIC EFFECT.

pH scale A logarithmic scale for expressing the acidity or alkalinity of a solution. To a first approximation, the pH of a solution can be defined as $-\log_{10}c$, where c is the concentration of hydrogen ions in moles per cubic decimetre. A neutral solution at 25°C has a hydrogen-ion concentration of 10^{-7} mol dm^{-3}, so the pH is 7. A pH below 7 indicates an acid solution; one above 7 indicates an alkaline solution. More accurately, the pH depends not on the concentration of hydrogen ions but on their *activity, which cannot be measured experimentally. For practical purposes, the pH scale is defined by using a hydrogen electrode in the solution of interest as one half of a cell, with a reference electrode (e.g. a calomel electrode) as the other half cell. The pH is then given by $(E - E_R)F/2.303RT$, where E is the e.m.f. of the cell and E_R the standard electrode potential of the reference electrode, and F the Faraday constant. In practice, a glass electrode is more convenient than a hydrogen electrode.

pH stands for 'potential of hydrogen'. The scale was introduced by Søren Sørensen (1868–1939) in 1909.

phthalic acid A colourless crystalline dicarboxylic acid, $C_6H_4(COOH)_2$; r.d. 1.6; m.p. 207°C. The two –COOH groups are substituted on adjacent carbon atoms of the ring, the technical name being **benzene-1,2-dicarboxylic acid**. The acid is made from **phthalic anhydride** (benzene-1,2-dicarboxylic anhydride, $C_8H_4O_3$), which is made by the catalytic oxidation of naphthalene. The anhydride is used in making plasticizers and polyester resins.

phthalic anhydride *See* PHTHALIC ACID.

phthalocyanine A synthetic compound having molecules with four isoindole rings linked by –N= bridges. The structure is similar to that of the *porphyrins. It can form complexes with central metal ions. Copper phthalocyanines are used as dyes.

phycomycetes In older classification schemes, all primitive *fungi, many of which are found in water (e.g. the water moulds,

which may be parasitic on fish) or in damp areas. Many are unicellular but those that form mycelia generally have hyphae lacking cross walls, which distinguishes them from the *Ascomycota and *Basidiomycota. They include the *Zygomycota.

phyllotaxis (phyllotaxy) The arrangement of leaves on a plant stem. The leaves may be inserted in whorls or pairs at each node or singly up the stem. When arranged in pairs the two leaves arise on opposite sides of the stem and are usually at right angles to the leaf pairs above and below them. Single leaves may be inserted alternately or in a spiral pattern up the stem. Phyllotaxis generally results in the minimum of shading of leaves by those above them.

phylogenetic Describing a system of *classification of organisms that aims to show their evolutionary history. *Compare* PHENETIC.

phylogenomics The field of *bioinformatics that integrates knowledge about the evolutionary history of organisms (phylogeny) with structural and functional analysis of their genomes (genomics) and proteins (proteomics). A basic supposition is that well-characterized genes (or proteins) in one organism provide valuable insights into the likely sequence and function of homologous genes or proteins in related organisms. Conversely, comparisons of gene or protein sequences from different species can provide evidence of possible homology, and hence shared evolutionary origins.

phylogeny The evolutionary history of an organism or group of related organisms. *Compare* ONTOGENY.

phylum A category used in the *classification of organisms that consists of one or several similar or closely related classes. Examples of phyla are the Rhodophyta, Ascomycota, Bryophyta, Annelida, and Chordata. In traditional classification schemes phyla are grouped into kingdoms, and for plants the *division is sometimes used instead of the phylum.

physical chemistry The branch of chemistry concerned with the effect of chemical structure on physical properties. It includes chemical thermodynamics and electrochemistry.

physical map (in genetics) Any map that shows the arrangement of the material (i.e. the nucleoprotein) making up a chromosome or segment of a genome (*see* CHROMOSOME MAP). The coarsest physical maps are ones depicting chromosome banding patterns, which are dark and light transverse bands obtained by staining entire chromosomes in mitosis. These **cytological maps** enable characterization of individual chromosomes and can reveal gross anomalies, such as missing or duplicated segments. On a much larger scale are **contig maps**; these show the order of cloned DNA segments taken from a *DNA library and fitted together to form a series of overlapping, or contiguous, segments, called a **contig**. Such segments are roughly on a gene-length scale. Once a contig has been correctly aligned, the base sequence of each component segment can be determined (*see* DNA SEQUENCING), and hence the overall sequence of the chromosomal DNA can be pieced together. *Compare* LINKAGE MAP.

physics The study of the laws that determine the structure of the universe with reference to the matter and energy of which it consists. It is concerned not with chemical changes that occur but with the forces that exist between objects and the interrelationship between matter and energy. Traditionally, the study was divided into separate fields: heat, light, sound, electricity and magnetism, and mechanics (*see* CLASSICAL PHYSICS). Since the turn of the century, however, quantum mechanics and relativistic physics have become increasingly important; the growth of modern physics has been accompanied by the studies of atomic physics, nuclear physics, and particle physics. The physics of astronomical bodies and their interactions is known as **astrophysics**, the physics of the earth is known as **geophysics**, and the study of the physical aspects of biology is called **biophysics**. *See also* THEORETICAL PHYSICS.

physiological saline A liquid medium in which animal tissues may be kept alive for a few hours during experiments without pathological changes or distortion of the cells taking place. Such fluids are salt solutions that are isotonic with and have the same pH as the body fluids of the animal. A well-known example is **Ringer's solution**, formulated by the British physiologist S. Ringer (1835–1910), which is a mixture of sodium chloride, calcium chloride, sodium bicarbonate, and potassium chloride solutions.

physiological specialization The occurrence within a species of several forms that are identical in appearance but differ in physiology: these are termed **physiological races**. For example, many pathogenic fungi develop new physiological races in response to the strong selection pressure exerted when disease-resistant crop varieties are sown over large areas.

physiology The branch of biology concerned with the vital functions of plants and animals, such as nutrition, respiration, reproduction, and excretion.

physisorption *See* ADSORPTION.

phyto- Prefix denoting plants. For example, phytopathology is the study of plant diseases.

phytochrome A protein-based plant pigment present in small quantities in many plant organs. It exists in two interconvertible forms: a physiologically active form, which forms when the plant is illuminated with red light or normal daylight; and an inactive form, formed when the plant is exposed to far-red light or darkness. The active form regulates many plant processes, such as seed germination and the initiation of flowering.

phytogeography *See* PLANT GEOGRAPHY.

phytohaemagglutinin (PHA) Any of various plant-derived compounds that induce changes in lymphocytes normally associated with antigen challenge. These changes include cell enlargement, increased RNA and DNA synthesis, and, finally, cell division. Response to PHAs is used to test for competence of cell-mediated *immunity, for example in patients suffering chronic virus infections.

phytohormone *See* PLANT HORMONE.

phytoplankton The photosynthesizing organisms of *plankton, consisting chiefly of microscopic algae, such as diatoms and dinoflagellates. Near the surface of the sea there may be many millions of such plants per cubic metre. Members of the phytoplankton are of great importance as they form the basis of food for all other forms of aquatic life, being the primary *producers. *Compare* ZOOPLANKTON.

phytoremediation The use of plants to decontaminate polluted land, water, or air. Different plant species that can grow on contaminated sites have evolved various ways of countering high concentrations of heavy metals, oil, solvents, or other toxic substances. Some absorb and degrade the toxins internally, whereas others secrete substances that stabilize or neutralize toxins in the soil. Yet others take up and accumulate the toxins in their tissues, so that when the plants are harvested the toxins are removed from the site.

pi Symbol π. The ratio of the circumference of any circle to its diameter. It is a *transcendental number with the value 3.141 592….

pia mater The innermost of the three membranes (*meninges) that surround the brain and spinal cord of vertebrates. The pia mater lies immediately adjacent to the central nervous system, and the *choroid plexus, which secretes cerebrospinal fluid, is an extension of it.

piano stool *See* SANDWICH COMPOUND.

pi bond *See* ORBITAL.

pico- Symbol p. A prefix used in the metric system to denote 10^{-12}. For example, 10^{-12} farad = 1 picofarad (pF).

picornavirus One of a group of small RNA-containing viruses (*pico* = small; hence pico-RNA-virus) commonly present in the alimentary and respiratory tracts of vertebrates. They cause mild infections of these tracts but the group also includes the polioviruses, which attack the central nervous system causing poliomyelitis; and the causal agent of foot and mouth disease in cattle, sheep, and pigs.

picrate A salt or ester of picric acid.

picric acid (2,4,6-trinitrophenol) A yellow highly explosive nitro compound, $C_6H_2(NO_2)_3$; r.d. 1.8; m.p. 122°C.

pie chart A diagram in which percentages are shown as sectors of a circle. If *x* percent of the prey of a carnivore comprises species *X*, *y* percent species *Y*, and *z* percent species *Z*, a pie chart would show three sectors having central angles $3.6x°$, $3.6y°$, and $3.6z°$.

pi electron An electron in a pi orbital. *See* ORBITAL.

piezoelectric effect The generation of a potential difference across the opposite faces of certain nonconducting crystals (**piezoelectric crystals**) as a result of the application of mechanical stress between these faces. The electric polarization produced is

proportional to the stress and the direction of the polarization reverses if the stress changes from compression to tension. The **reverse piezoelectric effect** is the opposite phenomenon: if the opposite faces of a piezoelectric crystal are subjected to a potential difference, the crystal changes its shape. Rochelle salt and quartz are the most frequently used piezoelectric materials. While Rochelle salt produces the greater polarization for a given stress, quartz is more widely used as its crystals have greater strength and are stable at temperatures in excess of 100°C.

If a quartz plate is subjected to an alternating electric field, the reverse piezoelectric effect causes it to expand and contract at the field frequency. If this field frequency is made to coincide with the natural elastic frequency of the crystal, the plate resonates; the direct piezoelectric effect then augments the applied electric field. This is the basis of the *crystal oscillator and the *quartz clock. *See also* CRYSTAL MICROPHONE; CRYSTAL PICK-UP.

pig iron The impure form of iron produced by a blast furnace, which is cast into pigs (blocks) for converting at a later date into cast iron, steel, etc. The composition depends on the ores used, the smelting procedure, and the use to which the pigs will later be put.

pigment (in biology) A compound that gives colour to a tissue. Pigments perform a variety of functions. For example, *haemoglobin in vertebrate erythrocytes gives blood its characteristic red colour and enables the transport of oxygen throughout the body. Other biological pigments include *chlorophyll, a photosynthetic pigment in plants that is responsible for their green coloration; and *melanin, a brown pigment in animals that provides protection from ultraviolet light and can be used in camouflaging colorations.

pileus The umbrella-shaped cap of certain fungi, such as mushrooms. Spores are produced from *gills or pores on the lower surface.

piliferous layer The part of the root epidermis that bears *root hairs. It extends over a region about 4–10 mm behind the root tip. Beyond this the piliferous layer is sloughed off to reveal the hypodermis.

pillow lava *See* LAVA.

Piltdown man Fossil remains, purported to have been found by Charles Dawson (1864–1916) at Piltdown, Sussex, in 1912, that were named *Eoanthropus dawsoni* and described as a representative of the true ancestors of modern humans. The skull resembled that of a human but the jaw was apelike. In 1953 dating techniques showed the specimen to be a fraud.

pi-meson *See* PION.

pinacol rearrangement A reaction in which the diol pinacol, $(CH_3)_2COH\text{-}(CH_3)_2COH$, converts to the ketone pinacolone, $CH_3COC(CH_3)_3$, under acid conditions, with loss of a molecule of water. A methyl group moves from one carbon atom to an adjacent one in order to stabilize an intermediate carbocation. The reaction, also called the **pinacol-pinacolone rearrangement**, gives its name to a class of similar rearrangements.

pinch effect A magnetic attraction between parallel conductors carrying currents flowing in the same direction. The force was noticed in early induction furnaces. Since the late 1940s it has been widely studied as a means of confining the hot plasma in a *thermonuclear reactor. In an experimental toroidal thermonuclear reactor a large electric current is induced in the plasma by electromagnetic induction; this current both heats the plasma and draws it away from the walls of the tube as a result of the pinch effect.

pineal eye *See* MEDIAN EYE.

pineal gland An outgrowth of the *forebrain. In humans its functions are obscure, but in other vertebrates it acts as an endocrine gland, secreting the hormone *melatonin.

pinna (auricle) The visible part of the *outer ear, present in some mammals. It is made of cartilage and its function is to channel sound waves into the external auditory meatus. In some species the pinna is movable and aids in detecting the direction from which a sound originates.

pinocytosis The process by which a living cell engulfs a minute droplet of liquid. It involves a mechanism similar to *phagocytosis. *See* ENDOCYTOSIS.

pion (pi-meson) An *elementary particle classified as a *meson. It exists in three forms: neutral, positively charged, and negatively charged. The charged pions decay into

muons and neutrinos; the neutral pion decays into two gamma-ray photons. Pions consist of a quark and an anti-quark.

pi orbital *See* ORBITAL.

piperidine A saturated heterocyclic compound having a nitrogen atom in a six-membered ring, $C_5H_{11}N$; r.d. 0.86; m.p. –7°C; b.p. 106°C. The structure is present in many alkaloids.

pipette A graduated tube used for transferring measured volumes of liquid.

Pirani gauge An instrument used to measure low pressures (1–10^{-4} torr; 100–0.01 Pa). It consists of an electrically heated filament, which is exposed to the gas whose pressure is to be measured. The extent to which heat is conducted away from the filament depends on the gas pressure, which thus controls its equilibrium temperature. Since the resistance of the filament is dependent on its temperature, the pressure is related to the resistance of the filament. The filament is arranged to be part of a *Wheatstone bridge circuit and the pressure is read from a microammeter calibrated in pressure units. As the effect depends on the thermal conductivity of the gas, the calibration has to be made each time the pressure of a different gas is measured.

PIR detector *See* PASSIVE DEVICE.

pirsonnite A mineral consisting of a hydrated mixed carbonate of sodium and calcium, $Na_2CO_3.CaCO_3.2H_2O$.

Pisces In some classifications, a superclass of the *Gnathostomata (jawed chordates) comprising the fishes (*compare* TETRAPODA). There are two classes of modern fish: *Chondrichthyes (cartilaginous fishes) and *Osteichthyes (bony fishes).

SEE WEB LINKS

- The Australian Museum Fish Site, an extensive site catering for fish enthusiasts at various levels.

pistil The female part of a flower, consisting either of a single *carpel (**simple pistil**) or a group of carpels (**compound pistil**).

pitch **1.** (in chemistry) A black or dark-brown residue resulting from the distillation of coal tar, wood tar, or petroleum (bitumen). The term is also sometimes used for the naturally occurring petroleum residue (asphalt). Pitch is used as a binding agent (e.g. in road tars), for waterproofing (e.g. in roofing felts), and as a fuel. **2.** (in physics) The property of a sound that characterizes its highness or lowness to an observer. It is related to, but not identical with, frequency. Below about 1000 Hz the pitch is slightly higher than the frequency and above 1000 the position is reversed. The loudness of a sound also affects the pitch. Up to 1000 Hz an increase in loudness causes a decrease in pitch. From about 1000 to 3000 Hz the pitch is independent of loudness, while above 3000 Hz an increase in loudness seems to cause a raising of pitch. Pitch is usually measured in mels; a note of 1000 Hz frequency with a loudness of 40 decibels above the absolute threshold of hearing has a pitch of 1000 mels. **3.** (in mechanics) *See* SCREW.

pitchblende *See* URANINITE.

pitfall trap A simple trap for small invertebrate animals consisting of a tin that is placed in the ground with its rim at ground level. The trap, which contains some kind of bait, can be covered by a tile suspended above ground level by stones so that rain does not enter the tin.

pith **1. (medulla)** The cylinder of *parenchyma tissue found in the centre of plant stems to the inside of the vascular tissue. It is light in weight and has been put to various commercial uses, notably the manufacture of pith helmets. **2.** (not in scientific usage) The white tissue below the rind of many citrus fruits. **3.** To destroy the central nervous system of an animal, especially a laboratory animal such as a frog, by severing its spinal cord.

Pithecanthropus *See* HOMO.

Pitot tube A device for measuring the speed of a fluid. It consists of two tubes, one with an opening facing the moving fluid and the other with an opening at 90° to the direction of the flow. The two tubes are connected to the opposite sides of a manometer so that the difference between the dynamic pressure in the first tube and the static pressure in the second tube can be measured. The speed v of the flow of an incompressible fluid is then given by: $v^2 = 2(P_2 - P_1)/\rho$, where P_2 is the dynamic pressure, P_1 is the static pressure, and ρ is the density of the fluid. The device has a wide variety of applications. It was devised by the Italian-born French engineer Henri Pitot (1695–1771).

pituitary gland (pituitary body; hypophysis) A pea-sized endocrine gland attached by a thin stalk to the *hypothalamus at the

base of the brain. It consists of two main lobes, the anterior and the posterior, separated in nonhumans by an intermediate lobe. The **anterior pituitary** secretes such hormones as *growth hormone, the *gonadotrophins, *prolactin, thyroid-stimulating hormone (*see* THYROID GLAND) and *ACTH. Because these hormones regulate the growth and activity of several other endocrine glands, the anterior pituitary is often referred to as the **master endocrine gland**. Activity of the anterior pituitary itself is regulated by specific *releasing hormones produced by the hypothalamus (*see also* NEUROENDOCRINE SYSTEM). The **posterior pituitary** secretes the hormones *oxytocin and antidiuretic hormone, and the **intermediate lobe** secretes *melanocyte-stimulating hormone.

pixel One of the tiny dots that make up an image on the screen of a computer's *visual-display unit (VDU) or on some types of television receiver; it is short for picture element. Screen resolution is determined by the number of pixels (the more pixels, the better the resolution), and each pixel is given a brightness and colour. A typical high-resolution colour VDU screen has a 1024×768 array of pixels.

p*K* value A measure of the strength of an acid or base on a logarithmic scale. For an acid, the value, denoted pK_a, is given by $\log_{10}(1/K_a)$, where K_a is the acid dissociation constant. Similarly, for a base pK_b is given by $\log_{10}(1/K_b)$. pK_a, values are often used to compare the strengths of different acids.

placenta **1.** The organ in mammals and other viviparous animals by means of which the embryo is attached to the wall of the uterus. It is composed of embryonic and maternal tissues: extensions of the *chorion and *allantois grow into the uterine wall so that materials (e.g. oxygen, nutrients) can pass between the blood of the embryo and its mother (there is, however, no direct connection between the maternal and embryonic blood). The placenta is eventually expelled as part of the *afterbirth. **2.** A ridge of tissue on the ovary wall of flowering plants to which the ovules are attached. The arrangement of ovules on the placenta (**placentation**) is variable, depending on the number of carpels and whether they are free (*see* APOCARPY) or fused (*see* SYNCARPY).

Placentalia *See* EUTHERIA.

placoid scale (denticle) *See* SCALES.

Placozoa A phylum of simple aquatic animals containing just a single known species, *Trichoplax adhaerens*. This has a transparent round flattened body, between 0.2 and 3 mm in diameter, without head, tail, or appendages. It is covered in cilia, which it uses to crawl over surfaces, and it feeds by secreting enzymes from its ventral surface. An adult comprises a few thousand cells of just four types, whose DNA content is the smallest of any animal. The evolutionary relationships of placozoans with other animals, especially the sponges (*Porifera), remain speculative. Molecular studies of ribosomal RNA sequences have indicated that the Placozoa may be secondarily simplified descendants of more complex ancestors and are not closely related to the sponges.

plagiotropism The tendency for a *tropism (growth response of a plant) to be orientated at an angle to the line of action of the stimulus concerned. For example, the growth of lateral branches and lateral roots is at an oblique angle to the stimulus of gravity (**plagiogeotropism**). *Compare* ORTHOTROPISM.

planarians *See* TURBELLARIA.

Planck, Max Carl Ernst Ludwig (1858–1947) German physicist, who became a professor at Berlin University in 1892. Here he formulated the *quantum theory, which had its basis in a paper of 1900. (See also *Planck constant; *Planck's radiation law). One of the most important scientific discoveries of the century, this theory earned him the 1918 Nobel Prize for physics.

Planck constant Symbol h. The fundamental constant equal to the ratio of the energy E of a quantum of energy to its frequency ν: $E = h\nu$. It has the value $6.626\,176 \times 10^{-34}$ J s. It is named after Max Planck. In quantum-mechanical calculations (especially particle physics) the **rationalized Planck constant** (or **Dirac constant**) $\hbar = h/2\pi = 1.054\,589 \times 10^{-34}$ J s is frequently used.

Planck length The length scale at which a classical description of gravity ceases to be valid, and *quantum mechanics must be taken into account. It is given by $L_P = \sqrt{(G\hbar/c^3)}$, where G is the gravitational constant, $\hbar$ is the rationalized Planck constant, and c is the speed of light. The value of the Planck length is of order 10^{-35} m (twenty or-

ders of magnitude smaller than the size of a proton, 10^{-15} m).

Planck mass The mass of a particle whose Compton wavelength is equal to the *Planck length. It is given by $m_P = \sqrt{(\hbar / G)}$, where $\hbar$ is the rationalized Planck constant, c is the speed of light, and G is the gravitational constant. The description of an elementary particle of this mass, or particles interacting with energies per particle equivalent to it (through $E = mc^2$), requires a *quantum theory of gravity. Since the Planck mass is of order 10^{-8} kg (equivalent energy 10^{19} GeV), and, for example, the proton mass is of order 10^{-27} kg and the highest energies attainable in present-day particle accelerators are of order 10^3 GeV, quantum-gravitational effects do not arise in laboratory particle physics. However, energies equivalent to the Planck mass did occur in the early universe according to *big-bang theory, and a quantum theory of gravity is important for discussing conditions there (*see* PLANCK TIME).

Planck's radiation law A law giving the distribution of energy radiated by a *black body. It introduced into physics the novel concept of energy as a quantity that is radiated by a body in small discrete packets rather than as a continuous emission. These small packets became known as quanta and the law formed the basis of *quantum theory. The **Planck formula** gives the energy radiated per unit time at frequency ν per unit frequency interval per unit solid angle into an infinitesimal cone from an element of the black-body surface that is of unit area in projection perpendicular to the cone's axis. The expression for this **monochromatic specific intensity** I_ν is:

$$I_\nu = 2hc^{-2}\nu^3 / [\exp(h\nu / kT - 1],$$

where h is the *Planck constant, c is the *speed of light, k is the *Boltzmann constant, and T is the thermodynamic temperature of the black body. I_ν has units of watts per square metre per steradian per hertz (W m^{-2} sr^{-1} Hz^{-1}). The monochromatic specific intensity can also be expressed in terms of the energy radiated at wavelength λ per unit wavelength interval; it is then written as I_λ, and the Planck formula is:

$$I_\lambda = 2hc^2\lambda^{-5} / [\exp(hc/\lambda kT) - 1].$$

There are two important limiting cases of the Planck formula. For low frequencies $\nu << kT/h$ (equivalently, long wavelengths $\lambda >> hc/kT$) the **Rayleigh–Jeans formula** is valid:

$$I_\nu = 2c^{-2}\nu^2 kT,$$

or

$$I_\lambda = 2c\lambda^{-4} kT.$$

Note that these expressions do not involve the Planck constant. They can be derived classically and do not apply at high frequencies, i.e. high energies, when the quantum nature of *photons must be taken into account. The second limiting case is the **Wien formula**, which applies at high frequencies $\nu >> kT/h$ (equivalently, short wavelengths $\lambda << hc/kT$):

$$I_\nu = 2hc^{-2}\nu^3 \exp(-h\nu / kT),$$

or

$$I_\lambda = 2hc^2\lambda^{-5} \exp(-hc/\lambda kT).$$

See also WIEN'S DISPLACEMENT LAW.

Planck time The time taken for a photon (travelling at the speed of light c) to move through a distance equal to the *Planck length. It is given by $t_P = \sqrt{(G\hbar / c^5)}$, where G is the gravitational constant and $\hbar$ is the rationalized Planck constant. The value of the Planck time is of order 10^{-43} s. In the *big-bang theory, up until a time t_P after the initial instant, it is necessary to use a *quantum theory of gravity to describe the evolution of the universe.

Planck units A system of *units, used principally in discussions of *quantum theories of gravity, in which length, mass, and time are expressed as multiples of the *Planck length, mass, and time respectively. This is equivalent to setting the gravitational constant, the speed of light, and the reduced Planck constant all equal to unity. All quantities that ordinarily have dimensions involving length, mass, and time become dimensionless in Planck units. Since, in the subject area where Planck units are used, it is normal to employ *Gaussian or *Heaviside–Lorentz units for electromagnetic quantities, these then become dimensionless. *See also* GEOMETRIZED UNITS; NATURAL UNITS.

plane A flat surface defined by the condition that any two points in the plane are joined by a straight line that lies entirely in the surface.

plane-polarized light *See* POLARIZATION OF LIGHT.

planet (major planet) A body in orbit around a star that has great enough mass to have contracted to a more or less spherical shape under its own gravitation and to have removed all other bodies, planetesimals,

etc., from its orbital zone. The earth is one of eight planets orbiting the sun, the others being Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. Pluto, which was thought to be a planet when it was discovered in 1930, is now classified as a *dwarf planet. Within our solar system, Mercury, Venus, the earth, and Mars are the **terrestrial planets**; Jupiter, Saturn, Uranus, and Neptune are *gas giants. Mercury and Venus are also called the **inner** (or **inferior**) **planets** because their orbits lie within that of the earth; Mars, Jupiter, Saturn, Uranus, and Neptune are the **outer** (or **superior**) **planets**. *See also* EXTRASOLAR PLANET; SOLAR SYSTEM.

SEE WEB LINKS

- The International Astronomical Union's Question and Answer Sheet about planets
- A multimedia tour of the planets, the sun, and the other members of the solar system

planetesimal One of the many small objects that underwent the process of *accretion to form the planets of the solar system. Planetesimals probably ranged in size from about 1 millimetre to several kilometres across.

planimeter An instrument used to measure the area of a closed curve. The outline of the curve is followed by a pointer on the instrument and the area is given on a graduated disc.

plankton Minute *pelagic organisms that drift or float passively with the current in a sea or lake. Plankton includes many microscopic organisms, such as algae, protozoans, various animal larvae, and some worms. It forms an important food source for many other members of the aquatic community and is divided into *zooplankton and *phytoplankton. *Compare* NEKTON.

plano-concave lens *See* CONCAVE; LENS.

plano-convex lens *See* CONVEX; LENS.

plant **1.** In traditional classification, any living organism of the kingdom Plantae. Plants are distinguished from other multicellular organisms by their life cycles, in which a haploid generation (*gametophyte) alternates with a diploid generation (*sporophyte). (*See also* ALTERNATION OF GENERATIONS.) Most plants manufacture carbohydrates by *photosynthesis, in which simple inorganic substances are built up into organic compounds. The radiant energy needed for this process is absorbed by *chlorophyll, a complex pigment not found in animals. Plants also differ from animals in the possession of *cell walls (usually composed of *cellulose). Plants are immobile, as there is no necessity to search for food, and they respond slowly to external stimuli. For a classification of the plant kingdom, see Appendix. **2.** Any member of an assemblage of eukaryotic organisms – the **Archaeplastida** – recognized on the basis of recent molecular data. As well as land plants, it contains green algae, red algae, and glaucophytes (algae whose chloroplasts are similar to cyanobacteria).

SEE WEB LINKS

- Movable hyperbolic tree of plant phylogeny, devised by 'Deep Green' and hosted by the University of California, Berkeley

plant geography (phytogeography) The study of the distribution of vegetation around the world, with particular emphasis on the influence of the environmental factors that determine this distribution.

plant hormone (growth substance; phytohormone) Any of a number of organic chemicals that are synthesized by plants and regulate growth and development. They are usually made in a particular region, such as the shoot tip, and transported to other regions, where they take effect. *See* ABSCISIC ACID; AUXIN; CYTOKININ; ETHENE; GIBBERELLIN.

plantigrade Describing the gait of many mammals, including humans, in which the whole lower surface of the foot is on the ground. *Compare* DIGITIGRADE; UNGULIGRADE.

planula The ciliated free-swimming larva of many cnidarians, consisting of a solid mass of cells. It eventually settles on a suitable surface and develops into a *polyp.

plaque **1.** A thin layer of organic material covering all or part of the exposed surface of a tooth. It contains dissolved food (mostly sugar) and bacteria. The bacteria in plaque metabolize the sugar and produce acid, which eats into the surface of the enamel of the tooth and eventually causes tooth decay (*dental caries). **2.** A clear area in a bacterial culture grown on an agar plate due to *lysis of the bacteria by a bacteriophage.

plasma **1.** (in physics) A highly ionized gas in which the number of free electrons is approximately equal to the number of positive ions. Sometimes described as the fourth

state of matter, plasmas occur in interstellar space, in the atmospheres of stars (including the sun), in discharge tubes, and in experimental thermonuclear reactors.

Because the particles in a plasma are charged, its behaviour differs in some respects from that of a gas. Plasmas can be created in the laboratory by heating a low-pressure gas until the mean kinetic energy of the gas particles is comparable to the *ionization potential of the gas atoms or molecules. At very high temperatures, from about 50 000 K upwards, collisions between gas particles cause cascading ionization of the gas. However, in some cases, such as a fluorescent lamp, the temperature remains quite low as the plasma particles are continually colliding with the walls of the container, causing cooling and recombination. In such cases ionization is only partial and requires a large energy input. In *thermonuclear reactors an enormous plasma temperature is maintained by confining the plasma away from the container walls using electromagnetic fields (*see* PINCH EFFECT). The study of plasmas is known as **plasma physics**.
2. (in physiology) *See* BLOOD PLASMA.

plasma cells Antibody-producing cells found in the epithelium of the lungs and gut and also in bone-forming tissue. They develop in the lymph nodes, spleen, and bone marrow when antigens stimulate lymphocytes to form the precursor cells that give rise to them (*see* B CELL).

plasma display A form of display used in television, in which light output is produced from the interaction between an electric current and an ionized inert gas such as neon. The display consists of a matrix of individual cells, one per pixel. A typical monochrome or grey-scale display generates red or orange light. Colour systems generate ultraviolet radiation, which excites phosphors (red, green, and blue) on the surface of the display; the excited phosphors emit light on return to the ground state. Plasma panels are rugged, largely immune to external fields, and do not suffer from flicker. Fabrication of large displays is possible. The device is essentially bistable so no special circuitry is required to isolate individual cells from their neighbours.

plasmagel The specialized outer gel-like *cytoplasm of living cells (such as *Amoeba*) that move by extruding part of the cell (known as a *pseudopodium) in the direction of motion. A reversible conversion of plasmagel to the more fluid *plasmasol is involved in the continuous flow forward of cytoplasm necessary for forming a pseudopodium. *See also* CYTOPLASMIC STREAMING.

plasma membrane (plasmalemma; cell membrane) The partially permeable membrane forming the boundary of a cell. It consists mostly of protein and lipid (*see* LIPID BILAYER) and plays various crucial roles in the cell's activities. A key task is to regulate the flow of materials and signals into and out of the cell; this is accomplished, for example, by membrane proteins that act as *ion channels or as *receptors for signal molecules arriving at the cell surface. The plasma membrane is the site of junctions with neighbouring cells and forms attachments to the *extracellular matrix, thus ensuring tissue integrity. In plants, fungi, bacteria, and many protists, it helps in assembling a cell wall or capsule on its outer surface.

plasma protein Any of the protein constituents of blood plasma. They comprise *albumins, *globulins, and *fibrinogen.

plasmasol The specialized inner sol-like *cytoplasm of living cells that move by producing *pseudopodia. *Compare* PLASMAGEL.

plasmid A structure in bacterial cells consisting of DNA that can exist and replicate independently of the chromosome. Plasmids provide genetic instructions for certain cell activities (e.g. resistance to antibiotic drugs). They can be transferred from cell to cell in a bacterial colony. Plasmids are widely used as *vectors to produce recombinant DNA for *gene cloning. *See also* GENETICALLY MODIFIED ORGANISMS (Feature).

plasmin (fibrinase; fibrinolysin) An enzyme, present in blood plasma, that breaks down a blood clot by destroying the fibrin threads of the clot and by inactivating factors involved in blood clotting, such as prothrombin and the *clotting factors. This occurs during *fibrinolysis. Plasmin is derived from an inactive precursor, *plasminogen.

plasminogen The inactive precursor of the enzyme *plasmin. Plasminogen is incorporated into blood clots and is converted to plasmin during *fibrinolysis.

plasmodesmata (*sing.* **plasmodesma**) Fine cytoplasmic strands that connect the *protoplasts of adjacent plant cells by pass-

ing through their cell walls and thus permit the passage of substances between cells. Plasmodesmata are cylindrical in shape (about 20–40 nm in diameter) and are lined by the plasma membrane of the two adjacent cells. The endoplasmic reticula of the two adjacent cells are connected by a narrower structure, the **desmotubule**, which runs through the centre of a plasmodesma.

plasmolysis The loss of water by *osmosis from a plant cell to the extent that the cytoplasm shrinks away from the cell wall. This happens when the cell is placed in a solution that has a higher solute concentration than that of the cell sap, i.e. it has a lower (more negative) *water potential, since water always moves from an area of high water potential to an area of low water potential. *Compare* TURGOR.

plasmon A *collective excitation for quantized oscillations of the electrons in a metal.

plasmonics The design and study of devices that make use of *plasmons, i.e. plasmonics is to plasmons what *electronics is to electrons and *photonics is to photons. Plasmonics has many appealing possibilities in technology but has the practical difficulty that plasmons are short-lived excitations.

plaster of Paris The hemihydrate of *calcium sulphate, $2CaSO_4.H_2O$, prepared by heating the mineral gypsum. When ground to a fine powder and mixed with water, plaster of Paris sets hard, forming interlocking crystals of gypsum. The setting results in an increase in volume and so the plaster fits tightly into a mould. It is used in pottery making, as a cast for setting broken bones, and as a constituent of the plaster used in the building industry.

plasticity The property of solids that causes them to change permanently in size or shape as a result of the application of a stress in excess of a certain value, called the **yield point**.

plasticizer A substance added to a synthetic resin to make it flexible. *See* PLASTICS.

plastics Materials that can be shaped by applying heat or pressure. Most plastics are made from polymeric synthetic *resins, although a few are based on natural substances (e.g. cellulose derivatives or shellac). They fall into two main classes. **Thermoplastic materials** can be repeatedly softened by heating and hardened again on cooling. **Thermosetting materials** are initially soft, but change irreversibly to a hard rigid form on heating. Plastics contain the synthetic resin mixed with such additives as pigments, plasticizers (to improve flexibility), antioxidants and other stabilizers, and fillers. See Chronology overleaf.

plastid An *organelle within a plant cell, often occurring in large numbers. Apart from the nucleus, plastids are the largest solid inclusions in a plant cell. For convenience they are classified into those containing pigments (*chromoplasts) and those that are colourless (*leucoplasts), although changes from one to the other frequently occur. Plastids develop from **proplastids**, colourless bodies found in meristematic and immature cells; they also arise by division of existing plastids. *See also* CHLOROPLAST.

plastoglobulus (*pl.* **plastoglobuli**) A densely staining droplet found, often in large numbers, in plastids of plant cells. Plastoglobuli consist of lipid pigment and are especially prominent in coloured plastids (*chromoplasts), for example in ripening fruits. Plastoglobuli also occur in chloroplasts, but are masked by the green chlorophyll. When the chlorophyll breaks down as the leaves start to die in autumn, the pigmented plastoglobuli become apparent as the red or yellow 'fall' colours.

plastron *See* CARAPACE.

platelet (thrombocyte) A minute disc-shaped cell fragment in mammalian blood. Platelets are formed as fragments of larger cells (**megakaryocytes**) found in red bone marrow; they have no nucleus. They play an important role in *blood clotting, releasing thromboxane A_2 (*see* PROSTAGLANDIN), serotonin, and other chemicals in response to local tissue damage, which causes a chain of events leading to the formation of a plug at the site of the damage, thus preventing further blood loss. There are about 250 000 platelets per cubic millimetre of blood.

platelet-derived growth factor *See* GROWTH FACTOR.

plate tectonics The theory, developed in the early 1960s, that the surface of the earth is made of lithospheric plates, which have moved throughout geological time resulting in the present-day positions of the continents. The theory explains the locations of mountain building as well as earthquakes and volcanoes. The rigid lithospheric plates

PLASTICS

1851 Scottish chemist Charles Macintosh (1766–1843) makes ebonite (from rubber).

1855 British chemist Alexander Parkes (1813–90) patents Parkesine, a plastic made from nitrocellulose, methanol, and wood pulp; it is later called 'celluloid'.

1860 British chemist Charles Williams (1829–1910) prepares isoprene (synthetic rubber).

1868 US printer John Hyatt (1837–1920) develops commercial process for making celluloid.

1884 French chemist Hilaire de Chardonnet (1839–1924) develops process for making rayon.

1892 British chemists Edward Bevan (1856–1921) and Charles Cross (1855–1935) develop the viscose process for making rayon.

1899 British chemist Frederick Kipping (1863–1949) discovers silicone plastics.

1901 German chemists Krische and Spitteler make formaldehyde–casein plastic (Galalith).

1905 Belgian-born US chemist Leo Baekland (1863–1944) invents Bakelite.

1912 Swiss chemist Jacques Brandenberger produces Cellophane (viscose cellulose film).

1913 US Formica Insulation company markets plastic laminate made from formaldehyde resins.

1918 Hans John prepares urea–formaldehyde resin.

1926 German chemist Hermann Staudinger (1881–1965) discovers the polymeric nature of plastics.

1930 US chemist Waldo Semon develops PVC (polyvinyl chloride).

1930 Canadian chemist William Chalmers discovers polymethylmethacrylate (Perspex and Plexiglass).

1930 German chemists at IG Farbenindustrie produce polystyrene.

1931 Wallace Carothers invents nylon.

1938 US chemist Roy Plunkett produces polytetrafluoroethene (PTFE).

1939 British company ICI develops commercial process for making polyethene.

1941 British chemists John Whinfield (1901–66) and J. Dickson develop Terylene (Dacron).

1941 German company IG Farbenindustrie produces polyurethane.

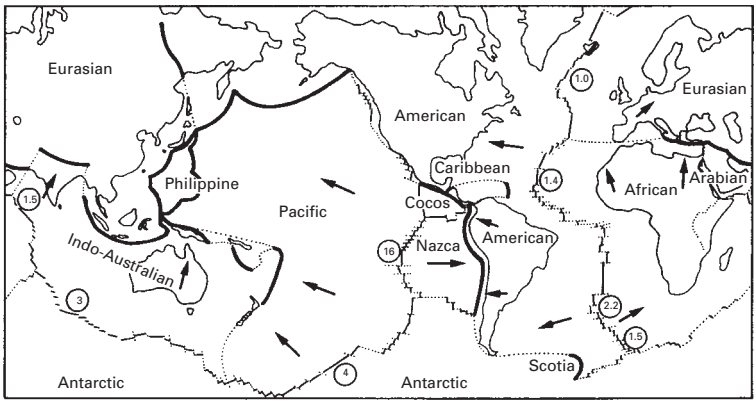
1943 US Dow Corning company produces silicone plastics.

1947 British chemists produce acrylic fibres.

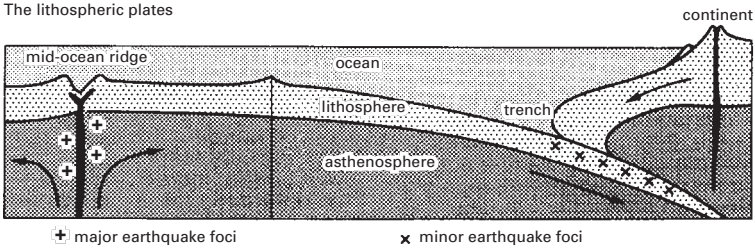
1953 German chemist Karl Ziegler (1896–1973) discovers catalyst for making high-density polyethene.

1954 Italian chemist Giulio Natta (1903–79) develops industrial process for making high-density polyethene (using Ziegler catalyst).

1989 Italian company Ferruzzi produces biodegradable plastic (based on starch).



The lithospheric plates



Cross-section showing a constructive plate margin, where two plates are drawing apart along a mid-ocean ridge, and a destructive plate margin, where the oceanic plate is being subducted below the continental plate. Volcanic activity and earthquakes are associated with these margins

p

Plate tectonics.

consist of continental and oceanic crust together with the upper mantle, which lie above the weaker plastic asthenosphere. These plates move relative to each other across the earth. Six major plates (Eurasian, American, African, Pacific, Indian, and Antarctic) are recognized, together with a number of smaller ones. The plate margins (boundaries) coincide with zones of seismic and volcanic activity.

A **constructive** (or **divergent**) plate margin occurs when two plates move away from each other. It is marked by a mid-oceanic ridge where basaltic material wells up from the mantle to form new oceanic crust, in a process known as **sea-floor spreading**. The production of new crust at constructive plate margins is compensated for by the destruction of material along a **destructive** (or **convergent**) plate margin. Along these margins, which are also known as **subduction zones** and marked by an oceanic trench, one plate (usually oceanic) is forced to plunge down beneath the other (which may be continental or oceanic). The crust becomes partially melted and rises to form a chain of volcanoes in the upper plate parallel to the trench. When two continental plates collide the compression results in the formation of mountain chains (e.g. the Himalayas formed by the collision of the Indian and Eurasian plates). A third type of plate margin – the **transform plate margin** – occurs where two plates are slipping past each other.

platinum Symbol Pt. A silvery white metallic *transition element (*see also* PLATINUM METALS); a.n. 78; r.a.m. 195.09; r.d. 21.45; m.p. 1772°C; b.p. 3827±100°C. It occurs in some nickel and copper ores and is also found native in some deposits. The main source is the anode sludge obtained in copper–nickel refining. The element is used in jewellery, laboratory apparatus (e.g. thermocouples, electrodes, etc.), electrical contacts, and in certain alloys (e.g. with iridium or rhodium). It is also a hydrogenation catalyst. The element does not oxidize nor dissolve in hydrochloric acid. Most of its compounds are platinum(II) or platinum(IV) complexes.

SEE WEB LINKS

- Information from the WebElements site

platinum black Black finely divided platinum metal produced by vacuum evaporation and used as an absorbent and a catalyst.

platinum metals The three members of the second and third transition series immediately proceeding silver and gold: ruthenium (Ru), rhodium (Rh), and palladium (Pd); and osmium (Os), iridium (Ir), and platinum (Pt). These elements, together with iron, cobalt, and nickel, were formerly classed as group VIII of the periodic table. The platinum-group metals are relatively hard and resistant to corrosion and are used in jewellery and in some industrial applications (e.g. electrical contacts). They have certain chemical similarities that justify classifying them together. All are resistant to chemical attack. In solution they form a vast range of complex ions. They also form coordination compounds with carbon monoxide and other pi-bonding ligands. A number of complexes can be made in which a hydrogen atom is linked directly to the metal. The metals and their organic compounds have considerable catalytic activity. *See also* TRANSITION ELEMENTS.

Platonic hydrocarbons Hydrocarbons that have the same molecular geometry as the five Platonic solids, i.e. the tetrahedron, the cube, the octahedron, the dodecahedron, and the icosahedron. These hydrocarbons have carbon atoms at the vertices of the polyhedra and single bonds along the edges. In fact, there are only two known Platonic hydrocarbons: cubane (C_8H_8) and dodecahedrane ($C_{20}H_{20}$). The hydrocarbon based on a tetrahedron (C_4H_4) does not exist because of angle strain, but substituted derivatives C_4X_4 are known. Angle strain is also the reason for the nonexistence of octahedrane (C_6H_6) and icosahedrane ($C_{12}H_{12}$).

Platyhelminthes A phylum of invertebrates comprising the flatworms, characterized by a flattened unsegmented body. The simple nervous system shows some concentration of cells at the head end. The mouth leads to a simple branched gut without an anus. Flatworms are hermaphrodite but self-fertilization is unusual. Many species are parasitic. The phylum contains the classes *Turbellaria (planarians), *Trematoda (flukes), and *Cestoda (tapeworms).

Playfair, John *See* HUTTON, JAMES.

pleiomorphism The existence of distinctly different forms during the life cycle of an individual, e.g. the caterpillar, pupa, and winged adult of a butterfly.

Pleistocene The third epoch of the *Neogene period. It extended from the end of the Pliocene, about 1.8 million years ago, to the beginning of the Holocene, (the present epoch), about 11 500 years ago. The Pleistocene is often known as the **Ice Age** as it was characterized by a series of glacials, in which ice margins advanced towards the equator, separated by interglacials when the ice retreated. *See also* ICE AGE.

pleochroic Denoting a crystal that appears to be of different colours, depending on the direction from which it is viewed. It is caused by polarization of light as it passes through an anisotropic medium.

pleura (pleural membrane) The double membrane that lines the thoracic cavity and covers the exterior surface of the lungs. It is a *serous membrane forming a closed sac, with a small space (the **pleural cavity**) between the two layers.

plexus A compact branching network of nerves or blood vessels, such as the **brachial plexus** – a network of spinal nerves that supply branches to the forelimbs in vertebrates. *See also* CHOROID PLEXUS.

Pliocene The second epoch of the *Neogene period. Preceded by the Miocene and followed by the Pleistocene, it extended from about 5 million years ago to 1.8 million years ago. Mammals similar to modern forms existed during the epoch and the australopithecines (*see* AUSTRALOPITHECUS), early forerunners of humans, appeared.

plumbago *See* CARBON.

plumbane (lead(IV) hydride) An extremely unstable gas, PbH_4, said to be formed by the action of acids on magnesium–lead alloys. It was first reported in 1924, although doubts have since been expressed about the existence of the compound. It demonstrates the declining stability of the hydrides in group 14. More stable organic derivatives are known; e.g. trimethyl plumbane, $(CH_3)_3PbH$.

plumbate A compound formed by reaction of lead oxides (or hydroxides) with alkali. The oxides of lead are amphoteric (weakly acidic) and react to give plumbate ions. With the lead(IV) oxide, reaction with molten alkali gives the plumbate(IV) ion

$$PbO_2 + 2OH^- \rightarrow PbO_3^{2-} + H_2O$$

In fact, various ions are present in which the lead is bound to hydroxide groups, the principal one being the hexahydroxoplumbate(IV) ion $Pb(OH)_6^{2-}$. This is the negative ion present in crystalline 'trihydrates' of the type $K_2PbO_3.3H_2O$. Lead(II) oxide gives the trihydroxoplumbate(II) ion in alkaline solutions

$$PbO(s) + OH^-(aq) + H_2O(l) \rightarrow Pb(OH)_3^{2-}(aq)$$

Plumbate(IV) compounds were formerly referred to as **orthoplumbates** (PbO_4^{4-}) or **metaplumbates** (PbO_3^{2-}). Plumbate(II) compounds were called **plumbites**.

plumbic compounds Compounds of lead in its higher (+4) oxidation state; e.g. plumbic oxide is lead(IV) oxide, PbO_2.

plumbite *See* PLUMBATE.

plumbous compounds Compounds of lead in its lower (+2) oxidation state; e.g. plumbous oxide is lead(II) oxide, PbO.

plumule **1.** (in zoology) A *down feather. **2.** (in botany) The part of a plant embryo that develops into the shoot system. It consists of the stem apex and first leaves. In seedlings showing *epigeal germination the plumule grows above the soil surface together with the cotyledons; in seeds showing *hypogeal germination, the plumule alone emerges. *Compare* RADICLE.

pluripotent *See* STEM CELL.

Pluto A *trans-Neptunian object that is the second largest *dwarf planet so far known and the tenth largest body in the *solar system. It was discovered in 1930 by Clyde Tombaugh (1906–97) and for 76 years was regarded as the ninth planet of the solar system. It is now classed as a *Kuiper belt object, the largest known at present. Its official designation is (134340) Pluto. Pluto orbits the sun at a mean distance of 5906.376×10^6 km, but its orbit is so eccentric that its *perihelion is 4436.825×10^6 km, well inside Neptune's orbit, and its aphelion is 7375.928×10^6 km. Pluto's orbital period is 248.09 years. With a diameter of 2300 km and a mass of about 1.3×10^{22} kg, Pluto is smaller than the earth's moon. It appears to be half rock and half ice, the ice – frozen nitrogen, methane, and carbon monoxide – surrounding a rocky core. Pluto's average temperature has been measured at 43 K. It has three natural satellites: Charon (discovered in 1978), which at 1200 km in diameter is more than half Pluto's size, and the much smaller Nix and Hydra (both discovered in 2005).

SEE WEB LINKS

- NASA's introduction to the planet and its satellites

plutonium Symbol Pu. A dense silvery radioactive metallic transuranic element belonging to the *actinoids; a.n. 94; mass number of most stable isotope 244 (half-life 7.6×10^7 years); r.d. 19.84; m.p. 641°C; b.p. 3232°C. Thirteen isotopes are known, by far the most important being plutonium–239 (half-life 2.44×10^4 years), which undergoes *nuclear fission with slow neutrons and is therefore a vital power source for *nuclear weapons and some *nuclear reactors. About 20 tonnes of plutonium are produced annually by the world's nuclear reactors, a detailed inventory of every gram of which is kept in order to prevent its military misuse. The element was first produced by Seaborg, McMillan, Kennedy, and Wahl in 1940.

SEE WEB LINKS

- Information from the WebElements site

pnicogens *See* PNICTOGENS.

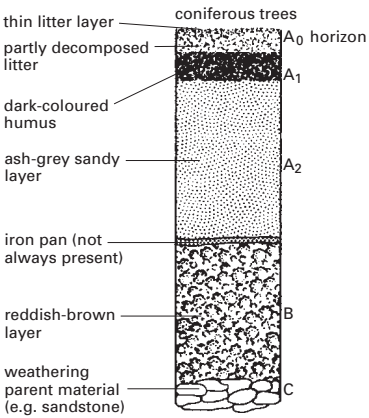
pnictides *See* PNICTOGENS.

pnictogens (pnicogens) The elements of group 15 of the periodic table, i.e. nitrogen (N), arsenic (As), antimony (Sb), and bismuth (Bi). The elements As, Sb, and Bi form a range of solid-state ternary compounds with interesting electrical and magnetic properties. Examples are $LaSiP_3$, $K_6Bi_2Sn_{23}$, and $Yb_{14}MnSb_{11}$. Compounds of this type are known as **pnictides**.

pod *See* LEGUME.

podcast A package of multimedia files that can be downloaded from the Internet and played on a computer or a mobile device. The first podcasts were of music tracks that could be played on MP3 players; the technique was subsequently generalized to include other audio content and then additional file types, in particular images and video. New podcasts are generally advertised by web feeds, then downloaded automatically to subscribers' computers and, if appropriate, transferred to portable players. Established broadcasting organizations are now making their television and radio output available as podcasts.

podzol (podsol) A type of soil that forms under cool humid conditions where the vegetation is coniferous or heath. It is characteristic of the taiga zones of Eurasia and North America. The soil has an ashen-coloured upper layer (the A horizon) overlying a layer (the B horizon) containing iron or humus that has been leached down from the A horizon and redeposited.



Podzol. A podzol soil profile.

poikilothermy The passive variation in the internal body temperature of an animal, which depends on the temperature of the environment. All animals except birds and mammals exhibit poikilothermy and are described as *ectotherms. Although unable to maintain a constant body temperature, they can respond to compensate for very low or very high temperatures. For example, the tissue composition (especially cell osmotic pressure) can change to regulate the blood flow to peripheral tissues (and thus increase heat loss or heat absorption), and the animals can actively seek sun or shade. Seasonal changes in metabolism are usually under hormonal control. In particularly hot climates, ectotherms may undergo *aestivation to escape the heat. *Compare* HOMOIOTHERMY.

point-contact transistor *See* TRANSISTOR.

point defect *See* CRYSTAL DEFECT.

point discharge *See* CORONA.

point group The group formed by all the symmetry operations applied to a pattern arranged around a fixed point. The symmetry operations of molecules form point groups. There are 32 point groups, called **crystallographic point groups**, that have symmetries that are also compatible with the translational symmetries of crystals.

point mutation (gene mutation) A change in the nucleotide sequence of the DNA within a gene; a gene in which such a change has occurred is known as a *mutant gene or allele. The DNA sequence can be altered in several ways; for example by *insertion, *substitution, *deletion, and *inversion. Point mutations can result in a misreading of the genetic code during the translation phase of protein synthesis and can change the order of amino acids making up a protein, which may or may not affect the function of that protein. *Compare* CHROMOSOME MUTATION; SINGLE NUCLEOTIDE POLYMORPHISM. *See also* MUTATION.

poise A *c.g.s. unit of viscosity equal to the tangential force in dynes per square centimetre required to maintain a difference in velocity of one centimetre per second between two parallel planes of a fluid separated by one centimetre. 1 poise is equal to 10^{-1} N s m^{-2}.

Poiseuille's equation An equation relating the volume flow rate, V, of a fluid through a cylindrical tube to the pressure difference, p, between the ends of the tube: $V = \pi pr^4/8l\eta$, where r is the radius and l the length of the tube; η is the viscosity of the fluid. It applies if the Reynolds number is less than 2000 and was first stated by Jean Louis Poiseuille (1799–1869).

poison **1.** (in biology) Any substance that is

injurious to the health of a living organism. **2.** (in chemistry) A substance that prevents the activity of a catalyst. **3.** (in physics) A substance that absorbs neutrons in a nuclear reactor and therefore slows down the reaction. It may be added intentionally for this purpose or may be formed as a fission product and need to be periodically removed.

Poisson distribution A probability distribution for a discrete random variable. It is defined, for a variable (r) that can take values in the range 0, 1, 2, …, and has a mean value μ, as

$$P(r) = e^{-\mu r}/r!$$

A binomial distribution with a small frequency of success p in a large number n of trials can be approximated by a Poisson distribution with mean np. It is named after the French mathematician and mathematical physicist Siméon-Denis Poisson (1781–1840). *See also* NORMAL DISTRIBUTION; T-DISTRIBUTION.

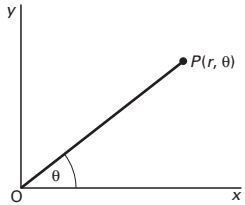
Poisson's ratio The ratio of the lateral strain to the longitudinal strain in a stretched rod. If the original diameter of the rod is d and the contraction of the diameter under stress is Δd, the lateral strain $\Delta d/d = s_d$; if the original length is l and the extension under stress Δl, the longitudinal strain is $\Delta l/l = s_l$. Poisson's ratio is then s_d/s_l. For steels the value is between 0.28 and 0.30 and for aluminium alloys it is about 0.33. It was first introduced by Simeon Poisson (1781–1840).

polar body *See* OOGENESIS.

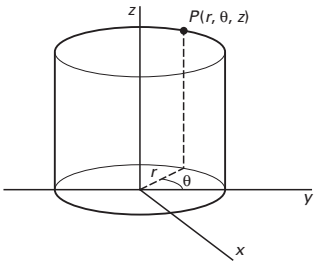
polar compound A compound that is either ionic (e.g. sodium chloride) or that has molecules with a large permanent dipole moment (e.g. water).

polar coordinates A system used in analytical geometry to locate a point P, with reference to two or three axes. The distance of P from the origin is r, and the angle between the x-axis and the **radius vector** OP is θ, thus in two-dimensional polar coordinates the coordinates of P are (r,θ). If the *Cartesian coordinates of P are (x,y) then, $x = r\cos\theta$ and $y = r\sin\theta$.

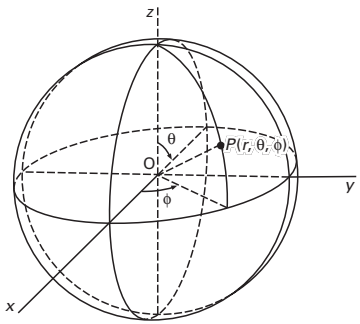
In three dimensions the point P may be regarded as lying on the surface of a cylinder, giving **cylindrical polar coordinates**, or on the surface of a sphere, giving **spherical polar coordinates**. In the former the coordinates of P would be (r,θ,z); in the latter they would be (r,θ,ϕ) (see illustration).



two-dimensional coordinates



cylindrical polar coordinates



spherical polar coordinates

Polar coordinates.

polarimeter (polariscope) An instrument used to determine the angle through which the plane of polarization of plane-polarized light is rotated on passing through an optically active substance. Essentially, a polarimeter consists of a light source, a **polarizer** (e.g. a sheet of Polaroid) for producing plane-polarized light, a transparent cell containing the sample, and an **analyser**. The analyser is a polarizing material that can

be rotated. Light from the source is plane-polarized by the polarizer and passes through the sample, then through the analyser into the eye or onto a light-detector. The angle of polarization is determined by rotating the analyser until the maximum transmission of light occurs. The angle of rotation is read off a scale. Simple portable polarimeters are used for estimating the concentrations of sugar solutions in confectionary manufacture. *See also* PHOTOELASTICITY.

polarity **1.** The property of a cell, tissue, or organism of being structurally and/or functionally different at opposite ends of its long axis. For example, plants consist of roots, which grow in the direction of the force of gravity, and stems, which grow away from the gravitational force (*see* GEOTROPISM). **2.** The property of molecules of having an uneven distribution of electrons, so that one part has a positive charge and the other a negative charge.

polarizability Symbol α. A measure of the response of a molecule to an external electric field. When a molecule is placed in an external electric field, the displacement of electric charge induces a dipole in the molecule (*see* ELECTRIC DISPLACEMENT). If the *electric field strength is denoted $\boldsymbol{E}$ and the electrical dipole moment induced by this electric field $\boldsymbol{p}$, the polarizability α is defined by $\boldsymbol{p} = \alpha\boldsymbol{E}$. To calculate the polarizability from first principles it is necessary to use the quantum mechanics of molecules. However, if regarded as a parameter, the polarizability α provides a link between microscopic and macroscopic theories as in the *Clausius–Mossotti equation and the *Lorentz–Lorenz equation.

polarization **1.** The process of confining the vibrations of the vector constituting a transverse wave to one direction. In unpolarized radiation the vector oscillates in all directions perpendicular to the direction of propagation. *See* POLARIZATION OF LIGHT. **2.** The formation of products of the chemical reaction in a *voltaic cell in the vicinity of the electrodes resulting in increased resistance to current flow and, frequently, to a reduction in the e.m.f. of the cell. *See also* DEPOLARIZATION. **3.** The partial separation of electric charges in an insulator subjected to an electric field. **4.** The separation of charge in a polar *chemical bond.

polarization of light The process of confining the vibrations of the electric vector of light waves to one direction. In unpolarized light the electric field vibrates in all directions perpendicular to the direction of propagation. After reflection or transmission through certain substances (*see* POLAROID) the electric field is confined to one direction and the radiation is said to be **plane-polarized light**. The plane of plane-polarized light can be rotated when it passes through certain substances (*see* OPTICAL ACTIVITY).

In **circularly polarized light**, the tip of the electric vector describes a circular helix about the direction of propagation with a frequency equal to the frequency of the light. The magnitude of the vector remains constant. In **elliptically polarized light**, the vector also rotates about the direction of propagation but the amplitude changes; a projection of the vector on a plane at right angles to the direction of propagation describes an ellipse. Circularly and elliptically polarized light are produced using a *retardation plate.

polarizer A device used to plane-polarize light (*see* POLARIZATION OF LIGHT). *Nicol prisms or *Polaroid can be used as polarizers. If a polarizer is placed in front of a source of unpolarized light, the transmitted light is plane-polarized in a specific direction. As the human eye is unable to detect that light is polarized, it is necessary to use an *analyser to detect the direction of polarization. **Crossing** a polarizer and analyser causes extinction of the light, i.e. if the plane of polarization of the polarizer and the plane of the analyser are perpendicular, no light is transmitted when the polarizer and analyser are combined. Both a polarizer and an analyser are components of a *polarimeter.

polarizing angle *See* BREWSTER'S LAW.

polar molecule A molecule that has a dipole moment; i.e. one in which there is some separation of charge in the *chemical bonds, so that one part of the molecule has a positive charge and the other a negative charge.

polarography An analytical technique having an electrochemical basis. A dropping-mercury electrode is used as the cathode along with a large nonpolarizable anode, and a dilute solution of the sample. The **dropping-mercury electrode** (**DME**) consists of a narrow tube through which mercury is slowly passed into the solution so as to form small drops at the end of the tube, which fall away. In this way the cathode can have a low surface area and be kept clean. A

variable potential is applied to the cell and a plot of current against potential (a **polarogram**) made. As each chemical species is reduced at the cathode (in order of their electrode potentials) a step-wise increase in current is obtained. The height of each step is proportional to the concentration of the component. It is also possible to use an electrode formed from a small rotating disc in place of the dropping-mercury electrode. The technique is useful for detecting trace amounts of metals and for the investigation of solvated complexes.

Polaroid Trade name for a doubly refracting material that plane-polarizes unpolarized light passed through it. It consists of a plastic sheet strained in a manner that makes it birefringent by aligning its molecules. Sunglasses incorporating a Polaroid material absorb light that is vibrating horizontally – produced by reflection from horizontal surfaces – and thus reduce glare.

polaron A coupled electron–ion system that arises when an electron is introduced into the conduction band of a perfect ionic crystal and induces lattice polarization around itself.

polar solvent *See* SOLVENT.

polar vector A *vector that reverses its sign when the coordinate system is changed to a new system by a reflection in the origin (i.e. $x'_i = -x_i$). *Compare* AXIAL VECTOR.

pole **1.** *See* MAGNETIC POLES; MAGNETIC MONOPOLE. **2.** The *optical centre of a curved mirror.

pollen The mass of grains containing the male gametes of seed plants, which are produced in large numbers in the *pollen sacs. The pollen grains of insect-pollinated plants may be spiny or pitted and are usually larger than those of wind-pollinated plants, which are usually smooth and light. The pollen grain represents the male *gametophyte generation; it contains two male gamete nuclei. The wall of the mature pollen grain consists of the tough outer wall (**exine**) and the more delicate narrower **intine**. The latter gives rise to the *pollen tube. *See also* POLLINATION.

pollen analysis *See* PALYNOLOGY.

pollen sac The structure in seed plants in which pollen is produced. In angiosperms there are usually four pollen sacs in each *anther. In gymnosperms variable numbers of pollen sacs are borne on the microsporophylls that make up the male *cone.

pollen tube An outgrowth of a pollen grain, which transports the male gametes to the ovule. It will only grow if the pollen grain is compatible with the female tissue. In angiosperms, the pollen grain is deposited on the stigma and the pollen tube grows down through the style and into the ovule. In some conifers, e.g. *Pinus* (pines), the pollen tube penetrates the *nucellus but does not develop further until the following year, when the female part of the plant is mature. *See also* EMBRYO SAC; FERTILIZATION.

pollex The innermost digit on the forelimb of a tetrapod vertebrate. It contains two phalanges (*see* PENTADACTYL LIMB) and in humans and higher primates it is the thumb, which is opposable (i.e. capable of facing and touching the other digits) and gives the hand greater manipulating ability. In some mammals a pollex is absent. *Compare* HALLUX.

pollination The transfer of pollen from an anther (the male reproductive organ) to a stigma (the receptive part of the female reproductive organ), either of the same flower (**self-pollination**) or of a different flower of the same species (**cross-pollination**). Cross-pollination involves the action of a pollinating agent to effect transfer of the pollen (*see* ANEMOPHILY; ENTOMOPHILY; HYDROPHILY). *See also* FERTILIZATION; INCOMPATIBILITY.

pollutant Any substance, produced and released into the environment as a result of human activities, that has damaging effects on living organisms. Pollutants may be toxic substances (e.g. *pesticides) or natural constituents of the atmosphere (e.g. carbon dioxide) that are present in excessive amounts. *See* POLLUTION.

pollution An undesirable change in the physical, chemical, or biological characteristics of the natural environment, brought about by human activities. It may be harmful to human or nonhuman life. Pollution may affect the soil, rivers, seas, or the atmosphere (*see* AIR POLLUTION). There are two main classes of *pollutants: those that are **biodegradable** (e.g. sewage), i.e. can be rendered harmless by natural processes and need therefore cause no permanent harm if adequately dispersed or treated; and those that are **nonbiodegradable** (e.g. *heavy metals (such as lead) in industrial effluents and

*DDT and other chlorinated hydrocarbons used as pesticides), which eventually accumulate in the environment and may be concentrated in food chains. Other forms of pollution in the environment include noise (e.g. from jet aircraft, traffic, and industrial processes), thermal pollution (e.g. the release of excessive waste heat into lakes or rivers causing harm to wildlife), and light pollution (from street lights, buildings, etc., which can disorientate wildlife). Recent pollution problems include the disposal of radioactive waste; *acid rain; *photochemical smog; increasing levels of human waste; high levels of carbon dioxide and other greenhouse gases in the atmosphere (*see* GREENHOUSE EFFECT); damage to the *ozone layer by nitrogen oxides, *chlorofluorocarbons (CFCs), and *halons; and pollution of inland waters by agricultural *fertilizers and *sewage effluent, causing eutrophication (*see* EUTROPHIC). Attempts to contain or prevent pollution include strict regulations concerning factory emissions, the use of smokeless fuels, the banning of certain pesticides, the greater use of renewable energy sources, restrictions on the use of chlorofluorocarbons, and the introduction, in some countries, of catalytic converters to cut pollutants in car exhausts.

SEE WEB LINKS

- The Blacksmith Institute's top ten worst pollution problems facing the world

polonium Symbol Po. A rare radioactive metallic element of group 16 (formerly VIB) of the periodic table; a.n. 84; r.a.m. 210; r.d. 9.32; m.p. 254°C; b.p. 962°C. The element occurs in uranium ores to an extent of about 100 micrograms per 1000 kilograms. It has over 30 isotopes, more than any other element. The longest-lived isotope is polonium–209 (half-life 103 years). Polonium has attracted attention as a possible heat source for spacecraft as the energy released as it decays is 1.4×10^5 J kg^{-1} s^{-1}. It was discovered by Marie Curie in 1898 in a sample of pitchblende.

SEE WEB LINKS

- Information from the WebElements site

poly- Prefix indicating a polymer, e.g. polyethene. Sometimes brackets are used in polymer names to indicate the repeated unit, e.g. poly(ethene).

polyamide A type of condensation polymer produced by the interaction of an amino group of one molecule and a carboxylic acid group of another molecule to give a protein-like structure. The polyamide chains are linked together by hydrogen bonding.

polyatomic molecule A molecule formed from several atoms (e.g. pyridine, C_5H_5N, or dinitrogen tetroxide, N_2O_4), as distinguished from diatomic and monatomic molecules.

polybasic acid An acid with more than one replaceable hydrogen atom. Examples include the dibasic sulphuric acid (H_2SO_4) and tribasic phosphoric(V) (orthophosphoric) acid (H_3PO_4). Replacement of all the hydrogens by metal atoms forms normal salts. If not all the hydrogens are replaced, *acid salts are formed.

Polychaeta A class of annelid worms in which each body segment has a pair of flattened fleshy lobes (**parapodia**) bearing numerous bristles (*chaetae). All polychaetes are aquatic and most of them are marine. They include the fanworms (*Sabella*), which construct tubes of sand, etc., in which they live; and the lugworms (*Arenicola*) and ragworms (*Nereis*), which burrow in sand or mud.

polychlorinated biphenyl (PCB) Any of a number of derivatives of biphenyl ($C_6H_5C_6H_5$) in which some of the hydrogen atoms on the benzene rings have been replaced by chlorine atoms. Polychlorinated biphenyls are used in the manufacture of certain polymers as electrical insulators. They are highly toxic and are suspected to be carcinogenic; their increasing use has caused concern because they have been shown to accumulate in the food chain.

polychloroethene (PVC; polyvinyl chloride) A tough white solid material, which softens with the application of a plasticizer, manufactured from chloroethene by heating in an inert solvent using benzoyl peroxide as an initiator, or by the free-radical mechanism initiated by heating chloroethene in water with potassium persulphate or hydrogen peroxide. The polymer is used in a variety of ways, being easy to colour and resistant to fire, chemicals, and weather.

polychromatic radiation Electromagnetic radiation that consists of a mixture of different wavelengths. This need not refer only to visible radiation. *Compare* MONOCHROMATIC RADIATION.

polycyclic Denoting a compound that has two or more rings in its molecules. Polycyclic compounds may contain single rings (as in phenylbenzene, $C_6H_5.C_6H_5$) or fused rings (as in naphthalene, $C_{10}H_8$).

polydioxoboric(III) acid *See* BORIC ACID.

polyembryony **1.** The formation of more than one embryo in a plant seed. Often one embryo develops from the fertilized egg cell, while the others have formed asexually from other tissues in the ovule. **2.** The formation of more than one embryo from a single animal zygote. *Identical twins are produced in this way.

polyene An unsaturated hydrocarbon that contains two or more double carbon–carbon bonds in its molecule.

polyester A condensation polymer formed by the interaction of polyhydric alcohols and polybasic acids. Linear polyesters are saturated thermoplastics and linked by dipole–dipole attraction as the carbonyl groups are polarized. They are extensively used as fibres (e.g. **Terylene**). Unsaturated polyesters readily copolymerize to give thermosetting products. They are used in the manufacture of glass-fibre products. *See also* ALKYD RESIN.

polyethene (polyethylene; polythene) A flexible waxy translucent polyalkene thermoplastic made in a variety of ways producing a polymer of varying characteristics. In the ICI process, ethene containing a trace of oxygen is subjected to a pressure in excess of 1500 atmospheres and a temperature of 200°C. Low-density polyethene (r.d. 0.92) has a formula weight between 50 000 and 300 000, softening at a temperature around 110°C, while the high-density polyethene (r.d. 0.945–0.96) has a formula weight up to 3 000 000, softening around 130°C. The low-density polymer is less crystalline, being more atactic. Polyethene is used as an insulator; it is acid resistant and is easily moulded and blown. *See* PHILLIPS PROCESS; ZIEGLER PROCESS.

polyethylene *See* POLYETHENE.

polygene Any of a group of genes influencing a quantitative trait, e.g. height in humans. *See* QUANTITATIVE INHERITANCE.

polygenic inheritance *See* QUANTITATIVE INHERITANCE.

polygon A plane figure with a number of sides. In a **regular polygon** all the sides and internal angles are equal. For such a polygon with n sides, the interior angle is $(180 - 360/n)$ degrees and the sum of the interior angles is $(180n - 360)$ degrees.

polygon of forces A polygon in which the sides represent, in magnitude and direction, all forces acting on a rigid body. The side required to close the polygon represents the resultant of a system of forces.

polyhedron A solid bounded by polygonal faces. In a **regular polyhedron** all the faces are congruent regular polygons. The cube is one of five possible regular polyhedrons. The others are the **tetrahedron** (four triangular faces), the **octahedron** (eight triangular faces), the **dodecahedron** (twelve pentagonal faces), and the **icosahedron** (twenty triangular faces).

polyhydric alcohol An *alcohol that has several hydroxyl groups per molecule.

polymer A substance having large molecules consisting of repeated units (the monomers). See Feature overleaf.

SEE WEB LINKS

- Information about IUPAC nomenclature

polymerase Any enzyme that catalyses the elongation of a polymeric molecule. **RNA polymerases** catalyse the synthesis of RNA using as a template either an existing DNA strand (**DNA-dependent RNA polymerase**) or an RNA strand. **DNA polymerases** catalyse the elongation of a new DNA strand during DNA replication, using an existing DNA strand as template. **RNA-directed DNA polymerase** is more usually known as *reverse transcriptase.

polymerase chain reaction (PCR) A technique used to replicate a fragment of DNA so as to produce many copies of a particular DNA sequence. PCR is commonly employed as an alternative to *gene cloning as a means of amplifying genetic material for *DNA sequencing. The technique has also proved invaluable in forensic science, enabling amplification of minute traces of genetic material for *DNA profiling or for detecting microsatellite DNA (*see* REPETITIVE DNA). The two strands of the DNA are separated by heating and short sequences of a single DNA strand (**primers**) are added, together with a supply of free nucleotides and DNA *polymerase obtained from a bacterium that can withstand extreme heat. In a

POLYMERS

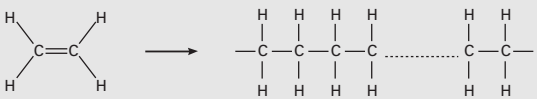
Polymers are substances that have *macromolecules composed of many repeating units (known as 'mers'). A large number of naturally occurring substances are polymers including *rubber and many substances based on glucose, such as the polysaccharides *cellulose and *starch (in plants) and *glycogen (in animals). *Proteins, nucleic acids, and inorganic macromolecular substances, such as *silicates, are other examples.

Synthetic polymers

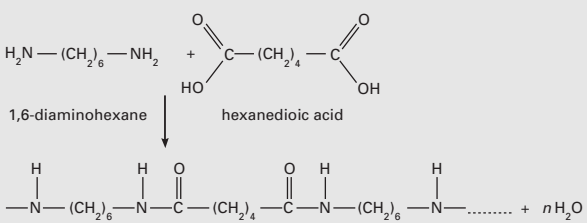
One of the unique features of the chemistry of carbon is its ability to form long chains of atoms. This property is the basis of an important area of industrial chemistry concerned with the manufacture of polymeric materials with a variety of properties (*see* PLASTICS). The molecules in these materials are essentially long chains of atoms of various lengths. In some polymers, cross-linkage occurs between the chains. Synthetic polymers are formed by chemical reactions in which individual molecules (monomers) join together to form larger units (*see* POLYMERIZATION). Two types of polymer, **homopolymers** and **heteropolymers**, can be distinguished.

Homopolymers

These are polymers formed from a single monomer. An example is *polyethene (polyethylene), which is made by polymerization of ethene (CH_2:CH_2). Typically such polymers are formed by *addition reactions involving unsaturated molecules. Other similar examples are *polypropene (polypropylene), polystyrene, and *polytetrafluoroethene (PTFE). Homopolymers may also be made by *condensation reactions (as in the case of *polyurethane).



Addition polymerization of ethene to form polyethene: a homopolymer



Condensation polymerization to form nylon: a heteropolymer

Formation of polymers

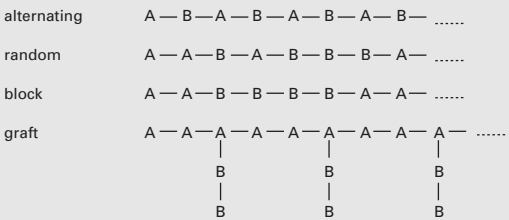
Heteropolymers

These are also known as **copolymers**. They are made from two (or more) different monomers, which usually undergo a condensation reaction with the elimination of a simple molecule, such as water. A typical example is the condensation of 1,6-diaminohexane (hexamethylenediamine) with hexanedioic acid (adipic acid) to form nylon 6,6. The reaction occurs between the amine groups on the diaminohexane and the carboxyl groups on the hexanedioic acid, with elimination of water molecules (see diagram opposite).

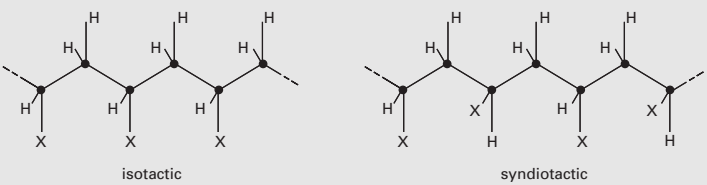
The properties of a polymeric plastic can most easily be modified if it is a copolymer of two or more different monomers. A well-known example is ABS (acrylonitrile–butadiene–styrene) copolymer, commonly used for the body shells of computers and other electronic apparatus. Its properties can be preselected by varying the proportions of the component monomers.

Stereospecific polymers

In both normal polyethene and nylon the polymer molecules take the form of long chains of various lengths with no regular arrangement of the subunits. Such polymers are said to be **atactic**. If the constituent subunits repeat along the chain in a regular way, a stereospecific polymer may result. The polymer may be **isotactic**, with a particular group always along the same side of the main chain, or **syndiotactic**, with the group alternating from side to side of the chain. Stereospecific polymerization can be performed by use of certain catalytic agents (*see* ZIEGLER PROCESS).



Types of copolymer depending on the arrangement of the monomers A and B



Types of stereospecific polymer

series of heating and cooling cycles, the DNA sequence flanked by the primers doubles with each cycle and is thus rapidly amplified.

polymerization A chemical reaction in which molecules join together to form a polymer. If the reaction is an addition reaction, the process is **addition polymerization**; condensation reactions cause **condensation polymerization**, in which a small molecule is eliminated during the reaction. Polymers consisting of a single monomer are **homopolymers**; those formed from two different monomers are **copolymers**.

polymethanal A solid polymer of methanal, formed by evaporation of an aqueous solution of methanal.

polymethylmethacrylate A clear thermoplastic acrylic material made by polymerizing methyl methacrylate. The technical name is **poly(methyl 2-methylpropenoate)**. It is used in such materials as **Perspex**.

polymorphism **1.** (in biology) The existence of two or more distinctly different forms (**morphs**) within a plant or animal species. An example is the *caste system of social insects, in which there are workers, drones, and queens. This is an **environmental polymorphism**, i.e. the differences are caused by environmental rather than genetic factors, in this case by the larvae receiving different types of food. There are also **heritable** or **genetic polymorphisms**. An example is the occurrence of sickle-cell disease, a genetic disease that principally affects Black populations of central Africa and is characterized by an abnormal form of the blood pigment haemoglobin and sickle-shaped red blood cells. Three different types of individual occur in such populations: those who have two genes (*AA*) for normal haemoglobin and therefore do not suffer from the disease; those with one normal and one abnormal gene (*AS*), who are described as having the **sickle-cell trait** and generally suffer no symptoms; and those with two abnormal genes (*SS*), who suffer a chronic and eventually fatal form of anaemia. Normally such a harmful gene would have been eliminated from the population by the process of natural selection, but it is maintained in this case because people with the sickle-cell trait are resistant to a severe form of malaria endemic in central Africa. *See also* RESTRICTION FRAGMENT LENGTH POLYMORPHISM; SINGLE NUCLEOTIDE POLYMORPHISM. **2.** (in chemistry) The existence of chemical substances in two (**dimorphism**) or more physical forms. *See* ALLOTROPY.

polynomial A mathematical expression containing three or more terms. It has the general form $a_0x^n + a_1x^{n-1} + a_2x^{n-2} + \ldots + a_n$, where a_0, a_1, etc., are constants and n is the highest power of the variable, called the **degree** of the polynomial.

polynucleotide *See* NUCLEOTIDE.

polyp The sedentary stage in the life cycle of the *Cnidaria, consisting of a cylindrical body fixed at one end to a firm base and having a mouth surrounded by a ring of tentacles at the other. Some polyps (e.g. *Hydra*) are single; others (e.g. the corals and *Obelia*) form colonies. Polyps typically reproduce asexually by budding to form either new polyps or *medusae. The latter reproduce sexually giving rise to new polyps. Sea anemones are solitary polyps that reproduce sexually to form new polyps.

polypeptide A *peptide comprising 20 or more amino acids. Polypeptides that constitute proteins usually contain 100–300 amino acids. Shorter ones include certain antibiotics, e.g. gramicidin, and some hormones, e.g. *ACTH, which has 39 amino acids. The properties of a polypeptide are determined by the type and sequence of its constituent amino acids.

polyphyletic Denoting any group of organisms the members of which have originated from several different ancestors. An example is the group including all insectivorous animals. Polyphyletic groups are not natural groups and do not have any place in natural classifications. *Compare* MONOPHYLETIC.

polyphyodont Describing a type of dentition in which the teeth are continuously shed and replaced during the lifetime of the animal. Sharks and frogs have a polyphyodont dentition. *Compare* DIPHYODONT; MONOPHYODONT.

polyploid Describing a nucleus that contains more than two sets of chromosomes (*see* DIPLOID) or a cell or organism containing such nuclei. For example, *triploid plants have three sets of chromosomes and **tetraploid** plants have four. Polyploidy is far more common in plants than in animals; many crops, in particular, are polyploid (bread wheat, for example, is **hexaploid**, i.e. 6n). It can be induced chemically with

*colchicine. *See also* ALLOPOLYPLOID; AUTOPOLYPLOID.

polypropene (polypropylene) An isotactic polymer existing in both low and high formula-weight forms. The lower-formula-weight polymer is made by passing propene at moderate pressure over a heated phosphoric acid catalyst spread on an inert material at 200°C. The reaction yields the trimer and tetramer. The higher-formula-weight polymer is produced by passing propene into an inert solvent, heptane, which contains a trialkyl aluminium and a titanium compound. The product is a mixture of isotactic and atactic polypropene, the former being the major constituent. Polypropene is used as a thermoplastic moulding material.

polypropylene *See* POLYPROPENE.

polyribosome (polysome) An aggregate of ribosomes in association with a single messenger RNA molecule during the *translation process of protein synthesis. In eukaryotes, polyribosomes are attached to the surface of the rough endoplasmic reticulum and the outer membrane of the nucleus; in bacteria they are found free in the cytoplasm.

polysaccharide (glycan) Any of a group of carbohydrates comprising long chains of monosaccharide (simple sugar) molecules. **Homopolysaccharides** consist of only one type of monosaccharide; **heteropolysaccharides** contain two or more different types. Polysaccharides may have molecular weights of up to several million and are often highly branched. Some important examples are starch, glycogen, and cellulose.

polysome *See* POLYRIBOSOME.

polyspermy The entry of several sperms into the egg during fertilization although only one sperm nucleus actually fuses with the egg nucleus. Polyspermy occurs in animals with yolky eggs (e.g. birds).

polystyrene A clear glasslike material manufactured by free-radical polymerization of phenylethene (styrene) using benzoyl peroxide as an initiator. It is used as both a thermal and electrical insulator and for packing and decorative purposes.

polysulphides *See* SULPHIDES.

polytetrafluoroethene (PTFE) A thermosetting plastic with a high softening point (327°C) prepared by the polymerization of tetrafluoroethene under pressure (45–50 atmospheres). The reaction requires an initiator, ammonium peroxosulphate. The polymer has a low coefficient of friction and its 'anti-stick' properties are probably due to its helical structure with the fluorine atoms on the surface of an inner ring of carbon atoms. It is used for coating cooking utensils and nonlubricated bearings.

polythene *See* POLYETHENE.

polythionate A salt of a polythionic acid.

polythionic acids Oxo acids of sulphur with the general formula $HO.SO_2.S_n.SO_2.OH$, where $n = 0–4$. *See also* SULPHURIC ACID.

polyurethane A polymer containing the urethane group –NH.CO.O–, prepared by reacting di-isocyanates with appropriate diols or triols. A wide range of polyurethanes can be made, and they are used in adhesives, durable paints and varnishes, plastics, and rubbers. Addition of water to the polyurethane plastics turns them into foams.

polyvinylacetate (PVA) A thermoplastic polymer used in adhesives and coatings. It is made by polymerizing vinyl acetate (CH_2:$CHCOOCH_3$).

polyvinyl chloride *See* POLYCHLOROETHENE.

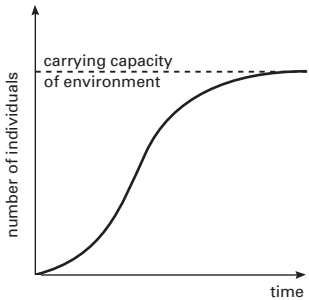
polyyne An unsaturated hydrocarbon that contains two or more triple carbon–carbon bonds in its molecule.

pome A type of fruit characteristic of apples and pears. The flesh of the fruit develops from the *receptacle of the flower, which completely encloses the fused carpels. After fertilization the carpels form the 'core' of the fruit, which contains the seeds. *See also* PSEUDOCARP.

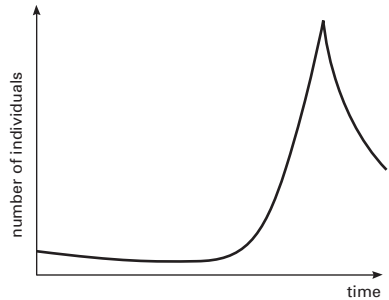
pons (pons Varolii) A thick tract of nerve fibres in the brain that links the medulla oblongata to the midbrain. Its function is to relay impulses between different parts of the brain. The pons is named after its discoverer, the Italian anatomist C. Varoli (1543–75).

POP *See* PERSISTENT ORGANIC POLLUTANT.

population (in ecology) **1.** A group of individuals of the same species within a *community. The nature of a population is determined by such factors as density, *sex ratio, birth and death rates, emigration, and immigration. **2.** The total number of indi-



Sigmoid growth curve



J-shaped growth curve

Population growth curves.

viduals of a given species or other class of organisms in a defined area, e.g. the population of rodents in Britain.

population dynamics The study of the fluctuations that occur in the numbers of individuals in animal and plant populations and the factors controlling these fluctuations. An important distinction is maintained between those factors that are dependent on population density and have a stabilizing effect (e.g. food supply) and those that are independent of population density (e.g. catastrophes, such as flooding).

population genetics The study of the distribution of inherited *variation among a group of organisms of the same species. The potential for change depends on the sum total of alleles that are available to the organisms (the **gene pool**), and estimates of changes in allele frequency in a population give an indication of its response to a changing condition.

population growth The increase in a population that occurs when the *birth rate is higher than the *death rate, or when immigration exceeds emigration, or when a combination of these factors is present. A growth curve, obtained by plotting population size against time, is typically S-shaped (sigmoid) or J-shaped (see graphs). A sigmoid curve shows an initial phase of *exponential growth. The curve levels off when the environment has reached its *carrying capacity. A J-shaped growth curve shows an initial phase of exponential growth that ceases abruptly, with a sudden decrease in population numbers. This decrease may be caused by a number of factors, such as the end of the life cycle of the prey or any other factor contributing to *environmental resistance that may suddenly take effect. *See also* BACTERIAL GROWTH CURVE.

population inversion *See* LASER.

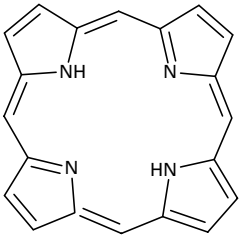
population type A method of classifying stars as either population I or population II bodies, devised in 1944 by Walter Baade (1893–1960). Population I stars are the young metal-rich highly luminous stars found in the spiral arms of galaxies. Population II stars are older metal-deficient stars that occur in the centres of galaxies and in galactic halos.

Porifera The phylum of marine and freshwater invertebrates that comprise the sponges, which live permanently attached to rocks or other surfaces. The body of a sponge is hollow and consists basically of an aggregation of cells between which there is little nervous coordination. The body is supported by an internal skeleton of spicules of chalk, silica, or fibrous protein (bath sponges have protein skeletons). Undulipodium-bearing cells (**choanocytes**) cause water to flow in through openings in the body wall and out through openings at the top; food particles are filtered from the water by the choanocytes.

SEE WEB LINKS

- Overview of the sponges, including their biology and classification, from the University of Michigan's Museum of Zoology Diversity Web

porphyrin Any of a group of organic pigments characterized by the possession of a cyclic group of four linked nitrogen-containing rings (a **tetrapyrrole** nucleus),



Porphyrin.

the nitrogen atoms of which are often coordinated to metal ions. Porphyrins differ in the nature of their side-chain groups. They include the *chlorophylls, which contain magnesium; and *haem, which contains iron and forms the *prosthetic group of haemoglobin, myoglobin, and the cytochromes.

portal vein (portal circulation; portal system) Any vein that collects blood from one network of capillaries and transports it directly to a second capillary network in another region of the body, without returning to the heart. *See* HEPATIC PORTAL SYSTEM.

positive charge *See* CHARGE.

positive feedback *See* FEEDBACK.

positron The antiparticle of the *electron. *See also* ANNIHILATION; ELEMENTARY PARTICLES; PAIR PRODUCTION.

positron emission tomography (PET) A noninvasive imaging technique that can produce three-dimensional pictures of certain biochemical changes within the body, such as areas of increased tissue metabolism. It is used for research in several areas, including neurology and pharmacology, and as a diagnostic technique in medicine, for example in detecting brain tumours. PET is based on the detection of photons produced by the decay of short-lived radioactive isotopes, such as fluorine-18 in labelled fluorodeoxyglucose (*see* LABELLING), injected into the body. The isotopes emit positrons, which almost immediately collide with electrons producing a pair of photons that travel in opposite directions. Simultaneously arriving photon pairs are detected by the scanner on either side of the body as flashes of light, and a computer calculates the point of their mutual origin within the body. By collating many thousands of such coincident flashes, the computer creates a map showing where the isotope is concentrated, which corresponds to locally increased blood flow or uptake as a consequence of elevated tissue activity. PET scans are often now integrated with images obtained by computed *tomography or magnetic resonance imaging (*see* NUCLEAR MAGNETIC RESONANCE) so that the biochemical information can be correlated with anatomy of the site.

positronium A bound state consisting of an electron and a positron. There are two types of positronium: **orthopositronium**, in which the spins of the two constituents are parallel, and **parapositronium**, in which the spins are anti-parallel. Both forms have brief existences, with orthopositronium decaying into three photons in about 1.5×10^{-7} s and parapositronium decaying into two photons in the even shorter time of about 10^{-10} s. Positronium has a hydrogen-like spectrum, but with different values of the frequencies since a positron is much lighter than a proton.

positron microscope An instrument for studying solids, similar in principle to a scanning electron mircoscope, but using positrons rather than electrons. Scanning positron microscopes are used in investigating surfaces and defects.

postcaval vein *See* VENA CAVA.

posterior **1.** Designating the part of an animal that is to the rear, i.e. that follows when the animal is moving. In humans and bipedal animals (e.g. kangaroos) the posterior surface is equivalent to the *dorsal surface. **2.** Designating the side of a flower or axillary bud that faces towards the flower stalk or main stem, respectively. *Compare* ANTERIOR.

post-Newtonian approximation An approximation used in the general theory of relativity in which the effects of relativity are regarded as small corrections to the Newtonian solution to the problem being considered. The post-Newtonian approximation is useful for problems in which the correction is small, as in considering relativistic effects on the motions of planets in the solar system. It cannot be used for systems such as black holes, which involve strong gravitational fields.

postsynaptic membrane The membrane at the end of a neuron that receives an impulse at a *synapse.

potash Any of a number of potassium compounds, such as the carbonate or the hydroxide.

potash alum *See* ALUMINIUM POTASSIUM SULPHATE; ALUMS.

potash mica *See* MUSCOVITE.

potassamide *See* POTASSIUM MONOXIDE.

potassium Symbol K. A soft silvery metallic element belonging to group 1 (formerly IA) of the periodic table (*see* ALKALI METALS); a.n. 19; r.a.m. 39.098; r.d. 0.86; m.p. 63.7°C; b.p. 774°C. The element occurs in seawater and in a number of minerals, such as sylvite (KCl), carnallite ($KCl.MgCl_2.6H_2O$), and kainite ($MgSO_4.KCl.3H_2O$). It is obtained by electrolysis. The metal has few uses but potassium salts are used for a wide range of applications. Potassium is an *essential element for living organisms. The potassium ion, K^+, is the most abundant cation in plant tissues, being absorbed through the roots and being used in such processes as protein synthesis. In animals the passage of potassium and sodium ions across the nerve-cell membrane is responsible for the changes of electrical potential that accompany the transmission of impulses. Chemically, it is highly reactive, resembling sodium in its behaviour and compounds. It also forms an orange-coloured superoxide, KO_2, which contains the O_2^- ion. Potassium was discovered by Sir Humphry Davy in 1807.

p

SEE WEB LINKS

- Information from the WebElements site

potassium–argon dating A *dating technique for certain rocks that depends on the decay of the radioisotope potassium–40 to argon–40, a process with a half-life of about 1.27×10^{10} years. It assumes that all the argon–40 formed in the potassium-bearing mineral accumulates within it and that all the argon present is formed by the decay of potassium–40. The mass of argon–40 and potassium–40 in the sample is estimated and the sample is then dated from the equation:

$$^{40}Ar = 0.1102\ ^{40}K(e^{\lambda t} - 1),$$

where λ is the decay constant and t is the time in years since the mineral cooled to about 300°C, when the ^{40}Ar became trapped in the crystal lattice. The method is effective for micas, feldspar, and some other minerals.

potassium bicarbonate *See* POTASSIUM HYDROGENCARBONATE.

potassium bichromate *See* POTASSIUM DICHROMATE.

potassium bromide A white or colourless crystalline solid, KBr, slightly hygroscopic and soluble in water and very slightly soluble in ethanol; cubic; r.d. 2.75; m.p. 734°C; b.p. 1435°C. Potassium bromide may be prepared by the action of bromine on hot potassium hydroxide solution or by the action of iron(III) bromide or hydrogen bromide on potassium carbonate solution. It is used widely in the photographic industry and is also used as a sedative. Because of its range of transparency to infrared radiation, KBr is used both as a matrix for solid samples and as a prism material in infrared spectroscopy.

potassium carbonate (pearl ash; potash) A translucent (granular) or white (powder) deliquescent solid known in the anhydrous and hydrated forms. K_2CO_3 (monoclinic; r.d. 2.4; m.p. 891°C) decomposes without boiling. $2K_2CO_3.3H_2O$ (monoclinic; r.d. 2.04) dehydrates to $K_2CO_3.H_2O$ above 100°C and to K_2CO_3 above 130°C. It is prepared by the Engel–Precht process in which potassium chloride and magnesium oxide react with carbon dioxide to give the compound **Engel's salt**, $MgCO_3.KHCO_3.4H_2O$. This is decomposed in solution to give the hydrogencarbonate, which can then be calcined to K_2CO_3. Potassium carbonate is soluble in water (insoluble in alcohol) with significant hydrolysis to produce basic solutions. Industrial uses include glasses and glazes, the manufacture of soft soaps, and in dyeing and wool finishing. It is used in the laboratory as a drying agent.

potassium chlorate A colourless crystalline compound, $KClO_3$, which is soluble in water and moderately soluble in ethanol; monoclinic; r.d. 2.32; m.p. 356°C; decomposes above 400°C giving off oxygen. The industrial route to potassium chlorate involves the fractional crystallization of a solution of potassium chloride and sodium chlorate but it may also be prepared by electrolysis of hot concentrated solutions of potassium chloride. It is a powerful oxidizing agent finding applications in weedkillers and disinfectants and, because of its ability to produce oxygen, it is used in explosives, pyrotechnics, and matches.

potassium chloride A white crystalline solid, KCl, which is soluble in water and very slightly soluble in ethanol; cubic; r.d. 1.98;

m.p. 772°C; sublimes at 1500°C. Potassium chloride occurs naturally as the mineral **sylvite** (KCl) and as **carnallite** ($KCl.MgCl_2.6H_2O$); it is produced industrially by fractional crystallization of these deposits or of solutions from lake brines. It has the interesting property of being more soluble than sodium chloride in hot water but less soluble in cold. It is used as a fertilizer, in photography, and as a source of other potassium salts, such as the chlorate and the hydroxide. It has low toxicity.

potassium chromate A bright yellow crystalline solid, K_2CrO_4, soluble in water and insoluble in alcohol; rhombic; r.d. 2.73; m.p. 968.3°C; decomposes without boiling. It is produced industrially by roasting powdered chromite ore with potassium hydroxide and limestone and leaching the resulting cinder with hot potassium sulphate solution. Potassium chromate is used in leather finishing, as a textile mordant, and in enamels and pigments. In the laboratory it is used as an analytical reagent and as an indicator. Like other chromium(III) compounds it is toxic when ingested or inhaled.

potassium chromium sulphate (chrome alum) A violet or ruby-red crystalline solid, $K_2SO_4.Cr_2(SO_4)_3.24H_2O$, that is soluble in water and insoluble in ethanol; cubic or octahedral; r.d. 1.826; m.p. 89°C; loses $10H_2O$ at 100°C, $12H_2O$ at 400°C. Six water molecules surround each of the chromium(III) ions and the remaining ones are hydrogen bonded to the sulphate ions. Like all alums, the compound may be prepared by mixing equimolar quantities of the constituent sulphates. *See* ALUMS.

potassium cyanide (cyanide) A white crystalline or granular deliquescent solid, KCN, soluble in water and in ethanol and having a faint characteristic odour of almonds (due to hydrolysis forming hydrogen cyanide at the surface); cubic; r.d. 1.52; m.p. 634°C. It is prepared industrially by the absorption of hydrogen cyanide in potassium hydroxide. The compound is used in the extraction of silver and gold, in some metal-finishing processes and electroplating, as an insecticide and fumigant (source of HCN), and in the preparation of cyanogen derivatives. In the laboratory it is used in analysis, as a reducing agent, and as a stabilizing *ligand for low oxidation states. The salt itself is highly toxic and aqueous solutions of potassium cyanide are strongly hydrolysed to give rise to the slow release of equally toxic hydrogen cyanide gas.

potassium dichromate (potassium bichromate) An orange-red crystalline solid, $K_2Cr_2O_7$, soluble in water and insoluble in alcohol; monoclinic or triclinic; r.d. 2.68; monoclinic changes to triclinic at 241.6°C; m.p. 396°C; decomposes above 500°C. It is prepared by acidification of crude potassium chromate solution (the addition of a base to solutions of potassium dichromate reverses this process). The compound is used industrially as an oxidizing agent in the chemical industry and in dyestuffs manufacture, in electroplating, pyrotechnics, glass manufacture, glues, tanning, photography and lithography, and in ceramic products. Laboratory uses include application as an analytical reagent and as an oxidizng agent. Potassium dichromate is toxic and considered a fire risk on account of its oxidizing properties.

potassium dioxide *See* POTASSIUM SUPEROXIDE.

potassium hydride A white or greyish white crystalline solid, KH; r.d. 1.43–1.47. It is prepared by passing hydrogen over heated potassium and marketed as a light grey powder dispersed in oil. The solid decomposes on heating and in contact with moisture and is an excellent reducing agent. Potassium hydride is a fire hazard because it produces hydrogen on reaction with water.

potassium hydrogencarbonate (potassium bicarbonate) A white crystalline solid, $KHCO_3$, soluble in water and insoluble in ethanol; r.d. 2.17; decomposes about 120°C. It occurs naturally as **calcinite** and is prepared by passing carbon dioxide into saturated potassium carbonate solution. It is used in baking, soft-drinks manufacture, and in CO_2 fire extinguishers. Because of its buffering capacity, it is added to some detergents and also used as a laboratory reagent.

potassium hydrogentartrate (cream of tartar) A white crystalline acid salt, $HOOC(CHOH)_2COOK$. It is obtained from deposits on wine vats (argol) and used in baking powders.

potassium hydroxide (caustic potash; lye) A white deliquescent solid, KOH, often sold as pellets, flakes, or sticks, soluble in water and in ethanol and very slightly soluble in ether; rhombic; r.d. 2.044; m.p. 360.4°C; b.p. 1320°C. It is prepared industri-

ally by the electrolysis of concentrated potassium chloride solution but it can also be made by heating potassium carbonate or sulphate with slaked lime, $Ca(OH)_2$. It closely resembles sodium hydroxide but is more soluble and is therefore preferred as an absorber for carbon dioxide and sulphur dioxide. It is also used in the manufacture of soft soap, other potassium salts, and in Ni–Fe and alkaline storage cells. Potassium hydroxide is extremely corrosive to body tissues and especially damaging to the eyes.

potassium iodate A white crystalline solid, KIO_3, soluble in water and insoluble in ethanol; monoclinic; r.d. 3.9; m.p. 560°C. It may be prepared by the reaction of iodine with hot concentrated potassium hydroxide or by careful electrolysis of potassium iodide solution. It is an oxidizing agent and is used as an analytical reagent. Some potassium iodate is used as a food additive.

potassium iodide A white crystalline solid, KI, with a strong bitter taste, soluble in water, ethanol, and acetone; cubic; r.d. 3.13; m.p. 681°C; b.p. 1330°C. It may be prepared by the reaction of iodine with hot potassium hydroxide solution followed by separation from the iodate (which is also formed) by fractional crystallization. In solution it has the interesting property of dissolving iodine to form the triiodide ion I_3^-, which is brown. Potassium iodide is widely used as an analytical reagent, in photography, and also as an additive to table salt to prevent goitre and other disorders due to iodine deficiency.

potassium manganate(VII) (potassium permanganate) A compound, $KMnO_4$, forming purple crystals with a metallic sheen, soluble in water (intense purple solution), acetone, and methanol, but decomposed by ethanol; r.d. 2.70; decomposition begins slightly above 100°C and is complete at 240°C. The compound is prepared by fusing manganese(IV) oxide with potassium hydroxide to form the manganate and electrolysing the manganate solution using iron electrodes at about 60°C. An alternative route employs production of sodium manganate by a similar fusion process, oxidation with chlorine and sulphuric acid, then treatment with potassium chloride to crystallize the required product.

Potassium manganate(VII) is widely used as an oxidizing agent and as a disinfectant in a variety of applications, and as an analytical reagent.

potassium monoxide A grey crystalline solid, K_2O; cubic; r.d. 2.32; decomposition occurs at 350°C. It may be prepared by the oxidation of potassium metal with potassium nitrate. It reacts with ethanol to form potassium ethoxide (KOC_2H_5), and with liquid ammonia to form potassium hydroxide and **potassamide** (KNH_2).

potassium nitrate (saltpetre) A colourless rhombohedral or trigonal solid, KNO_3, soluble in water, insoluble in alcohol; r.d. 2.109; transition to trigonal form at 129°C; m.p. 334°C; decomposes at 400°C. It occurs naturally as **nitre** and may be prepared by the reaction of sodium nitrate with potassium chloride followed by fractional crystallization. It is a powerful oxidizing agent (releases oxygen on heating) and is used in gunpowder and fertilizers.

potassium nitrite A white or slightly yellow deliquescent solid, KNO_2, soluble in water and insoluble in ethanol; r.d. 1.91; m.p. 440°C; may explode at 600°C. Potassium nitrite is prepared by the reduction of potassium nitrate. It reacts with cold dilute mineral acids to give nitrous acid and is also able to behave as a reducing agent (if oxidized to the nitrate) or as an oxidizing agent (if reduced to nitrogen). It is used in organic synthesis because of its part in diazotization, and in detecting the presence of the amino groups in organic compounds.

potassium permanganate *See* POTASSIUM MANGANATE(VII).

potassium sulphate A white crystalline powder, K_2SO_4, soluble in water and insoluble in ethanol; rhombic or hexagonal; r.d. 2.66; m.p. 1069°C. It occurs naturally as **schönite** (Strassfurt deposits) and in lake brines, from which it is separated by fractional crystallization. It has also been produced by the **Hargreaves process**, which involves the oxidation of potassium chloride with sulphuric acid. In the laboratory it may be obtained by the reaction of either potassium hydroxide or potassium carbonate with sulphuric acid. Potassium sulphate is used in cements, in glass manufacture, as a food additive, and as a fertilizer (source of K^+) for chloride-sensitive plants, such as tobacco and citrus.

potassium sulphide A yellow-red or brown-red deliquescent solid, K_2S, which is soluble in water and in ethanol but insoluble in diethyl ether; cubic; r.d. 1.80; m.p. 840°C.

It is made industrially by reducing potassium sulphate with carbon at high temperatures in the absence of air. In the laboratory it may be prepared by the reaction of hydrogen sulphide with potassium hydroxide. The pentahydrate is obtained on crystallization. Solutions are strongly alkaline due to hydrolysis. It is used as an analytical reagent and as a depilatory. Potassium sulphide is generally regarded as a hazardous chemical with a fire risk; dusts of K_2S have been known to explode.

potassium sulphite A white crystalline solid, K_2SO_3, soluble in water and very sparingly soluble in ethanol; r.d. 1.51; decomposes on heating. It is a reducing agent and is used as such in photography and in the food and brewing industries, where it prevents oxidation.

potassium superoxide (potassium dioxide) A yellow paramagnetic solid, KO_2, produced by burning potassium in an excess of oxygen; it is very soluble (by reaction) in water, soluble in ethanol, and slightly soluble in diethyl ether; m.p. 380°C. When treated with cold water or dilute mineral acids, hydrogen peroxide is obtained. The compound is a powerful oxidizing agent and on strong heating releases oxygen with the formation of the monoxide, K_2O.

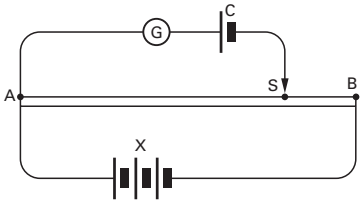
potential barrier A region containing a maximum of potential that prevents a particle on one side of it from passing to the other side. According to classical theory a particle must possess energy in excess of the height of the potential barrier to pass it. However, in quantum theory there is a finite probability that a particle with less energy will pass through the barrier (*see* TUNNEL EFFECT). A potential barrier surrounds the atomic nucleus and is important in nuclear physics; a similar but much lower barrier exists at the interface between *semiconductors and metals and between differently doped semiconductors. These barriers are important in the design of electronic devices.

potential difference *See* ELECTRIC POTENTIAL.

potential divider *See* VOLTAGE DIVIDER.

potential energy *See* ENERGY.

potentiometer **1.** *See* VOLTAGE DIVIDER. **2.** An instrument for measuring, comparing, or dividing small potential differences. A typical example of its use is the measurement of



Potentiometer.

the e.m.f. (E_1) of a cell by comparing it with the e.m.f. (E_2) of a standard cell. In this case a circuit is set up as illustrated, in which AB is a wire of uniform resistance and S is a sliding contact onto this wire. An accumulator X maintains a steady current through the wire. To measure the e.m.f. of a cell C, it is connected up as shown in the diagram and the sliding contact moved until the e.m.f. of C exactly balances the p.d. from the accumulator, as indicated by a zero reading on the galvanometer G. If the length AS is then l_1, the value of E_1 is given by $E_1/E_2 = l_1/l_2$, where l_2 is the length AS when the standard cell is used as the cell C.

potentiometric titration A titration in which the end point is found by measuring the potential on an electrode immersed in the reaction mixture.

potometer An apparatus used to measure the rate of water loss from a shoot (*see* TRANSPIRATION) under natural or artificial conditions.

pound The unit of mass in the *f.p.s. system of units defined as 0.453 592 37 kilogram. Before 1963 it was defined in terms of a platinum cylinder called the Imperial Standard Pound.

poundal The unit of force in the *f.p.s. system of units equal to the force required to impart to a mass of one pound an acceleration of one foot per second per second.

Pourbaix diagram A diagram showing how oxidation–reduction behaviour for compounds of a given element depends on pH.

powder metallurgy A process in which powdered metals or alloys are pressed into a variety of shapes at high temperatures. The process started with the pressing of powdered tungsten into incandescent lamp filaments in the first decade of the 20th century

and is now widely used for making self-lubricating bearings and cemented tungsten carbide cutting tools.

The powders are produced by atomization of molten metals, chemical decomposition of a compound of the metal, or crushing and grinding of the metal or alloy. The parts are pressed into moulds at pressures ranging from 140×10^6 Pa to 830×10^6 Pa after which they are heated in a controlled atmosphere to bond the particles together (*see* SINTERING).

powder method *See* DEBYE–SCHERRER METHOD.

power **1.** (in physics) Symbol *P*. The rate at which work is done or energy is transferred. In SI units it is measured in watts (joules per second). *See also* HORSEPOWER. **2.** (in mathematics) The number of times a quantity is multiplied; e.g. x^5 is the fifth power of x. A **power series** is one in which the power of the variable increases with each term, e.g. $a_0 + a_1x + a_2x^2 + a_3x^3 + \ldots + a_nx^n$.

power factor *See* ELECTRIC POWER.

power reactor A *nuclear reactor designed to produce electrical power.

poxvirus One of a group of DNA-containing viruses, often enclosed in an outer membrane, that typically produce skin lesions in vertebrates. They include the viruses causing smallpox (variola), cowpox (vaccinia), and myxomatosis (myxoma). Some poxviruses produce tumours.

Poynting vector Symbol *S*. A vector that gives a measure of the flow of energy in an electromagnetic field. It is given by the vector product $\boldsymbol{S} = \boldsymbol{E} \times \boldsymbol{H}$, where $\boldsymbol{E}$ is the electric field strength and $\boldsymbol{H}$ is the magnetic field strength. It was discovered by the British physicist John Henry Poynting (1852–1914) in 1884.

praseodymium Symbol Pr. A soft silvery metallic element belonging to the *lanthanoids; a.n. 59; r.a.m. 140.91; r.d. 6.773; m.p. 931°C; b.p. 3512°C. It occurs in bastnasite and monazite, from which it is recovered by an ion-exchange process. The only naturally occurring isotope is praseodymium–141, which is not radioactive; however, fourteen radioisotopes have been produced. It is used in mischmetal, a rare-earth alloy containing 5% praseodymium, for use in lighter flints. Another rare-earth mixture containing 30% praseodymium is used as a catalyst in cracking crude oil. The element was discovered by Carl von Welsbach (1856–1929) in 1885.

SEE WEB LINKS

- Information from the WebElements site

preamplifier An *amplifier in a radio, record player, etc., providing a first stage of amplification. It is usually located close to the signal source (i.e. the aerial or pick-up) and the signal is then transmitted by cable to the main amplifier. Preamplification at this early stage improves the signal-to-noise ratio of the whole system.

Precambrian Describing the time from the formation of the earth, nearly 5 billion years ago, to the beginning of the Cambrian period, some 542 million years ago. The term 'Precambrian' is no longer used for a specific geological time interval but remains as a general adjective. Precambrian time is now divided into three eons: *Hadean, *Archaean, and *Proterozoic. Fossils are rare, although *stromatolites indicate that there were flourishing populations of bacteria. However, subsequent metamorphism of Precambrian rocks makes correlation of rocks and events extremely difficult. The largest areas of exposed Precambrian rocks are the shield areas, such as the Canadian (Laurentian) Shield and the Baltic Shield.

precaval vein *See* VENA CAVA.

precessional motion A form of motion that occurs when a torque is applied to a rotating body in such a way that it tends to change the direction of its axis of rotation. It arises because the resultant of the angular velocity of rotation and the increment of angular velocity produced by the torque is an angular velocity about a new direction; this commonly changes the axis of the applied torque and leads to sustained rotation of the original axis of rotation.

A spinning top, the axis of which is not exactly vertical, has a torque acting on it as a result of gravity. Instead of falling over, the top precesses about a vertical line through the pivot. The earth also experiences a torque and undergoes a slow precession, primarily as a result of the gravitational attraction of the sun and the moon on its equatorial bulge (*see* PRECESSION OF THE EQUINOXES).

precession of the equinoxes The slow westward motion of the *equinoxes about the ecliptic as a result of the earth's *preces-

sional motion. The equinoxes move round the ecliptic with a period of 25 800 years.

precipitate A suspension of small solid particles produced in a liquid by chemical reaction.

precipitation **1.** All liquid and solid forms of water that are deposited from the atmosphere; it includes rain, drizzle, snow, hail, dew, and hoar frost. **2.** The formation of a precipitate.

precipitin Any *antibody that combines with its specific soluble *antigen to form a precipitate. The term is sometimes applied to the precipitate itself. *See also* AGGLUTINATION.

precursor A compound that leads to another compound in a series of chemical reactions.

predation An interaction between two populations of animals in which one (the **predator**) hunts, captures, and kills the other (the **prey**) for food. Predator–prey relationships form important links in many food chains. They are also important in regulating population sizes of both predator and prey, especially when the predator relies on a single prey species. The term predation is also used, more loosely, for any feeding relationship in which an organism feeds on any other living organism (animal or plant).

predator An animal that obtains its food by *predation. All predators are *carnivores, although not all carnivores are predators.

pregnancy *See* GESTATION.

preimplantation genetic diagnosis (PGD) The screening of early embryos for disease-causing genes to enable the selection of 'healthy' embryos. The technique is used in conjunction with *in vitro* fertilization, which typically yields a number of embryos. A single cell is removed from an eight-stage embryo and subjected to genetic testing; for example, it may be tested for a specific disease allele. If the results are satisfactory, the embryo is implanted in the mother's uterus, and development proceeds. Removal of a single cell at this stage does not affect the embryo's subsequent development. PGD can help especially when couples who are being treated for fertility problems also have a history of genetic disease. However, use of PGD can be extended in non-therapeutic ways, such as choosing a baby's sex or selecting particular desired traits to produce so-called 'designer babies'. These highly controversial applications of PGD are prohibited in certain countries, including the UK.

premolar A broad ridged tooth in mammals that is situated behind the *canine teeth (when present) and in front of the *molars. Premolars are adapted for grinding and chewing food and are present in both the deciduous and permanent dentitions.

premutation A gene variant (allele) that produces a normal individual but is predisposed to become a full mutation in subsequent generations. Genetic analysis of human families has revealed the involvement of premutations in several genetic diseases. For example, in the gene for Huntington's disease, normal individuals have a string of 6 to 39 CAG repeats near the start of the coding sequence. In individuals with the disease, this region extends to 36–180 CAG repeats. Individuals with CAG repeats in the low 30s have a premutation for Huntington's disease; this region of the gene is amplified during meiosis to become an abnormal allele, sufficient to produce the disease in that individual's offspring.

preons Hypothetical entities that are postulated as being 'building blocks' of quarks and leptons. There is no experimental evidence for preons but the idea has considerable theoretical appeal. It is expected that evidence for preons would only be obtained at much higher energies than are available from present accelerators.

presbyopia A loss of accommodation that normally develops in human eyes over the age of 45–50 years. Vision of distant objects remains unchanged but accommodation of the eye to near objects is reduced as a result of loss of elasticity in the lens of the eye. The defect is corrected by reading glasses using weak converging lenses.

pressure The force acting normally on unit area of a surface or the ratio of force to area. It is measured in *pascals in SI units. **Absolute pressure** is pressure measured on a gauge that reads zero at zero pressure rather than at atmospheric pressure. **Gauge pressure** is measured on a gauge that reads zero at atmospheric pressure.

pressure gauge Any device used to measure pressure. Three basic types are in use: the liquid-column gauge (e.g. the mercury *barometer and the *manometer), the ex-

panding-element gauge (e.g. the *Bourdon gauge and the aneroid *barometer), and the electrical transducer. In the last category the *strain gauge is an example. Capacitor pressure gauges also come into this category. In these devices, the pressure to be measured displaces one plate of a capacitor and thus alters its capacitance.

pressurized-water reactor *See* NUCLEAR REACTOR.

presumptive Describing embryonic tissue that is not yet *determined but which will eventually develop into a certain kind of tissue by virtue of its position in the embryo.

presumptive test A simple test for a given substance using a reagent that changes colour when mixed with the substance under investigation. Presumptive tests are not definitive and further confirmatory tests are always required. They are used extensively in forensic science. Examples are the Duquenois–Levine test for marijuana and Scott's test for cocaine. In general analytical chemistry, presumptive tests are often called **spot tests**.

presynaptic membrane The membrane of a neuron that releases neurotransmitter into the synaptic cleft between nerve cells (*see* SYNAPSE).

Prévost's theory of exchanges A body emits and absorbs radiant energy at equal rates when it is in equilibrium with its surroundings. Its temperature then remains constant. If the body is not at the same temperature as its surroundings there is a net flow of energy between the surroundings and the body because of unequal emission and absorption. The theory was proposed by Pierre Prévost (1751–1839) in 1791.

prey An animal that is a source of food for a predator. *See* PREDATION.

Pribnow box A *consensus sequence of nucleotides – TATAAT – occurring in the promoter region of prokaryote genes (*see* OPERON) about 10 nucleotides before the start of transcription. The predominance of adenine and thymine bases means that hydrogen bonding between the two DNA strands in this region is relatively weak, enabling the strands to be separated more easily to permit transcription by RNA polymerase. *See also* TATA BOX.

prickle A hard sharp protective outgrowth, many of which may cover the surface of a plant. It contains cortical and vascular tissue and is not regarded as an epidermal outgrowth. *Compare* SPINE; THORN.

Priestley, Joseph (1733–1804) British chemist, who in 1755 became a Presbyterian minister. In Leeds, in 1767, he experimented with carbon dioxide ('fixed air') from a nearby brewery; with it he invented soda water. He moved to a ministry in Birmingham in 1780, and in 1791 his revolutionary views caused a mob to burn his house, as a result of which he emigrated to the USA in 1794. In the early 1770s he experimented with combustion and produced the gases hydrogen chloride, sulphur dioxide, and dinitrogen oxide (nitrous oxide). In 1774 he isolated oxygen (*see also* LAVOISIER, ANTOINE LAURENT).

primary Any celestial object that has one or more other objects in direct orbit around it. For example, the sun is the primary for the bodies in the *solar system, while the earth is the moon's primary.

primary alcohol *See* ALCOHOLS.

primary amine *See* AMINES.

primary cell A *voltaic cell in which the chemical reaction producing the e.m.f. is not satisfactorily reversible and the cell cannot therefore be recharged by the application of a charging current. *See* DANIELL CELL; LECLANCHÉ CELL; WESTON CELL; MERCURY CELL. *Compare* SECONDARY CELL.

primary colour Any one of a set of three coloured lights that can be mixed together to give the sensation of white light as well as approximating all the other colours of the spectrum. An infinite number of such sets exists, the condition being that none of the individual colours of a set should be able to be matched by mixing the other two; however, unless the colours are both intense and very different the range that they can match well will be limited. The set of primary colours most frequently used is red, green, and blue. *See also* COLOUR.

primary consumer *See* CONSUMER.

primary growth The increase in size of shoots and roots of plants that results from the activity of the *apical (tip) meristems and subsequent expansion of the cells produced. The tissues thus produced are called **primary tissues** and the resultant plant parts constitute the **primary plant body**. *Compare* SECONDARY GROWTH.

primary producer *See* PRODUCER.

primary structure *See* PROTEIN.

primary winding The winding on the input side of a *transformer or *induction coil. *Compare* SECONDARY WINDING.

Primates An order of mammals that includes the monkeys, apes, and humans. Primates evolved from arboreal insectivores 63–70 million years ago. They are characterized by thumbs and big toes that are opposable (i.e. capable of facing and touching the other digits), which permits manual dexterity, and forward-facing eyes allowing *binocular vision. The brain, particularly the cerebrum, is relatively large and well-developed, accounting for the intelligence and quick reactions of these mammals. The young are usually produced singly and undergo a long period of growth and development to the adult form.

SEE WEB LINKS

- Wide-ranging account of primate characteristics and taxonomy, compiled by Dennis O'Neil, Palomar College, California

primordium A group of cells that represents the initial stages in development of a plant organ. Root and shoot primordia are present in a young plant embryo while leaf primordia (or **leaf buttresses**) are seen as small bulges just below the shoot apex.

principal axis *See* OPTICAL AXIS.

principal focus A point through which rays close to and parallel to the axis of a lens or spherical mirror pass, or appear to pass, after refraction or reflection. A mirror has one principal focus, a lens has a principal focus on both sides.

principal plane The plane that is perpendicular to the optical axis of a lens and that passes through the optical centre. A thick lens has two principal planes, each passing through a *principal point.

principal point Either of two points on the principal axis of a thick lens from which simply related distances can be measured, as from the optical centre of a thin lens.

principle of parsimony The principle that the most acceptable explanation of an occurrence, phenomenon, or event is the simplest, involving the fewest entities, assumptions, or changes. In phylogenetics, for example, the preferred tree showing evolutionary relationships between species, molecules, or other entities is the one that requires the least amount of evolutionary change, that is, maximum parsimony.

principle of superposition The resultant displacement at any point in a region through which two waves of the same type pass is the algebraic sum of the displacements that the two would separately produce at that point. Both waves leave the region of superposition unaltered.

printed circuit An electronic circuit consisting of a conducting material deposited (printed) onto the surface of an insulating sheet. These devices are now common in all types of electronic equipment, facilitating batch production and eliminating the unreliability of the hand-soldered joint.

printer A device for producing a printed version of text (and, sometimes, pictures) from a computer. There are several types. **Impact printers** work on the same principle as a typewriter, in which a ribbon is hit by a surface embossed with the character. A **line printer** produces a whole line of text at a time. In this device the characters are held on a row of spinning cylinders. In a **daisy-wheel printer**, the characters are held on the ends of a series of arms radiating from the centre of a wheel. A **dot-matrix printer** forms the image of each character from a rectangular matrix of dots. An **inkjet printer** works by spraying fine jets of quick-drying ink onto the paper. A **laser printer** uses a xerographic technique in which a photosensitive plate is scanned by a low-power laser.

prion An abnormal form of a normal cell protein (PrP) found in the brain of mammals that is believed to be the agent responsible for the diseases scrapie in sheep, *bovine spongiform encephalopathy (BSE) in cattle, and *Creutzfeldt–Jakob disease in humans. Produced by mutation of the normal PrP gene, the abnormal prion protein interacts with normal protein, causing it to accumulate in the brain and progressively damage and destroy brain cells. It can be transmitted to other individuals of the same or closely related species, by injection or ingestion of infected tissue, and some forms appear to be transmissible between species that are not closely related (e.g. between cattle and humans).

prism **1.** (in mathematics) A polyhedron with two parallel congruent polygons as bases and parallelograms for all other faces.

A **triangular prism** has triangular bases. **2.** (in optics) A block of glass or other transparent material, usually having triangular bases. Prisms have several uses in optical systems: they can be used to deviate a ray, to disperse white light into the visible spectrum, or to erect an inverted image (*see* BINOCULARS). Prisms of other materials are used for different kinds of radiation. *See also* NICOL PRISM; WOLLASTON PRISM.

prismane A saturated hydrocarbon, C_6H_6, in which the six carbon atoms are arranged at the corners of a triangular prism. The structure was suggested in 1869 by Albert Ladenburg as a possible structure for benzene (since referred to as **Ladenburg benzene**). The actual compound was synthesized by T. J. Katz and N. Acton in 1973. Hexamethylprismane, in which the carbon atoms are linked to methyl groups rather than hydrogen atoms, was synthesized in 1966.

private key *See* PUBLIC KEY ENCRYPTION.

probability The likelihood of a particular event occurring. If there are n equally likely outcomes of some experiment, and a ways in which event E could occur, then the probability of event E is a/n. For instance, if a die is thrown there are 6 possible outcomes and 3 ways in which an odd number may occur. The probability of throwing an odd number is 3/6 = 1/2.

Proboscidea The order of mammals that comprises the elephants. They are herbivorous, with a muscular trunk (*proboscis) used for drinking, bathing, and collecting food. The tusks are continuously growing upper incisors and the enormous ridged molar teeth are produced in sequence to replace worn teeth throughout life. The order, which evolved in the Eocene epoch, was formerly much larger and more widespread than it is today and included the extinct mammoths. There are only two species of modern elephants: the African and Indian species.

proboscis **1.** The trunk of an elephant: a muscular and very flexible elongation of the nose, which has a finger-like extremity and is capable of picking up and moving objects, taking in water, collecting food, etc. **2.** The elongated mouthparts of certain invertebrates, such as the two-winged flies (Diptera).

procambium A plant tissue formed by the *apical meristems of shoots and roots. It consists of cells elongated parallel to the long axis of the plant. The procambium subsequently gives rise to the primary *vascular tissue.

procaryote *See* PROKARYOTE.

Proconsul A genus of extinct apes known from fossil remains, roughly 23–14 million years old, found in East Africa and assigned to at least three species. These apes were quadrupeds and appear to have been tailless.

producer An organism considered as a source of energy for those above it in a *food chain (i.e. at the next *trophic level). Green plants, which convert energy from sunlight into chemical energy, are **primary producers**; herbivores are **secondary producers**, as they utilize energy from green plants and supply energy for carnivores. *Compare* CONSUMER.

producer gas (air gas) A mixture of carbon monoxide and nitrogen made by passing air over very hot carbon. Usually some steam is added to the air and the mixture contains hydrogen. The gas is used as a fuel in some industrial processes.

product *See* CHEMICAL REACTION.

productivity (production) (in ecology) The rate at which an organism, population, or community assimilates energy (**gross productivity**) or makes energy potentially available (as body tissue) to an animal that feeds on it (**net productivity**). The difference between these two rates is due to the rate at which energy is lost through excretion and respiration. Thus **gross primary productivity** is the rate at which plants (or other *producers) assimilate light energy, and **net primary productivity** is the rate at which energy is incorporated as plant tissue. It is measured in kilojoules per square metre per year (kJ m^{-2} y^{-1}). In terrestrial plants, much of the net productivity is not actually available to *consumers, e.g. tree roots are not eaten by herbivores. *See also* ENERGY FLOW.

profundal Occurring in or designating the deep-water zone of an inland lake. Light intensity, oxygen concentration, and (during summer and autumn) temperature are markedly lower than in the surface layer. *Compare* LITTORAL; SUBLITTORAL.

progeny *See* OFFSPRING.

progesterone A hormone, produced primarily by the *corpus luteum of the ovary but also by the placenta, that prepares the inner lining of the uterus for implantation of a fertilized egg cell. If implantation fails, the corpus luteum degenerates and progesterone production ceases accordingly. If implantation occurs, the corpus luteum continues to secrete progesterone, under the influence of *luteinizing hormone and *prolactin, for several months of pregnancy, by which time the placenta has taken over this function. During pregnancy, progesterone maintains the constitution of the uterus and prevents further release of eggs from the ovary. Small amounts of progesterone are produced by the testes. *See also* PROGESTOGEN.

progestogen One of a group of naturally occurring or synthetic hormones that maintain the normal course of pregnancy. The best known is *progesterone. In high doses progestogens inhibit secretion of *luteinizing hormone, thereby preventing ovulation, and alter the consistency of mucus in the vagina so that conception tends not to occur. They are therefore used as major constituents of *oral contraceptives.

program *See* COMPUTER.

programmed cell death *See* APOPTOSIS.

progressive wave *See* WAVE.

projectile Any body that is thrown or projected. If the projectile is discharged on the surface of the earth at an angle θ to the horizontal it will describe a parabolic flight path (if $\theta < 90°$ and the initial velocity < the *escape velocity). Neglecting air resistance, the maximum height of this flight path will be $(v^2\sin^2\theta)/2g$, where v is the velocity of discharge and g is the acceleration of free fall. The horizontal distance covered will be $(v^2\sin 2\theta)/g$ and the time of the flight will be $(2v\sin\theta)/g$.

projective relativity theory A type of *unified-field theory in which projective geometry is used. This type of unified-field theory has not been successful, but it may be related to *twistor theory.

projector An optical device for throwing a large image of a two-dimensional object onto a screen. In an **episcope**, light is reflected from the surface of an opaque two-dimensional object (such as a diagram or photographic print) and an enlarged image is thrown onto a distant screen by means of a system of mirrors and lenses. The **diascope** passes light through the two-dimensional object (such as a photographic transparency, slide, or film) and uses a converging projection lens to form an enlarged image on a distant screen. An **epidiascope** is a device that can be used as both episcope and diascope. An **overhead projector** is a form of diascope that throws its image on a wall or screen behind and above the operator. In a **motion-picture projector** (or **ciné projector**) the film, consisting of a long sequence of transparent pictures, is driven by a motor past the light source in such a way that each picture comes to rest for a brief period in front of the light source. The illusion of motion is created as each image on the screen is replaced by the next; during the picture change the light is interrupted.

prokaryote (procaryote) Any organism in which the genetic material is not enclosed in a cell nucleus. Prokaryotes consist exclusively of bacteria, i.e. archaebacteria and eubacteria, which are now generally classified in separate domains, *Archaea and Eubacteria. *See also* ENDOSYMBIONT THEORY.

Prokhorov, Aleksandr *See* BASOV, NIKOLAI GENNEDIYEVITCH.

prolactin (lactogenic hormone; luteotrophic hormone; luteotrophin) A hormone produced by the anterior pituitary gland. In mammals it stimulates the mammary glands to secrete milk (*see* LACTATION) and the corpus luteum of the ovary to secrete the hormone *progesterone. Secretion of prolactin is increased by suckling. In birds prolactin stimulates secretion of crop milk by the crop glands.

proline *See* AMINO ACID.

PROM *See* ROM.

promethium Symbol Pm. A soft silvery metallic element belonging to the *lanthanoids; a.n. 61; r.a.m. 145; r.d. 7.26 (20°C); m.p. 1080°C; b.p. 2460°C. The only naturally occurring isotope, promethium–147, has a half-life of only 2.52 years. Eighteen other radioisotopes have been produced, but they have very short half-lives. The only known source of the element is nuclear-waste material. Promethium–147 is of interest as a beta-decay power source but the promethium–146 and –148, which emit penetrating gamma radiation, must first be removed. It

was discovered by J. A. Marinsky, L. E. Glendenin, and C. D. Coryell in 1947.

SEE WEB LINKS

- Information from the WebElements site

prominence A cloud of hot gas from the sun's chromosphere that rises into the lower corona. Cooler than its surroundings, it forms a bright luminous plume lasting for minutes or even for months, and is best seen at the edge of the sun against the blackness of space. Against the sun's disc it appears as a dark feature and is known as a filament. The plumes may be straight (surge and spray prominences), arched (arch prominences) or form a loop (loop prominences). They often form over sunspots, where they are supported by magnetic fields. *See also* SOLAR FLARE.

promoter **1.** (in chemistry) A substance added to a catalyst to increase its activity. **2.** (in protein synthesis) The region of a DNA molecule that signals the start of transcription. *See* OPERON; PRIBNOW BOX; TATA BOX.

prompt neutrons The neutrons emitted during a nuclear fission process within less than a microsecond of fission. *Compare* DELAYED NEUTRONS.

pronation Rotation of the lower forearm so that the hand faces backwards or downwards with the radius and ulna crossed. *Compare* SUPINATION.

p

proof A measure of the amount of alcohol (ethanol) in drinks. **Proof spirit** contains 49.28% ethanol by weight (about 57% by volume). Degrees of proof express the percentage of proof spirit present, so 70° proof spirit contains $0.7 \times 57\%$ alcohol.

1,2-propadiene (allene) A colourless gas, CH_2CCH_2; r.d. 1.79; m.p. –136°C; b.p. –34.5°C. Propadiene may be prepared from 1,3-dibromopropane ($CH_2BrCHCH_2Br$) by the action of zinc dust. *See also* ALLENES.

propagation **1.** (in botany) *See* VEGETATIVE PROPAGATION. **2.** (in neurophysiology) The process whereby a nerve *impulse travels along the axon of a neuron. *Compare* TRANSMISSION.

propagule Any cellular structure produced by an organism that is capable of dispersing and surviving in the environment before developing into a new individual. Examples are seeds, spores, and cysts.

propanal (propionaldehyde) A colourless liquid *aldehyde, C_2H_5CHO; m.p. –81°C; b.p. 48.8°C.

propane A colourless gaseous hydrocarbon, C_3H_8; m.p. –190°C; b.p. –42°C. It is the third member of the *alkane series and is obtained from petroleum. Its main use is as bottled gas for fuel.

propanedioic acid (malonic acid) A white crystalline dicarboxylic acid, $HOOCCH_2COOH$; m.p. 132°C. It decomposes above its melting point to ethanoic acid. Propanedioic acid is used in the synthesis of other dicarboxylic acids.

propanoic acid (propionic acid) A colourless liquid *carboxylic acid, CH_3CH_2COOH; r.d. 0.99; m.p. –20.8°C; b.p. 141°C. It is used to make calcium propanate – an additive in bread.

propanol Either of two *alcohols with the formula C_3H_7OH. Propan-1-ol is $CH_3CH_2CH_2OH$ and propan-2-ol is $CH_3CH(OH)CH_3$. Both are colourless volatile liquids. Propan-2-ol is used in making propanone (acetone).

propanone (acetone) A colourless flammable volatile compound, CH_3COCH_3; r.d. 0.79; m.p. –95.4°C; b.p. 56.2°C. The simplest *ketone, propanone is miscible with water. It is made by oxidation of propan-2-ol (*see* PROPANOL) or is obtained as a by-product in the manufacture of phenol from cumene; it is used as a solvent and as a raw material for making plastics.

propellant **1.** A substance that burns rapidly in a controlled way, used to propel a projectile (e.g. from a gun). In firearms, gunpowder and cordite are common examples. **2.** A fuel used in a rocket engine. Usually the propellant is a fuel and an oxidizer; for example kerosene or liquid hydrogen with a liquid oxygen propellant. **3.** A substance used to produce the spray in an aerosol can. Aerosol propellants are volatile substances that can be liquefied under pressure and are able to dissolve the working substance. When the pressure is released, the liquid vaporizes, producing the spray. Formerly chlorofluorocarbons were used but their use has been discontinued because of their effect on the ozone layer. Most aerosol cans use liquid hydrocarbon mixtures as the propellant.

propenal (acrolein) A colourless pungent liquid unsaturated aldehyde, $CH_2{:}CHCHO$;

r.d. 0.84; m.p. –87°C; b.p. 53°C. It is made from propene and is used in producing polyester and polyurethane resins.

propene (propylene) A colourless gaseous hydrocarbon, $CH_3CH{:}CH_2$; m.p. –185.25°C; b.p. –47.4°C. It is an *alkene obtained from petroleum by cracking alkanes. Its main use is in the manufacture of polypropene.

propenoate (acrylate) A salt or ester of *propenoic acid.

propenoic acid (acrylic acid) An unsaturated liquid *carboxylic acid, $CH_2{:}CHCOOH$; m.p. 13°C; b.p. 141.6°C. It readily polymerizes and it is used in the manufacture of *acrylic resins.

propenonitrile (acrylonitrile; vinyl cyanide) A colourless liquid, $H_2C{:}CHCN$; r.d. 0.81; m.p. –83.5°C. It is an unsaturated nitrile, made from propene and used to make acrylic resins.

propenyl group (allyl group) The organic group $H_2C{=}CHCH_2{-}$.

proper motion The apparent angular motion of a star on the *celestial sphere, expressed in arcseconds per year. This is motion in a direction that is perpendicular to the line of sight. Proper motion is a combination of the star's own actual movement through space and its apparent changes in position caused by the movements of the sun and the earth.

prophage The DNA of a temperate *bacteriophage following its incorporation into the host bacterium. The process of incorporation of the viral DNA is known as **lysogeny**.

prophase The first stage of cell division, during which chromosomes contract and divide along their length (except for the centromeres) into chromatids. In *mitosis, the chromosomes remain separate from each other. In the first division of *meiosis, homologous chromosomes become paired (*see* PAIRING). By the end of first prophase the two chromosomes begin to move apart.

propionaldehyde *See* PROPANAL.

proplastid *See* PLASTID.

proportional counter A type of detector for *ionizing radiation in which the size of the output pulse is proportional to the number of ions formed in the initial ionizing event. It operates in a voltage region, called the **proportional region**, intermediate between that of an *ionization chamber and a *Geiger counter, avalanche ionization being limited to the immediate vicinity of the primary ionization rather than the entire length of the central wire electrode.

proportional limit *See* ELASTICITY.

proprioceptor Any *receptor that is sensitive to movement, pressure, or stretching within the body. Proprioceptors occurring in muscles, tendons, and ligaments are important for the coordination of muscular activity and the maintenance of balance and posture. *See also* MUSCLE SPINDLE.

prop root Any of the modified roots that arise from the stem of certain plants and provide extra support. Such stems are usually tall and slender and the prop roots develop at successively higher levels as the stem elongates, as in the maize plant. **Buttress roots**, which develop at the base of the trunks of many tropical trees, are similar but tend to have a more flattened appearance. **Stilt roots** are stouter than prop roots. Those formed at the base of the mangrove tree provide firm anchorage in the soft mud of the swamps.

propylene *See* PROPENE.

propyl group The organic group $CH_3CH_2CH_2{-}$.

prosencephalon *See* FOREBRAIN.

prostacyclin *See* PROSTAGLANDIN.

prostaglandin Any of a group of lipid-soluble organic compounds synthesized within cell membranes from arachidonic acid and detected in most body tissues. They cause a range of physiological effects in animals, including the contraction of smooth muscle; natural and synthetic prostaglandins are used to induce abortion or labour in humans and domestic animals. Two prostaglandin derivatives have antagonistic effects on blood circulation: **thromboxane A_2**, released by platelets activated by local tissue damage, promotes blood clotting and causes constriction of blood vessels, while **prostacyclin** inhibits blood clotting by preventing aggregation of platelets and causes blood vessels to dilate. Prostaglandins are also involved in inflammation, being released from macrophages and mast cells. *See also* ASPIRIN.

prostate gland A gland in male mammals that surrounds and opens into the urethra

where it leaves the bladder. During ejaculation it secretes a slightly alkaline fluid into the *semen that activates the sperms and prevents them from sticking together.

prosthetic group A tightly bound non-peptide inorganic or organic component of a protein. Prosthetic groups may be lipids, carbohydrates, metal ions, phosphate groups, etc. Some *coenzymes are more correctly regarded as prosthetic groups.

protactinium Symbol Pa. A radioactive metallic element belonging to the *actinoids; a.n. 91; r.a.m. 231.036; r.d. 15.37 (calculated); m.p. <1600°C (estimated). The most stable isotope, protactinium–231, has a half-life of 3.43×10^4 years; at least ten other radioisotopes are known. Protactinium–231 occurs in all uranium ores as it is derived from uranium–235. Protactinium has no practical applications; it was discovered by Lise Meitner and Otto Hahn in 1917.

SEE WEB LINKS

- Information from the WebElements site

protamine Any of a group of proteins of relatively low molecular weight found in association with the chromosomal *DNA of vertebrate sperm cells. They contain a single polypeptide chain comprising about 67% arginine. Protamines serve in packaging the highly condensed DNA of the germ-cell chromosomes. Protamine sulphate is used therapeutically to treat heparin overdosage.

protandry **1.** The condition in which the male reproductive organs (stamens) of a flower mature before the female ones (carpels), thereby ensuring that self-fertilization does not occur. Examples of protandrous flowers are ivy and rosebay willowherb. *Compare* PROTOGYNY; HOMOGAMY. *See also* DICHOGAMY. **2.** The condition in some hermaphrodite or colonial invertebrates in which the male gonads or individuals are sexually mature before the female ones. *Compare* PROTOGYNY.

protease (peptidase; proteinase; proteolytic enzyme) Any enzyme that catalyses the hydrolysis of proteins into smaller *peptide fractions and amino acids, a process known as **proteolysis**. Examples are *pepsin and *trypsin. Several proteases, acting sequentially, are normally required for the complete digestion of a protein to its constituent amino acids.

protecting group A group used to protect a certain functional group in a chemical synthesis. For example, a hydroxyl group (–OH) can be converted into an acetyl group ($-OOCCH_3$) to protect it taking part in a certain step of the synthesis. In this case, the acetyl is the protecting group. Later it can easily be changed back into the original hydroxyl group.

protein Any of a large group of organic compounds found in all living organisms. Proteins comprise carbon, hydrogen, oxygen, and nitrogen and most also contain sulphur; molecular weights range from six to several thousand *kilodaltons. Protein molecules consist of one or several long chains (*polypeptides) of *amino acids linked in a characteristic sequence. This sequence is called the **primary structure** of the protein. These polypeptides may undergo coiling or pleating, the nature and extent of which is described as the **secondary structure**. The three-dimensional shape of the coiled or pleated polypeptides is called the **tertiary structure**. **Quaternary structure** specifies the structural relationship of the component polypeptides.

Proteins may be globular or fibrous, with various intermediate forms. **Globular proteins** have compact rounded molecules and are usually water-soluble. Of prime importance are the *enzymes, proteins that catalyse biochemical reactions. Other globular proteins include the *antibodies, which combine with foreign substances in the body; the carrier proteins, such as *haemoglobin; the storage proteins (e.g. *casein in milk and *albumin in egg white), and certain hormones (e.g. *insulin). **Fibrous proteins** are generally insoluble in water and consist of long coiled strands or flat sheets, which confer strength and elasticity. In this category are *keratin and *collagen. Actin and myosin are the principal fibrous proteins of muscle, the interaction of which brings about muscle contraction. *Blood clotting involves the fibrous protein called fibrin.

When heated over 50°C or subjected to strong acids or alkalis, proteins lose their specific tertiary structure and may form insoluble coagulates (e.g. egg white). This usually inactivates their biological properties.

SEE WEB LINKS

- Comprehensive survey of protein biochemistry, from the Virtual Library of Biochemistry, Molecular Biology and Cell Biology

protein blotting *See* WESTERN BLOTTING.

protein engineering The techniques used to alter the structure of proteins (especially enzymes) in order to improve their use to humans. This involves artificially modifying the DNA sequences that encode them so that, for example, new amino acids are inserted into existing proteins. Synthesized lengths of novel DNA can be used to produce new proteins by cells or other systems containing the necessary factors for *transcription and *translation. Alternatively, new proteins can be synthesized by **solid state synthesis**, in which polypeptide chains are assembled under the control of chemicals. One end of the chain is anchored to a solid support and the chemicals selectively determine which amino acids are added to the free end. The appropriate chemicals can be renewed during the process; when synthesized, the polypeptide is removed and purified. Protein engineering is used to synthesize enzymes (so-called 'designer enzymes') used in biotechnology. The three-dimensional tertiary structure of proteins is crucially important for their function, and this can be investigated using computer-aided modelling.

protein kinase An enzyme that catalyses the transfer of a phosphate group from ATP to an intracellular protein, thereby affecting the biological activity of the protein (*see* KINASE). Protein kinases phosphorylate specific amino-acid residues of their target proteins, usually either serine, threonine, or tyrosine. They play an important role in increasing or decreasing enzyme activity and in transmitting signals from receptors on the cell surface. The activity of the protein kinases is itself controlled by cyclic AMP, calcium ions, or other intracellular chemicals. It can be reversed by the action of phosphatase enzymes in the cell.

proteinoid A protein-like substance formed by polymerization of amino acids under inorganic conditions, such as heating to over 140°C. In the 1970s it was discovered that proteinoids could also be formed by relatively mild heating (70°C) in the presence of certain inorganic catalysts (e.g. phosphoric acid). In water, proteinoids aggregate to form small round bodies called **proteinoid microspheres**, or 'protocells'. These have certain attributes of living cells, such as a differentially permeable filmlike outer layer, the ability to swell and shrink due to osmotic movements of water, and the capability for budding and binary fission. It has been proposed that such microspheres could have provided a suitable vehicle for the chemical components of life to evolve a primitive form of metabolism and pave the way for the emergence of the first living cells.

protein sequencing The process of determining the amino-acid sequence of a protein or its component polypeptides. The technique most commonly used is Edman degradation (devised by Pehr Edman), in which the terminal amino-acid residues are removed sequentially and identified chromatographically. Each step is automated and the whole process can now be performed by a single machine – the sequenator. Large polypeptides must be cleaved into smaller peptides before sequencing.

The results of this chemical sequencing can often be compared with the amino-acid sequence deduced by *DNA sequencing. The gene coding for the protein under investigation may be found by screening a *DNA library, for example by *Western blotting. However, the base sequence of the gene gives only the amino-acid sequence of the nascent protein, i.e. before post-translational modification. The sequence of the functional protein can only be found by chemical analysis.

protein synthesis The process by which living cells manufacture proteins from their constituent amino acids, in accordance with the genetic information carried in the DNA of the chromosomes. This information is encoded in messenger *RNA, which is transcribed from DNA in the nucleus of the cell (*see* GENETIC CODE; TRANSCRIPTION): the sequence of amino acids in a particular protein is determined by the sequence of nucleotides in messenger RNA. At the ribosomes the information carried by messenger RNA is translated into the sequence of amino acids of the protein in the process of *translation.

proteolysis The enzymic splitting of proteins. *See* PROTEASE.

proteolytic enzyme *See* PROTEASE.

proteome The entire complement of proteins synthesized by a cell or organism at a given time. This can be determined by analysing protein constituents of cell contents using such techniques as gel electrophoresis, high-throughput liquid chromatography, microarrays, and mass spectroscopy, coupled with automated data-

base searching to identify proteins. Unlike the genome, the proteome is constantly changing due to the influence of intracellular and extracellular factors. *See* PROTEOMICS.

proteomics The study of the proteins synthesized by a particular cell or organism (*see* PROTEOME). This vast and rapidly expanding field is of fundamental significance to many areas of biology and medicine. It endeavours to determine what proteins a cell makes, how and when it makes them and in what quantities, how different proteins function, where they function, and how they interact with other cell components, including other proteins. Moreover, proteomics seeks to discover the internal and external factors that influence the proteome, for example during development, disease, or ageing. *See also* TRANSCRIPTOMICS.

Proterozoic The eon of geological time extending from the end of the *Archaean, about 2500 million years ago, to the start of the present eon (*see* PHANEROZOIC), about 542 million years ago. Life in the early Proterozoic was dominated by bacteria, which flourished in shallow seas and muds. They depended on a wide variety of metabolic strategies, including photosynthesis, which were crucial in determining the composition of the earth's atmosphere and oceans. The oldest eukaryotic fossils date from after the middle Proterozoic, about 1200 million years ago. These early protists are thought to have arisen through symbiotic associations of various prokaryotes (*see* ENDOSYMBIONT THEORY), probably on several independent occasions.

prothallus A small flattened multicellular structure that represents the independent *gametophyte generation of clubmosses, horsetails, and ferns. In some of these plants a single prothallus bears both male and female sex organs. In others there are separate male and female prothalli.

prothrombin (Factor II) One of the blood *clotting factors. It is the precursor of the enzyme thrombin, which catalyses the formation of the fibrin matrix of the blood clot. Prothrombin synthesis occurs in the liver and is dependent on adequate supplies of vitamin K. *See also* BLOOD CLOTTING.

protist Any eukaryotic organisms that is unicellular or colonial in form and lacks cellular differentiation into tissues. Protists include algae, simple fungi, and protozoa. The kingdom Protista was originally proposed by Ernst Haeckel in 1866 to include the algae, bacteria, fungi, and protozoa; it was later restricted first to unicellular organisms, and then to protozoa, unicellular algae, and organisms then regarded as simple fungi. Molecular studies have revealed that this kingdom is no longer taxonomically valid, and 'protist' is now purely a descriptive term.

Protoctista A former kingdom consisting of unicellular or simple multicellular organisms that possess nuclei and cannot be classified as animals, plants, or fungi.

protogyny **1.** The condition in which the female reproductive organs (carpels) of a flower mature before the male ones (stamens), thereby ensuring that self-fertilization does not occur. Examples of protogynous flowers are plantain and figwort. *Compare* PROTANDRY; HOMOGAMY. *See also* DICHOGAMY. **2.** The condition in hermaphrodite or colonial invertebrates in which the female gonads or individuals are sexually mature before the male ones. *Compare* PROTANDRY.

proton An *elementary particle that is stable, bears a positive charge equal in magnitude to that of the *electron, and has a mass of $1.672\,614 \times 10^{-27}$ kg, which is 1836.12 times that of the electron. The proton occurs in all atomic nuclei (the hydrogen nucleus consists of a single proton).

proton decay A process of the type

$$p \rightarrow e^+ + \pi^0$$

where a proton decays into a positron and a pion, predicted to occur in *grand unified theories (GUTs) because baryon number is no longer conserved. The lifetime depends on the theory used and is typically 10^{35} years, but a combination of GUTs and *supersymmetry gives a lifetime of about 10^{45} years. Considerable experimental effort has been spent in looking for proton decay, so far with no success.

protonic acid An *acid that forms positive hydrogen ions (or, strictly, oxonium ions) in aqueous solution. The term is used to distinguish 'traditional' acids from Lewis acids or from Lowry–Brønsted acids in nonaqueous solvents.

proton number *See* ATOMIC NUMBER.

proto-oncogene *See* ONCOGENE.

protoplasm The material comprising the living contents of a *cell, i.e. all the substances in a cell except large vacuoles and material recently ingested or to be excreted. The term is no longer used; the material of the cell is now referred to as the *nucleoplasm and the *cytoplasm.

protoplast (energid) The living unit of a cell, consisting of the nucleus and cytoplasm bounded by the plasma membrane. Protoplasts of bacterial and plant cells can be prepared by removing the cell wall; they are used to study the processes involved in cell metabolism and reproduction.

protostar *See* STELLAR EVOLUTION.

Prototheria A subclass of mammals – the monotremes – that lay large yolky eggs. It contains only the duckbilled platypus and the spiny anteater. After hatching, the young feed on milk from simple mammary glands inside a maternal abdominal pouch. In the anteater the eggs are also incubated in this pouch, while the platypus builds an underground nest. Adult monotremes have no true teeth. Their skeleton resembles that of a reptile, and although they are warm-blooded the body temperature is somewhat variable. They are believed to have originated at least 150 million years ago.

protozoa A group of unicellular or acellular, usually microscopic, eukaryotic organisms classified in various phyla. They were formerly regarded either as a phylum of simple animals or as members of the kingdom Protista (*see* PROTIST). They are very widely distributed in marine, freshwater, and moist terrestrial habitats; most protozoans are saprotrophs, but some are parasites, including the agents causing malaria (*Plasmodium*) and sleeping sickness (*Trypanosoma*), and a few contain chlorophyll and carry out photosynthesis, like plants. Protozoan cells may be flexible or rigid, with an outer *pellicle or protective **test**. In some (such as *Paramecium* and *Trypanosoma*) cilia or flagella (*see* UNDULIPODIUM) are present for locomotion; others (such as *Amoeba*) have *pseudopodia for movement and food capture. *Contractile vacuoles occur in freshwater protozoans. Reproduction is usually asexual, by binary *fission, but some protozoans undergo a form of sexual reproduction (*see* CONJUGATION).

Prout's hypothesis The hypothesis put forward by the British chemist William Prout (1785–1850) in 1815 that all atomic weights are integer multiples of the atomic weight of hydrogen and hence that all atoms are made out of hydrogen. Subsequent work on atomic weights in the 19th century showed that this hypothesis is incorrect (with chlorine having an atomic weight of 35.5 being a glaring example of this). The understanding of atomic structure that emerged in the 20th century, with atomic number being the number of protons in an atom and non-integer atomic weights being due to mixtures of isotopes, has vindicated the spirit of Prout's hypothesis.

SEE WEB LINKS

- William Prout's original paper

proventriculus **1.** The anterior part of the stomach of a bird, where digestive enzymes are secreted. Food passes from the proventriculus to the *gizzard. **2.** *See* GASTRIC MILL.

provirus The intermediate stage in the infection of a host cell by a virus, e.g. a *retrovirus, in which the viral genome is integrated into the host cell DNA, where it can undergo successive replications before being transcribed to form new RNA viruses. A provirus, notably that of *HIV, can remain dormant for long periods before being transcribed.

proximal Denoting the part of an organ that is nearest to the organ's point of attachment. For example, the knuckles are at the proximal end of the fingers. *Compare* DISTAL.

proximal convoluted tubule (first convoluted tubule) The section of a *nephron situated between Bowman's capsule and the loop of Henle in the vertebrate kidney. Reabsorption of salt, water, and glucose from the *glomerular filtrate occurs in this tubule; at the same time certain substances, including uric acid and drug metabolites, are actively transferred from the blood capillaries into the tubule. Both activities are facilitated by finger-like projections (*see* BRUSH BORDER) on the inner surface of the tubule, which increase its effective surface area.

prussic acid *See* HYDROGEN CYANIDE.

pseudoaromatic (antiaromatic) A compound that has a ring of atoms containing alternating double and single bonds, yet does not have the characteristic properties of *aromatic compounds. Such compounds do not obey the Hückel rule. Cyclooctatetraene (C_8H_8), for instance, has a ring of eight carbon atoms with conjugated double bonds,

but the ring is not planar and the compound acts like an alkene, undergoing addition reactions. *See also* ANNULENES.

pseudocarp (false fruit) A fruit that incorporates, in addition to the ovary wall, other parts of the flower, such as the *receptacle. For example, the fleshy part of the strawberry is formed from the receptacle and the 'pips' on the surface are the true fruits. *See also* COMPOSITE FRUIT; POME; SOROSIS; SYCONUS.

pseudoephedrine *See* EPHEDRINE.

pseudogene A sequence of nucleotides in DNA that resembles a functional gene but is not transcribed. Pseudogenes are thought to arise by duplication of an existing gene through unequal crossing-over during meiosis, with accompanying loss of the promoter or other flanking regions required for transcription. For example, the α- and β-globin gene clusters in humans contain several pseudogenes.

pseudohalogens A group of compounds, including cyanogen $(CN)_2$ and thiocyanogen $(SCN)_2$, that have some resemblance to the halogens. Thus, they form hydrogen acids (HCN and HSCN) and ionic salts containing such ions as CN^- and SCN^-.

pseudo order An order of a chemical reaction that appears to be less than the true order because of the experimental conditions used. Pseudo orders occur when one reactant is present in large excess. For example, a reaction of substance A undergoing hydrolysis may appear to be proportional only to [A] because the amount of water present is so large.

pseudoparenchyma A tissue that superficially resembles plant parenchyma but is made up of an interwoven mass of hyphae (in fungi) or filaments (in algae). Examples of pseudoparenchymatous structures are the fruiting bodies (mushrooms, toadstools, etc.) of certain fungi and the thalli of certain red and brown algae.

pseudopodium A temporary outgrowth of the cell of some protozoans (e.g. *Amoeba*), which serves as a feeding and locomotory organ. Pseudopodia may be blunt or threadlike, form a branching network, or be stiffened with an internal supporting rod. Phagocytic white blood cells also form pseudopodia to engulf invading bacteria.

pseudopregnancy A state resembling pregnancy that may occur in some mammals (e.g. rabbits and rodents) in which many of the phenomena of pregnancy are present but there is no fetus developing in the uterus. It is caused by an extended dioestrus (*see* OESTROUS CYCLE) in the absence of fertilization.

pseudo-scalar A *scalar quantity that changes sign when the coordinate system is changed to a new system by a reflection in the origin (i.e. $x'_i = -x_i$). It is the *scalar product of an *axial vector and a *polar vector.

pseudo-vector *See* AXIAL VECTOR.

psilocin *See* PSILOCYBIN.

psilocybin A hallucinogen, similar in effect to *mescaline, found in certain species of mushroom. It is accompanied by a related, more active, compound **psilocin**. Both are classified as class A drugs in the UK. They can be detected by the Marquis test or the Froehde test.

psi particle (J particle) A *meson discovered in 1974, which led to the extension of the quark model and the hypothesis that a fourth quark existed with the property of charm (*see* ELEMENTARY PARTICLES). The psi particle is believed to consist of a charmed quark and its antiquark.

psychrometer *See* HYGROMETER.

Pteridophyta In traditional classification systems, a division of the plant kingdom that included ferns, horsetails, and clubmosses, i.e. the nonseed-bearing tracheophytes. These are now classified as separate phyla: *Filicinophyta (ferns), *Sphenophyta (horsetails), and *Lycophyta (clubmosses).

Pteridospermales *See* CYCADOFILICALES.

pterodactyls *See* PTEROSAURIA.

Pterophyta *See* FILICINOPHYTA.

Pteropsida In older classifications, a subdivision of tracheophytes that contained the ferns and seed plants, or a class of the *Pteridophyta containing only the ferns.

Pterosauria An extinct order of flying reptiles – the pterodactyls – that lived in the late Triassic, Jurassic, and Cretaceous periods (220–70 million years ago). Pterodactyls had beaked jaws and an elongated fourth finger that supported a membranous wing. They had long jointed tails, no feathers, and could probably only fly by soaring.

PTFE *See* POLYTETRAFLUOROETHENE.

PTH *See* PARATHYROID HORMONE.

Ptolemaic astronomy The system of astronomy embodied in the model of a *geocentric universe developed by the Alexandrian astronomer Claudius Ptolemaeus (Ptolemy) (100–178 AD). His model, the **Ptolemaic system** was a refinement of those developed by Plato, Aristotle, and especially the 3rd-century BC mathematician Apollonius of Perga. In Ptolemaic astronomy, the spherical earth was at rest, lying at the centre of a universe made up of a series of concentric spheres; the sun, the moon, and each of the five known planets moved round the earth in a circular orbit within its own sphere, on a path called the **deferent**. In addition to this motion the orbiting bodies also described **epicycles**, small circles about points on the deferent. Ptolemy published his system together with a star catalogue and mathematical treatise that owed much to the work of the ancient Greek astronomer Hipparchus. It is best known in an Arabic translation, the *Almagest*, or 'Great Book'. The system gave moderately good predictions of phenomena and planetary positions, and won the support of the Christian and Islamic religious authorities because it emphasized circles and uniform perpetual motion, which were symbols of divine perfection and unchanging eternity, and placed the earth and humanity at the very heart of God's creation. For 1600 years the Ptolemaic system remained the accepted model of the universe but in the 17th century it was completely replaced by the model of a heliocentric universe and *Copernican astronomy.

ptyalin An enzyme that digests carbohydrates (*see* AMYLASE). It is present in mammalian *saliva and is responsible for the initial stages of starch digestion.

***p*-type conductivity** *See* SEMICONDUCTOR; TRANSISTOR.

puberty *See* ADOLESCENCE.

pubis One of the three bones that make up each half of the *pelvic girdle. It is the most anterior of the three pelvic bones. In mammals and many reptiles the pubes are united at a slightly movable joint, the **pubic symphysis**. *See also* ILIUM; ISCHIUM.

public key certificate *See* CERTIFICATE.

public key encryption (asymmetric encryption) In computing, a type of cryptography where one of a pair of keys is used to encrypt a message and the other is used to decrypt it. It does not matter which key is used to encrypt and which to decrypt: both combinations will work; however, attempting to encrypt and decrypt with the same key will not work. The two keys are integers that are related mathematically, but – crucially – it must not be viable to deduce the other key if only one is known. In computational terms this means that it must be proven that there does not exist an algorithm to calculate the second key efficiently from the first, and that the range of possible integers must be large enough to make a 'brute force' attack impractical.

In usage, a given key pair belongs to a specific person or organization. One key of the pair, the **public key**, can be distributed freely; the other, the **private key**, must be kept secret by the owner. The keys can then be used in one of two ways:

(1) Anybody wishing to send confidential data encrypts it with the recipient's public key. It can then only be decrypted by the recipient's private key, which only the recipient possesses.

(2) Anybody wishing to add a digital signature to data encrypts the signature with their private key. If the signature is valid when decrypted with the signer's public key, a user can be confident that the data indeed originated with the signer and has not been altered (*see also* CERTIFICATE).

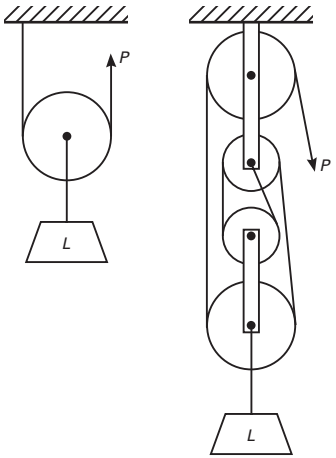
PubMed *See* MEDLINE.

pulley A simple machine consisting of a wheel with a flat, crowned, or grooved rim to take a belt, rope, or chain with which a load can be raised (see illustration overleaf).

In fig (a), assuming the system is frictionless, the force P in any part of the rope is constant, therefore $2P = L$, where L is the load. In general, $nP = L$, where n is the number of supporting ropes. In fig (b), the number of supporting ropes is 4. The mechanical advantage of a pulley system is the ratio of the load, L, to the effort applied to the free end of the rope, P, i.e. mechanical advantage $= L/P = L(L/n)^{-1} = n$. Thus in fig (b) the mechanical advantage is 4. A combination of ropes and pulleys as in fig (b) is called a **block and tackle**.

pulmonary Of or relating to the lungs.

pulmonary artery The artery that conveys deoxygenated blood from the right ven-



Pulleys.

tricle of the heart to the lungs, where it receives oxygen.

pulmonary circulation The part of the circulatory system of birds and mammals that transports deoxygenated blood from the right side of the heart to the lungs and returns oxygenated blood to the left side of the heart. *Compare* SYSTEMIC CIRCULATION. *See* DOUBLE CIRCULATION.

pulmonary vein The vein that conveys oxygenated blood from the lungs to the left atrium of the heart.

pulp cavity The central region of a tooth, which is connected by a narrow channel at the tip of the root with the surrounding tissues. The pulp cavity contains the **pulp** – connective tissue in which blood vessels and nerve fibres are embedded, and it is lined with *odontoblasts, which produce the *dentine.

pulsar A celestial source of radiation emitted in brief (0.03 second to 4 seconds) regular pulses. First discovered in 1967, pulsars are believed to be rotating *neutron stars. The strong magnetic field of the neutron star concentrates charged particles in two regions and the radiation is emitted in two directional beams. The pulsing effect occurs as the beams rotate, periodically pointing in the direction of the earth. Most pulsars are radio sources (emit electromagnetic radiation of radio frequencies) but a few that emit light or X-rays have been detected. Over 300 pulsars are now known in our Galaxy.

pulsatance *See* ANGULAR FREQUENCY.

pulse **1.** (in physics) **a.** A brief variation in a quantity, usually for a finite time, especially in a quantity that is normally constant. **b.** A series of such variations having a regular waveform in which the variable quantity rises sharply from a base value to a maximum value and then falls back to the base value in a relatively short time. **2.** (in physiology) A series of waves of dilation that pass along the arteries, caused by pressure of blood pumped from the heart through contractions of the left ventricle. In humans it can be felt easily where arteries pass close to the skin surface, e.g. at the wrist.

pulse jet A type of ramjet (*see* JET PROPULSION) in which a louvred valve at the front of the projectile is blown open by the ram effect of the moving projectile and remains open until pressure has built up in the combustion chamber. Fuel is then admitted and the mixture exploded by spark ignition. This closes the louvred valve and produces thrust at the open rear end of the projectile. The German flying bombs of World War II were powered by pulse jets.

pulse modulation *See* MODULATION.

pulvinus A group of cells at the base of a leaf or leaflet in certain plants that, by rapidly losing water, brings about changes in the position of the leaves. In the sensitive plant (*Mimosa pudica*), the pulvinus is responsible for the folding of the leaves that occurs at nightfall or when the plant is touched or injured.

pumice A porous volcanic rock that is light and full of cavities due to expanding gases that were liberated from solution in *lava while it solidified. Pumice is often light enough to float on water. It is usually acid (siliceous) in composition, and is used as an abrasive and for polishing.

pump A device that imparts energy to a fluid in order to move it from one place or level to another or to raise its pressure (*compare* VACUUM PUMP). **Centrifugal pumps** and *turbines have rotating impellers, which increase the velocity of the fluid, part of the energy so acquired by the fluid then being converted to pressure energy. Displacement

pumps act directly on the fluid, forcing it to flow against a pressure. They include piston, plunger, gear, screw, and cam pumps. *See also* ELECTROMAGNETIC PUMP.

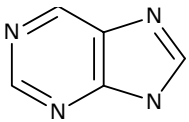
punctuated equilibrium A controversial hypothesis, published in 1972 by N. Eldredge and Stephen J. Gould, proposing that in evolutionary history the development of new species occurs very rapidly in short bursts (lasting typically less than 100 000 years), which are separated by long periods in which little evolutionary change occurs. This hypothesis, which contradicted the orthodox Darwinian view of evolution as a gradual and continuous process, was based on studies of various fossil lineages (e.g. ammonite molluscs) in which forms intermediate between species are absent. Subsequent scrutiny of the evidence supports a pattern of punctuated equilibrium for some, but not all, lineages, so it cannot be regarded as universal. For example, the rodent lineage shows as much morphological change between speciation events as during speciation.

pupa The third stage of development in the life cycle of some insects. During the pupal stage locomotion and feeding cease and *metamorphosis from the larva to the adult form takes place. There are three types of pupa. The commonest is the **exarate** or free pupa, in which the wings and other appendages are visible and movable. In the **obtect** type the wings are stuck to the body and immovable, as in the **chrysalis** of a butterfly or moth; and in the **co-arctate** type an exarate pupa develops within a hard barrel-shaped **puparium**, as in the housefly and other Diptera.

pupil *See* IRIS.

pure line A population of plants or animals all having a particular feature that has been retained unchanged through many generations. The organisms are *homozygous and are said to 'breed true' for the feature concerned.

purine An organic nitrogenous base (see formula), sparingly soluble in water, that gives rise to a group of biologically important derivatives, notably *adenine and *guanine, which occur in *nucleotides and nucleic acids (DNA and RNA).



Purine.

Purkyne fibres (Purkinje fibres) Modified fibres in the mammalian heart that originate in the *bundle of His and spread out in a network over the ventricles. Action potentials generated in the sinoatrial node (the *pacemaker of the heart) are conducted extremely rapidly through the ventricles, due to the extensive branching of the Purkyne fibres, causing both ventricles to contract almost simultaneously. They are named after the Czech physiologist Johannes Purkyne (1787–1869).

putrefaction The microbial decomposition of organic matter, especially the anaerobic breakdown of proteinaceous material with the production of foul-smelling amines.

PVA *See* POLYVINYLACETATE.

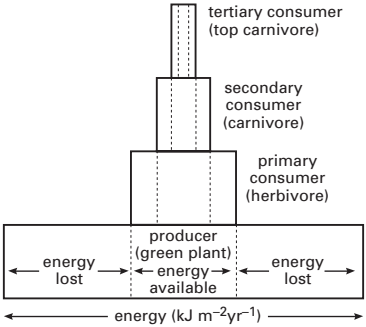
PVC *See* POLYCHLOROETHENE.

pyloric sphincter *See* SPHINCTER; STOMACH.

pyramid A solid having a polygonal base with n sides, each side forming the base of a triangle. The n triangles so formed have a common vertex. The **axis** of the pyramid is a line joining the vertex to the centre of symmetry of the base. If the axis is perpendicular to the base the solid is a **right pyramid**. A **square pyramid** has a square base and a **triangular pyramid** has a triangular base (*see* TETRAHEDRON). The volume of a pyramid is one third of the base area multiplied by the height.

pyramid of biomass A diagrammatic representation of the amount of organic material (*see* BIOMASS), measured in grams of dry mass per square metre (g m^{-2}), found in a particular habitat at ascending *trophic levels of a *food chain. Biomass decreases at each ascending level of the food chain. A pyramid of biomass is a more accurate representation of the flow of energy through a food chain than a *pyramid of numbers, but seasonal variations in the rate of turnover of the organisms at a particular level may result in higher or lower values for the amount of biomass sampled at a particular time than the average amount over the whole year. The best representation of energy flow in a food chain is a *pyramid of energy.

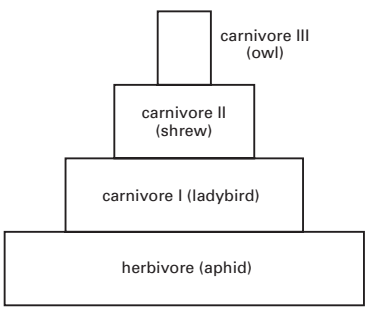
pyramid of energy A diagrammatic representation of the amount of energy, meas-



Pyramid of energy.

ured in kilojoules per square metre per year (kJ m^{-2} yr^{-1}), available at ascending *trophic levels of a *food chain in a particular habitat. A pyramid of energy is the most accurate representation of the *energy flow through a food chain as it indicates how much energy is lost at each trophic level (through respiration, etc.). *Compare* PYRAMID OF BIOMASS; PYRAMID OF NUMBERS.

pyramid of numbers A diagramatic representation of the numbers of animals found in an area at ascending *trophic levels of a *food chain (e.g. a woodland food chain: see illustration). Because only a small proportion of the energy taken in by an organism is converted to tissue and is thus available to consumers at the next trophic level, the number of organisms that can be supported at each level is generally much less than the number at the level that supplies its food (i.e. the level below). *See also* PYRAMID OF BIOMASS; PYRAMID OF ENERGY.



Pyramid of numbers.

pyran A heterocyclic compound having an oxygen atom and two double bonds in a six-membered ring, C_5H_6O. There are two isomers depending on the position of the CH_2 group.

pyranose A *sugar having a six-membered ring containing five carbon atoms and one oxygen atom.

pyrazine An unsaturated heterocyclic compound having two nitrogen atoms in a six-membered ring, $C_4H_4N_2$; r.d. 1.03; m.p. 52°C; b.p. 115°C. Pyrazine is a symmetric diazine.

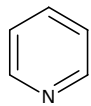
pyrazole An unsaturated heterocyclic compound having two nitrogen atoms in a five-membered ring, $C_3H_4N_2$; m.p. 66–70°C; b.p. 168–188°C. Pyrazine is a symmetric diazine.

pyrenocarp *See* DRUPE.

pyrenoid A spherical protein body found in the *chloroplasts of many algae. Pyrenoids are associated with the storage of starch: layers of starch are often found around them.

pyrethrum **1.** Any of several plants of the genus *Chrysanthemum* that contain natural insecticidal compounds (**pyrethrins**). Various synthetic insecticides – the **pyrethroids** – are chemically similar to pyrethrins. Examples include permethrin. The pyrethrins penetrate the insect's cuticle and are fast-acting, nontoxic to many animals and to plants, and readily biodegradable. **2.** An insecticidal preparation containing natural pyrethrins.

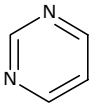
pyridine A colourless liquid with a strong unpleasant smell, C_5H_5N (see formula); r.d. 0.98; m.p. –42°C; b.p. 115°C. Pyridine is an aromatic heterocyclic compound present in coal tar. It is used in making other organic chemicals.



Pyridine.

pyridoxine *See* VITAMIN B COMPLEX.

pyrimidine An organic nitrogenous base (see formula), sparingly soluble in water, that gives rise to a group of biologically important derivatives, notably *uracil,



Pyrimidine.

*thymine, and *cytosine, which occur in *nucleotides and nucleic acids (DNA and RNA).

pyrite (iron pyrites) A mineral form of iron(II) sulphide, FeS_2. Superficially it resembles gold in appearance, hence it is also known as **fool's gold**, but it is harder and more brittle than gold (which may be cut with a knife). Pyrite crystallizes in the cubic system, is brass yellow in colour, has a metallic lustre, and a hardness of 6–6.5 on the Mohs' scale. It is the most common and widespread of the sulphide minerals and is used as a source of sulphur for the production of sulphuric acid. Sources include the Rio Tinto mines in Spain.

pyro- Prefix denoting an oxo acid that could be obtained from a lower acid by dehydration of two molecules. For example, pyrosulphuric acid is $H_2S_2O_7$ (i.e. $2H_2SO_4$ minus H_2O).

pyroboric acid *See* BORIC ACID.

pyroelectricity The property of certain crystals, such as tourmaline, of acquiring opposite electrical charges on opposite faces when heated. In tourmaline a rise in temperature of 1 K at room temperature produces a polarization of some 10^{-5} C m^{-2}.

pyrogallol 1,2,3-trihydroxybenzene, $C_6H_3(OH)_3$, a white crystalline solid, m.p. 132°C. Alkaline solutions turn dark brown on exposure to air through reaction with oxygen. It is a powerful reducing agent, employed in photographic developers. It is also used in volumetric gas analysis as an absorber of oxygen.

pyrolusite A soft black mineral consisting mainly of manganese dioxide (MnO_2); it is the most important ore of manganese. It is generally found as a secondary deposit of masses of fibrous or needle-shaped crystals. As well as an ore, it is used as a decolourizer and oxidizing agent.

pyrolysis Chemical decomposition occurring as a result of high temperature.

pyrometric cones *See* SEGER CONES.

pyrometry The measurement of high temperatures from the amount of radiation emitted, using a **pyrometer**. Modern **narrow-band** or **spectral** pyrometers use infrared-sensitive *photoelectric cells behind filters that exclude visible light. In the **optical pyrometer** (or disappearing filament pyrometer) the image of the incandescent source is focused in the plane of a tungsten filament that is heated electrically. A variable resistor is used to adjust the current through the filament until it blends into the image of the source, when viewed through a red filter and an eyepiece. The temperature is then read from a calibrated ammeter or a calibrated dial on the variable resistor. In the **total-radiation pyrometer** radiation emitted by the source is focused by a concave mirror onto a blackened foil to which a thermopile is attached. From the e.m.f. produced by the thermopile the temperature of the source can be calculated.

pyrophoric Igniting spontaneously in air. **Pyrophoric alloys** are alloys that give sparks when struck. *See* MISCH METAL.

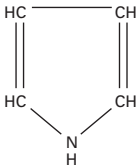
pyrophosphoric acid *See* PHOSPHORIC(V) ACID.

pyrosilicate *See* SILICATE.

pyrosulphuric acid *See* DISULPHURIC(VI) ACID.

pyroxenes A group of ferromagnesian rock-forming silicate minerals. They are common in basic igneous rocks but may also be developed by metamorphic processes in gneisses, schists, and marbles. Pyroxenes have a complex crystal chemistry; they are composed of continuous chains of silicon and oxygen atoms linked by a variety of other elements. They are related to the *amphiboles, from which they differ in cleavage angles. The general formula is $X_{1-p}Y_{1+p}Z_2O_6$, where X = Ca,Na; Y = Mg,Fe^{2+},Mn,Li,Al,Fe^{3+},Ti; and Z = Si,Al.

Orthorhombic pyroxenes (**orthopyroxenes**), $(Mg,Fe)_2Si_2O_6$, vary in composition between the end-members enstatite ($Mg_2Si_2O_6$) and orthoferrosilite ($Fe_2Si_2O_6$). Monoclinic pyroxenes (**clinopyroxenes**), the larger group, include:
diopside, $CaMgSi_2O_6$;
hedenbergite, $CaFe^{2+}Si_2O_6$;
johannsenite, $CaMnSi_2O_6$;
augite, $(Ca,Mg,Fe,Ti,Al)_2(Si,Al)_2O_6$;
aegirine, $NaFe^{3+}Si_2O_6$;
jadeite (*see* JADE);
pigeonite $(Mg,Fe^{2+},Ca)(Mg,Fe^{2+})Si_2O_6$.



Pyrrole.

pyrrole An organic nitrogen-containing compound (see formula) that forms part of the structure of *porphyrins.

pyrrolidine A saturated heterocyclic compound having one nitrogen atom in a five-membered ring, C_4H_9N; r.d. 0.87; m.p. –63°C b.p. 87°C. It is found in certain plants and the ring structure is present in many alkaloids.

pyruvic acid (2-oxopropanoic acid) A colourless liquid organic acid, $CH_3COCOOH$. Pyruvate is an important intermediate compound in metabolism, being produced during *glycolysis and converted to acetyl coenzyme A, required for the *Krebs cycle. Under anaerobic conditions pyruvate is converted to lactate or ethanol.

Pythagoras of Samos (*c.* 580–*c.* 500 BC) Greek philosopher and mathematician, who in about 520 BC went to Croton in Italy, where he founded an academy at which numbers and their mystical significance were studied. Pythagoras discovered *irrational numbers and the celebrated *Pythagoras' theorem.

Pythagoras' theorem For a right-angled triangle of lengths h (where h is the hypotenuse, the side opposite the right angle), a, and b (where a and b are the other two sides), the relationship

$h^2 = a^2 + b^2$.