C

C A high-level general-purpose computer language developed in 1972. It is fast and can be used as an alternative to assembly language, with which it shares some features. It was superseded in the mid-1980s by an object-oriented version known as C++, which is better suited to the design of modular programs.

SEE WEB LINKS

- The current C standard

cadmium Symbol Cd. A soft bluish metal belonging to *group 12 (formerly IIB) of the periodic table; a.n. 48; r.a.m. 112.41; r.d. 8.65; m.p. 320.9°C; b.p. 765°C. The element's name is derived from the ancient name for calamine, zinc carbonate $ZnCO_3$, and it is usually found associated with zinc ores, such as sphalerite (ZnS), but does occur as the mineral greenockite (CdS). Cadmium is usually produced as an associate product when zinc, copper, and lead ores are reduced. Cadmium is used in low-melting-point alloys to make solders, in Ni–Cd batteries, in bearing alloys, and in electroplating (over 50%). Cadmium compounds are used as phosphorescent coatings in TV tubes. Cadmium and its compounds are extremely toxic at low concentrations; great care is essential where solders are used or where fumes are emitted. It has similar chemical properties to zinc but shows a greater tendency towards complex formation. The element was discovered in 1817 by F. Stromeyer.

SEE WEB LINKS

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cadmium cell *See* WESTON CELL.

cadmium sulphide A water-insoluble compound, CdS; r.d. 4.82. It occurs naturally as the mineral **greenockite** and is used as a pigment and in semiconductors and fluorescent materials.

caecum A pouch in the alimentary canal of vertebrates between the *small intestine and *colon. The caecum (and its *appendix) is large and highly developed in herbivorous animals (e.g. rabbits and cows), in which it contains a large population of bacteria essential for the breakdown of cellulose. In humans the caecum is a *vestigial organ and is poorly developed.

caesium Symbol Cs. A soft silvery-white metallic element belonging to *group 1 (formerly IA) of the periodic table; a.n. 55; r.a.m. 132.905; r.d. 1.88; m.p. 28.4°C; b.p. 678°C. It occurs in small amounts in a number of minerals, the main source being carnallite ($KCl.MgCl_2.6H_2O$). It is obtained by electrolysis of molten caesium cyanide. The natural isotope is caesium–133. There are 15 other radioactive isotopes. Caesium–137 (half-life 33 years) is used as a gamma source. As the heaviest alkali metal, caesium has the lowest ionization potential of all elements, hence its use in photoelectric cells, etc.

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- Information from the WebElements site

caesium chloride structure A type of ionic crystal structure in which the anions are at the eight corners of a cubic unit cell with one cation at the centre of the cell. It can equivalently by described as cations at the corners of the cell with an anion at the centre. Each type of ion has a coordination number of 8. Examples of compounds with this structure are CsCl, CsBr, CsI, CsCN, CuZn, and NH_4Cl.

caesium clock An *atomic clock that depends on the energy difference between two states of the caesium–133 nucleus when it is in a magnetic field. In one type, atoms of caesium–133 are irradiated with *radio-frequency radiation, whose frequency is chosen to correspond to the energy difference between the two states. Some caesium nuclei absorb this radiation and are excited to the higher state. These atoms are deflected by a further magnetic field, which causes them to hit a detector. A signal from this detector is fed back to the radio-frequency oscillator to prevent it drifting from the resonant frequency of 9 192 631 770 hertz. In this way the device is locked to this frequency with an accuracy better than 1 part in 10^{13}.

The caesium clock is used in the *SI unit definition of the second.

caffeine (1,3,7-trimethylxanthine) An alkaloid, $C_8H_{10}N_4O_2$; m.p. 235°C; sublimes at 176°C. It is a stimulant and diuretic and is present in coffee, tea, and some soft drinks. *See* METHYLXANTHINES.

cage compound *See* CLATHRATE.

Cainozoic *See* CENOZOIC.

calciferol *See* VITAMIN D.

calcination The formation of a calcium carbonate deposit from hard water. *See* HARDNESS OF WATER.

calcinite A mineral form of *potassium hydrogencarbonate, $KHCO_3$.

calcite One of the most common and widespread minerals, consisting of crystalline calcium carbonate, $CaCO_3$. Calcite crystallizes in the rhombohedral system; it is usually colourless or white and has a hardness of 3 on the Mohs' scale. It has the property of double refraction, which is apparent in Iceland spar – the transparent variety of calcite. It is an important rock-forming mineral and is a major constituent in limestones, marbles, and carbonatites.

calcitonin (thyrocalcitonin) A peptide hormone in vertebrates that lowers the concentration of calcium (and phosphate) in the blood. It operates in opposition to *parathyroid hormone. Calcitonin is produced by the *C cells, which in mammals are located in the *thyroid gland.

calcitriol *See* VITAMIN D.

calcium Symbol Ca. A soft grey metallic element belonging to *group 2 (formerly IIA) of the periodic table; a.n. 20; r.a.m. 40.08; r.d. 1.54; m.p. 839°C; b.p. 1484°C. Calcium compounds are common in the earth's crust; e.g. limestone and marble ($CaCO_3$), gypsum ($CaSO_4.2H_2O$), and fluorite (CaF_2). The element is extracted by electrolysis of fused calcium chloride and is used as a getter in vacuum systems and a deoxidizer in producing nonferrous alloys. It is also used as a reducing agent in the extraction of such metals as thorium, zirconium, and uranium.

Calcium is an *essential element for living organisms, being required for normal growth and development. In animals it is an important constituent of bones and teeth and is present in the blood, being required for muscle contraction and other metabolic processes. In plants it is a constituent (in the form of calcium pectate) of the *middle lamella.

SEE WEB LINKS

- Information from the WebElements site

calcium acetylide *See* CALCIUM DICARBIDE.

calcium bicarbonate *See* CALCIUM HYDROGENCARBONATE.

calcium carbide *See* CALCIUM DICARBIDE.

calcium carbonate A white solid, $CaCO_3$, which is only sparingly soluble in water. Calcium carbonate decomposes on heating to give *calcium oxide (quicklime) and carbon dioxide. It occurs naturally as the minerals *calcite (rhombohedral; r.d. 2.71) and *aragonite (rhombic; r.d. 2.93). Rocks containing calcium carbonate dissolve slowly in acidified rainwater (containing dissolved CO_2) to cause temporary hardness. In the laboratory, calcium carbonate is precipitated from *limewater by carbon dioxide. Calcium carbonate is used in making lime (calcium oxide) and is the main raw material for the *Solvay process.

calcium chloride A white deliquescent compound, $CaCl_2$, which is soluble in water; r.d. 2.15; m.p. 782°C; b.p. >1600°C. There are a number of hydrated forms, including the monohydrate, $CaCl_2.H_2O$, the dihydrate, $CaCl_2.2H_2O$ (r.d. 0.84), and the hexahydrate, $CaCl_2.6H_2O$ (trigonal; r.d. 1.71; the hexahydrate loses $4H_2O$ at 30°C and the remaining $2H_2O$ at 200°C). Large quantities of it are formed as a byproduct of the *Solvay process and it can be prepared by dissolving calcium carbonate or calcium oxide in hydrochloric acid. Crystals of the anhydrous salt can only be obtained if the hydrated salt is heated in a stream of hydrogen chloride. Solid calcium chloride is used in mines and on roads to reduce dust problems, whilst the molten salt is the electrolyte in the extraction of calcium. An aqueous solution of calcium chloride is used in refrigeration plants.

calcium cyanamide A colourless solid, $CaCN_2$, which sublimes at 1300°C. It is prepared by heating calcium dicarbide at 800°C in a stream of nitrogen:

$$CaC_2(s) + N_2(g) \rightarrow CaCN_2(s) + C(s)$$

The reaction has been used as a method of fixing nitrogen in countries in which cheap electricity is available to make the calcium dicarbide (the **cyanamide process**). Calcium

cyanamide can be used as a fertilizer because it reacts with water to give ammonia and calcium carbonate:

$$CaCN_2(s) + 3H_2O(l) \rightarrow CaCO_3(s) + 2NH_3(g)$$

It is also used in the production of melamine, urea, and certain cyanide salts.

calcium dicarbide (calcium acetylide; calcium carbide; carbide) A colourless solid compound, CaC_2; tetragonal; r.d. 2.22; m.p. 450°C; b.p. 2300°C. In countries in which electricity is cheap it is manufactured by heating calcium oxide with either coke or ethyne at temperatures above 2000°C in an electric arc furnace. The crystals consist of Ca^{2+} and C_2^- ions arranged in a similar way to the ions in sodium chloride. When water is added to calcium dicarbide, the important organic raw material ethyne (acetylene) is produced:

$$CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + C_2H_2(g)$$

calcium fluoride A white crystalline solid, CaF_2; r.d. 3.2; m.p. 1423°C; b.p. 2500°C. It occurs naturally as the mineral *fluorite (or fluorspar) and is the main source of fluorine. The **calcium fluoride structure** (**fluorite structure**) is a crystal structure in which the calcium ions are each surrounded by eight fluoride ions arranged at the corners of a cube. Each fluoride ion is surrounded by four calcium ions at the corners of a tetrahedron.

calcium hydrogencarbonate (calcium bicarbonate) A compound, $Ca(HCO_3)_2$, that is stable only in solution and is formed when water containing carbon dioxide dissolves calcium carbonate:

$$CaCO_3(s) + H_2O(l) + CO_2(g) \rightarrow Ca(HCO_3)_2(aq)$$

It is the cause of temporary *hardness of water, because the calcium ions react with soap to give scum. Calcium hydrogencarbonate is unstable when heated and decomposes to give solid calcium carbonate. This explains why temporary hardness is removed by boiling and the formation of 'scale' in kettles and boilers.

calcium hydroxide (slaked lime) A white solid, $Ca(OH)_2$, which dissolves sparingly in water (*see* LIMEWATER); hexagonal; r.d. 2.24. It is manufactured by adding water to calcium oxide, a process that evolves much heat and is known as slaking. It is used as a cheap alkali to neutralize the acidity in certain soils and in the manufacture of mortar, whitewash, bleaching powder, and glass.

calcium nitrate A white deliquescent compound, $Ca(NO_3)_2$, that is very soluble in water; cubic; r.d. 2.50; m.p. 561°C. It can be prepared by neutralizing nitric acid with calcium carbonate and crystallizing it from solution as the tetrahydrate $Ca(NO_3)_2.4H_2O$, which exists in two monoclinic crystalline forms (α, r.d. 1.9; β, r.d. 1.82). There is also a trihydrate, $Ca(NO_3)_2.3H_2O$. The anhydrous salt can be obtained from the hydrate by heating but it decomposes on strong heating to give the oxide, nitrogen dioxide, and oxygen. Calcium nitrate is sometimes used as a nitrogenous fertilizer.

calcium octadecanoate (calcium stearate) An insoluble white salt, $Ca(CH_3(CH_2)_{16}COO)_2$, which is formed when soap is mixed with water containing calcium ions and is the scum produced in hard-water regions.

calcium oxide (quicklime) A white solid compound, CaO, formed by heating calcium in oxygen or by the thermal decomposition of calcium carbonate; cubic; r.d. 3.35; m.p. 2580°C; b.p. 2850°C. On a large scale, calcium carbonate in the form of limestone is heated in a tall tower (lime kiln) to a temperature above 550°C:

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

Although the reaction is reversible, the carbon dioxide is carried away by the upward current through the kiln and all the limestone decomposes. Calcium oxide is used to make calcium hydroxide, as a cheap alkali for treating acid soil, and in extractive metallurgy to produce a slag with the impurities (especially sand) present in metal ores.

calcium phosphate(V) A white insoluble powder, $Ca_3(PO_4)_2$; r.d. 3.14. It is found naturally in the mineral *apatite, $Ca_5(PO_4)_3(OH,F,Cl)$, and as rock phosphate. It is also the main constituent of animal bones. Calcium phosphate can be prepared by mixing solutions containing calcium ions and hydrogenphosphate ions in the presence of an alkali:

$$HPO_4^{2-} + OH^- \rightarrow PO_4^{3-} + H_2O$$

$$3Ca^{2+} + 2PO_4^{3-} \rightarrow Ca_3(PO_4)_2$$

It is used extensively as a fertilizer. The compound was formerly called **calcium orthophosphate** (*see* PHOSPHATES).

calcium stearate *See* CALCIUM OCTADECANOATE.

calcium sulphate A white solid compound, $CaSO_4$; r.d. 2.96; 1450°C. It occurs naturally as the mineral *anhydrite, which has a rhombic structure, transforming to a monoclinic form at 200°C. More commonly, it is found as the dihydrate, *gypsum, $CaSO_4.2H_2O$ (monoclinic; r.d. 2.32). When heated, gypsum loses water at 128°C to give the hemihydrate, $2CaSO_4.H_2O$, better known as *plaster of Paris. Calcium sulphate is sparingly soluble in water and is a cause of permanent *hardness of water. It is used in the manufacture of certain paints, ceramics, and paper. The naturally occurring forms are used in the manufacture of sulphuric acid.

calculus A series of mathematical techniques developed independently by Isaac Newton and Gottfried Leibniz (1646–1716). **Differential calculus** treats a continuously varying quantity as if it consisted of an infinitely large number of infinitely small changes. For example, the velocity v of a body at a particular instant can be regarded as the infinitesimal distance, written ds, that it travels in the vanishingly small time interval, dt; the instantaneous velocity v is then ds/dt, which is called the **derivative** of s with respect to t. If s is a known function of t, v at any instant can be calculated by the process of *differentiation. The differential calculus is a powerful technique for solving many problems concerned with rate processes, maxima and minima, and similar problems.

Integral calculus is the opposite technique. For example, if the velocity of a body is a known function of time, the infinitesimal distance ds travelled in the brief instant dt is given by d$s = v$dt. The measurable distance s travelled between two instants t_1 and t_2 can then be found by a process of summation, called *integration, i.e.

$$s = \int_{t_2}^{t_1} v\,\mathrm{d}t$$

The technique is used for finding areas and volumes and other problems involving the summation of infinitesimals.

caldera A crater or large depression at the top of an inactive shield *volcano, which may be 1–20 km in diameter. It forms when magma subsides from the summit, sometimes aided by the explosive ejection of material. Often a caldera fills with water, forming a crater lake. Large calderas appear to be characteristic features of the landscapes of Mars and Venus.

Calgon Trade name for a water-softening agent. *See* HARDNESS OF WATER.

caliche A mixture of salts found in deposits between gravel beds in the Atacama and Tarapaca regions of Chile. They vary from 4 m to 15 cm thick and were formed by periodic leaching of soluble salts during wet geological epochs, followed by drying out of inland seas in dry periods. They are economically important as a source of nitrates. A typical composition is $NaNO_3$ 17.6%, NaCl 16.1%, Na_2SO_4 6.5%, $CaSO_4$ 5.5%, $MgSO_4$ 3.0%, KNO_3 1.3%, $Na_2B_4O_7$ 0.94%, $KClO_3$ 0.23%, $NaIO_3$ 0.11%, sand and gravel to 100%.

californium Symbol Cf. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 98; mass number of the most stable isotope 251 (half-life about 700 years). Nine isotopes are known; californium–252 is an intense neutron source, which makes it useful in neutron *activation analysis and potentially useful as a radiation source in medicine. The element was first produced by Glenn Seaborg (1912–99) and associates in 1950.

SEE WEB LINKS

- Information from the WebElements site

calixarenes Compounds that have molecules with a cuplike structure (the name comes from the Greek *calix*, cup). The simplest, has four phenol molecules joined by four $–CH_2–$ groups into a ring (forming the base of the 'cup'). The four phenol hexagons point in the same direction to form a cavity that can bind substrate molecules. Interest has been shown in the potential ability of calixarene molecules to mimic enzyme action.

callus **1.** (in botany) A protective tissue, consisting of parenchyma cells, that develops over a cut or damaged plant surface. Callus tissue can also be induced to form in cell cultures by hormone treatment. **2.** (in pathology) A thick hard area of skin that commonly forms on the palms of the hands and soles of the feet as a result of continuous pressure or friction. **3.** (in physiology) Hard tissue formed round bone ends following a fracture, which is gradually converted to new bone.

calomel *See* MERCURY(I) CHLORIDE.

C

calomel half cell (calomel electrode) A type of half cell in which the electrode is mercury coated with calomel (HgCl) and the electrolyte is a solution of potassium chloride and saturated calomel. The standard electrode potential is –0.2415 volt (25°C). In the calomel half cell the reactions are

$$HgCl(s) \rightleftharpoons Hg^{+}(aq) + Cl^{-}(aq)$$

$$Hg^{+}(aq) + e \rightleftharpoons Hg(s)$$

The overall reaction is

$$HgCl(s) + e \rightleftharpoons Hg(s) + Cl^{-}(aq)$$

This is equivalent to a $Cl_2(g)|Cl^{-}(aq)$ half cell.

caloric theory A former theory concerning the nature of heat, which was regarded as a weightless fluid (called **caloric**). It was unable to account for the fact that friction could produce an unlimited quantity of heat and it was abandoned when Joule showed that heat is a form of energy.

calorie The quantity of heat required to raise the temperature of 1 gram of water by 1°C (1 K). The calorie, a c.g.s. unit, is now largely replaced by the *joule, an *SI unit. 1 calorie = 4.186 8 joules.

Calorie (kilogram calorie; kilocalorie) 1000 calories. This unit is still in limited use in estimating the energy value of foods, but is obsolescent.

calorific value The heat per unit mass produced by complete combustion of a given substance. Calorific values are used to express the energy values of fuels; usually these are expressed in megajoules per kilogram (MJ kg^{-1}). They are also used to measure the energy content of foodstuffs; i.e. the energy produced when the food is oxidized in the body. The units here are kilojoules per gram (kJ g^{-1}), although Calories (kilocalories) are often still used in nontechnical contexts. Calorific values are measured using a *bomb calorimeter.

calorimeter Any of various devices used to measure thermal properties, such as *calorific value, specific *heat capacity, specific *latent heat, etc. *See* BOMB CALORIMETER.

Calvin, Melvin (1911–97) US biochemist. After World War II, at the Lawrence Radiation Laboratory, Berkeley, he investigated the light-independent reactions of *photosynthesis. Using radioactive carbon-14 to label carbon dioxide, he discovered the *Calvin cycle, for which he was awarded the 1961 Nobel Prize for chemistry.

Calvin cycle The metabolic pathway of the light-independent stages of *photosynthesis, which occurs in the stroma of the chloroplasts. The pathway was elucidated by Melvin Calvin and his co-workers and involves the fixation of carbon dioxide and its subsequent reduction to carbohydrate. During the cycle, carbon dioxide combines with *ribulose bisphosphate, through the mediation of the enzyme ribulose bisphosphate carboxylase/oxygenase (rubisco), to form an unstable six-carbon compound that breaks down to form two molecules of the three-carbon compound glycerate 3-phosphate. This is converted to glyceraldehyde 3-phosphate, which is used to regenerate ribulose bisphosphate and to produce glucose and fructose.

calx A metal oxide formed by heating an ore in air.

calyptra **1.** A layer of cells that covers the developing sporophyte of mosses, liverworts, clubmosses, horsetails, and ferns. In mosses it forms a hood over the *capsule and in liverworts it forms a sheath at the base of the capsule stalk. **2.** *See* ROOT CAP.

calyptrogen The region within the root *apical meristem that divides to produce the *root cap (calyptra).

calyx The *sepals of a flower, collectively, forming the outer whorl of the *perianth. It encloses the petals, stamens, and carpels and protects the flower in bud. *See also* PAPPUS.

cambium (lateral meristem) A plant tissue consisting of actively dividing cells (*see* MERISTEM) that is responsible for increasing the girth of the plant, i.e. it causes secondary growth. The two most important cambia are the **vascular** (or **fascicular**) **cambium** and the *cork cambium. The vascular cambium occurs in the stem and root; it divides to produce secondary *xylem and secondary *phloem (new food- and water-conducting tissues). In mature stems the vascular cambium is extended laterally to form a complete ring: the sections of this ring between the vascular bundles comprises the **interfascicular cambium**. *Compare* APICAL MERISTEM.

Cambrian The earliest geological period of the Palaeozoic era. It is estimated to have

begun about 542 million years ago and lasted for some 54 million years. During this period marine animals with mineralized shells made their first appearance and Cambrian rocks are the first to contain an abundance of fossils. Cambrian fossils are chiefly of marine animals; they include *trilobites, which dominated the Cambrian seas, echinoderms, brachiopods, molluscs, and primitive *graptolites (from the mid Cambrian). Trace *fossils also provide evidence for a variety of worms.

Cambrian explosion A relatively short interval of rapid intense evolution that supposedly occurred in the early to mid-Cambrian period, some 540 to 520 million years ago. The supposition is based on the sudden appearance in the fossil record from this time of many diverse and novel forms, particularly marine animals, among which can be found representatives of all major modern groups. *See* BURGESS SHALE.

camcorder *See* VIDEO CAMERA.

camera **1.** An optical device for obtaining still photographs or for exposing cinematic film. It consists of a light-proof box with a lens at one end and a plate or film at the other. To make an exposure the shutter is opened and an image of the object to be photographed is formed on the light-sensitive film. The length of the exposure is determined by the intensity of light available, the film speed, and the *aperture of the lens. In the simpler cameras the shutter speed and aperture are controlled manually, but in automatic cameras the iris over the lens or the shutter is adjusted on the basis of information provided by a built-in *exposure meter. In ciné cameras the shutter automatically opens as the film comes to rest behind the lens for each frame; the film passes through the camera so that a set number (commonly 16, 18, or 24) of frames are exposed every second. **2.** A similar device (a **digital camera**) in which the film is replaced by a semiconductor array, which records the picture and stores it within the camera in a (usually) replaceable memory module. Moving pictures can be similarly recorded using a *video camera. **3.** The part of a television system that converts optical images into electronic signals. It consists of a lens system, which focuses the image to be televised on the photosensitive mosaic of the camera tube, causing localized discharge of those of its elements that are illuminated. This mosaic is scanned from behind by an electron beam so that the beam current is varied as it passes over areas of light and shade. The signal so picked up by the scanning beam is preamplified in the camera and passed to the transmitter with sound and synchronization signals. In *colour television three separate camera tubes are used, one for each *primary colour.

camouflage A high degree of similarity between an animal and its visual environment, which enables it to be disguised or concealed. By blending into the background the animal can elude predators or remain invisible to potential prey. *See also* CRYPTIC COLORATION; MIMICRY. *Compare* WARNING COLORATION.

cAMP *See* CYCLIC AMP.

camphor A white crystalline cyclic ketone, $C_{10}H_{16}O$; r.d. 0.99; m.p. 179°C; b.p. 204°C. It was formerly obtained from the wood of the Formosan camphor tree, but can now be synthesized. The compound has a characteristic odour associated with its use in mothballs. It is a plasticizer in celluloid.

Canada balsam A yellow-tinted resin used for mounting specimens in optical microscopy. It has similar optical properties to glass.

canaliculus A very small channel that occurs between the cells of the liver and bone. In the liver the bile canaliculi carry bile to the bile ducts; in bone, canaliculi connect lacunae, the cavities containing bone cells.

canal rays Streams of positive ions produced in a *discharge tube by boring holes (canals) in the cathode. The positive ions attracted to the cathode pass through the holes and emerge on the other side as positive rays.

cancer Any disorder of cell growth that results in invasion and destruction of surrounding healthy tissue by abnormal cells. Cancer cells arise from normal cells whose nature is permanently changed. They multiply more rapidly than healthy body cells and do not seem subject to normal control by nerves and hormones. They may spread via the bloodstream or lymphatic system to other parts of the body, where they produce further tissue damage (**metastases**). **Malignant tumour** is another name for cancer. A cancer that arises in epithelium is called a **carcinoma**; one that arises in connective tis-

sue is called a **sarcoma**. **Leukaemia** is cancer of white blood cells; **lymphoma** is cancer of *lymphoid tissue; and **myeloma** is cancer of *plasma cells of the bone marrow. Causative agents (**carcinogens**) include various chemicals (including those in tobacco smoke), ionizing radiation, silica and asbestos particles, and *oncogenic viruses (*see also* ONCOGENE). Hereditary factors and stress may also play a role. Whatever the initiating factor, the mechanism by which cancer arises is mutation of genes in somatic cells.

SEE WEB LINKS

- Extensive multimedia coverage of cancer biology and different types of cancer, produced by Emory University.

candela Symbol Cd. The *SI unit of luminous intensity equal to the luminous intensity in a given direction of a source that emits monochromatic radiation of frequency 540×10^{12} Hz and has a radiant intensity in that direction of 1/683 watt per steradian.

candle power Luminous intensity as formerly expressed in terms of the international candle but now expressed in candela.

cane sugar *See* SUCROSE.

canine tooth A sharp conical *tooth in mammals that is large and highly developed in carnivores (e.g. dogs) for tearing meat. There are two canines in each jaw, each situated between the second *incisor and the first *premolar. In some animals (e.g. herbivores, such as giraffes and rabbits) canine teeth are absent.

cannabinoids A large group of structurally related phenolic compounds found in the plant *Cannabis sativa*. The main one is tetrahydrocannabinol (THC), which is the compound responsible for the effects of cannabis. It effects cannabinoid receptors found in the brain (and also in the spleen). The name 'cannabinoid' is also applied to structurally unrelated compounds found naturally in animal tissue and having an effect on the cannabinoid receptors. These **endocannabinoids** (endogenous cannabinoids) are believed to act as 'messengers' between cells.

cannabis An illegal drug produced from the plant *Cannabis sativa*. The dried inflorescences of the plant are known as **marijuana** and the thick resin produced from the plant is known as **hashish**. The normal method of using cannabis is to smoke it, although it can also be taken in certain foods. Cannabis is a class B controlled substance in the UK. It contains a large number of related compounds known as herbal *cannabinoids. The main active component is tetrahydrocannabinol (THC).

Cannizzaro reaction A reaction of aldehydes to give carboxylic acids and alcohols. It occurs in the presence of strong bases with aldehydes that do not have alpha hydrogen atoms. For example, benzenecarbaldehyde gives benzenecarboxylic acid and benzyl alcohol:

$$2C_6H_5CHO \rightarrow C_6H_5COOH + C_6H_5CH_2OH$$

Aldehydes that have alpha hydrogen atoms undergo the *aldol reaction instead. The Cannizzaro reaction is an example of a *disproportionation. It was discovered in 1853 by the Italian chemist Stanislao Cannizzaro (1826–1910).

canonical form One of the possible structures of a molecule that together form a *resonance hybrid.

capacitance The property of a conductor or system of conductors that describes its ability to store electric charge. The capacitance (C) is given by Q/V, where Q is stored charge on one conductor and V the potential difference between the two conductors (or between a single conductor and earth); it is measured in farads (or, in practice, microfarads).

An isolated sphere has a capacitance of $4\pi\varepsilon r$, where r is the radius and ε the *permittivity of the medium surrounding it. Capacitance is more commonly applied to systems of conductors (or semiconductors) separated by insulators (*see* CAPACITOR).

capacitation The final stage in the maturation process of a spermatozoon. This takes place inside the genital tract as the sperm penetrates the ovum.

capacitor An arrangement of conductors separated by an insulator (dielectric) used to store charge or introduce *reactance into an alternating-current circuit. The earliest form was the *Leyden jar. Capacitors used as circuit elements have two conducting plates separated by the dielectric. The dielectric may be air, paper impregnated with oil or wax, plastic film, or ceramic. The simplest form has two parallel rectangular conducting plates (area A) separated by a dielectric (thickness d, permittivity ε). The capacitance

of such a capacitor is $A\varepsilon/d$. **Electrolytic capacitors** are devices in which a thin layer of an oxide is deposited on one of the electrodes to function as the dielectric.

capacitor microphone A microphone consisting of a *capacitor with a steady voltage applied across its parallel plates. One plate is fixed, the other is a thin diaphragm that is moved by the pressure of the sound waves. The movements of the diaphragm cause a variation in the spacing and therefore in the *capacitance of the device. This variation in capacitance is, in turn, reflected in a similar variation in the charge carried by each plate. The consequent current to and from one plate is carried by a resistor, the varying potential difference across which constitutes the device's output signal. It was formerly known as a **condenser microphone**.

capillarity *See* SURFACE TENSION.

capillary **1.** A tube of small diameter. **2. (blood capillary)** The narrowest type of blood vessel in the vertebrate circulatory system. Capillaries conduct blood from *arterioles to all living cells: their walls are only one cell layer thick, so that oxygen and nutrients can pass through them into the surrounding tissues. Capillaries also transport waste material (e.g. urea and carbon dioxide) to venules for ultimate excretion. Capillaries can be constricted or dilated, according to local tissue requirements.

capillary electrophoresis (CE) A technique for investigating mixtures of charged species. In **capilliary zone electrophoresis** (**CZE**), the sample is introduced into a fine capillary tube, with each end of the capillary placed in a reservoir containing an electrolyte (e.g. a buffer solution). The source reservoir contains a positive electrode and the destination reservoir contains a negative electrode. A high potential difference is maintained between the electrodes. Components of the sample flow through the buffer solution in the capillary under the influence of the electric field. Their mobility depends on their charge, size, and shape, and the components separate as they move through the tube. They are detected close to the end of the capillary, usually by ultraviolet absorption. **Capilliary gel electrophoresis** (**CGE**) is used for separating large charged species, such as DNA fragments. The capilliary is filled with a gel and separation depends on the size of the species. In CE, a graph of detector output against time is known as an **electropherogram**. Individual components can be identified by their retention times in the capillary. The technique can be highly sensitive and is widely used in forensic laboratories.

capillary gel electrophoresis (CGE) *See* CAPILLARY ELECTROPHORESIS.

capillary zone electrophoresis (CZE) *See* CAPILLARY ELECTROPHORESIS.

capitulum A type of flowering shoot (*see* RACEMOSE INFLORESCENCE) characteristic of plants of the family Compositae (Asteraceae), e.g. daisy and dandelion. The tip of the shoot is flattened and bears many small stalkless flowers (**florets**) surrounded by an involucre (ring) of bracts. This arrangement gives the appearance of a single flower.

capric acid *See* DECANOIC ACID.

caproic acid *See* HEXANOIC ACID.

caprolactam (6-hexanelactam) A white crystalline substance, $C_6H_{11}NO$; r.d. 1.02; m.p. 69–71°C; b.p. 139°C. It is a *lactam containing the –NH.CO– group with five CH_2 groups making up the rest of the seven-membered ring. Caprolactam is used in making *nylon.

caprylic acid *See* OCTANOIC ACID.

capsid The protein coat of a *virus. The chemical nature of the capsid is important in stimulating the body's *immune response against the invading virus.

capsule **1.** (in botany) **a.** A dry fruit that releases its seeds when ripe; it is formed from several fused carpels and contains many seeds. The seeds may be dispersed through pores (as in the poppy), through a lid (as in plantain), or by the splitting and separation of the individual carpels (as in the crocus). Various other forms of capsules include the *silicula and *siliqua. **b.** The part of the sporophyte of mosses and liverworts in which the haploid spores are produced. It is borne on a long stalk (**seta**) and sheds its spores when mature (*see* PERISTOME). **2.** (in microbiology) A thick gelatinous layer completely surrounding the cell wall of certain bacteria. It appears to have a protective function, making ingestion of the bacterial cell by *phagocytes more difficult and preventing desiccation. **3.** (in animal anatomy) **a.** The membranous or fibrous envelope that surrounds certain organs, e.g. the kidneys,

spleen, and lymph nodes. **b.** The ligamentous sheath of connective tissue that surrounds various skeletal joints.

capture Any of various processes in which a system of particles absorbs an extra particle. There are several examples in atomic and nuclear physics. For instance, a positive ion may capture an electron to give a neutral atom or molecule. Similarly, a neutral atom or molecule capturing an electron becomes a negative ion. An atomic nucleus may capture a neutron to produce a different (often unstable) nucleus. Another type of nuclear capture is the process in which the nucleus of an atom absorbs an electron from the innermost orbit (the K shell) to transform into a different nucleus. In this process (called **K capture**) the atom is left in an excited state and generally decays by emission of an X-ray photon.

Radiative capture is any such process in which the capture results in an excited state that decays by emission of photons. A common example is neutron capture to yield an excited nucleus, which decays by emission of a gamma ray.

carapace **1.** The dorsal part of the *exoskeleton of some crustaceans (e.g. crabs), which spreads like a shield over several segments of the head and thorax. **2.** The domed dorsal part of the shell of tortoises and turtles, formed of bony plates fused with the ribs and vertebrae and covered by a horny epidermal layer. The ventral part of the shell (**plastron**) is similar but flatter.

carat **1.** A measure of fineness (purity) of gold. Pure gold is described as 24-carat gold. 14-carat gold contains 14 parts in 24 of gold, the remainder usually being copper. **2.** A unit of mass equal to 0.200 gram, used to measure the masses of diamonds and other gemstones.

carbamide *See* UREA.

carbanion An organic ion with a negative charge on a carbon atom; i.e. an ion of the type R_3C^-. Carbanions are intermediates in certain types of organic reaction (e.g. the *aldol reaction).

carbene A species of the type R_2C:, in which the carbon atom has two electrons that do not form bonds. **Methylene**, $:CH_2$, is the simplest example. Carbenes are highly reactive and exist only as transient intermediates in certain organic reactions. They attack double bonds to give cyclopropane derivatives. They also cause insertion reactions, in which the carbene group is inserted between the carbon and hydrogen atoms of a C–H bond:

$$C\text{–}H + :CR_2 \rightarrow C\text{–}CR_2\text{–}H$$

carbenium ion *See* CARBOCATION.

carbide Any of various compounds of carbon with metals or other more electropositive elements. True carbides contain the ion C^{4-} as in Al_4C_3. These are saltlike compounds giving methane on hydrolysis, and were formerly called **methanides**. Compounds containing the ion C_2^{2-} are also saltlike and are known as **dicarbides**. They yield ethyne (acetylene) on hydrolysis and were formerly called **acetylides**. The above types of compound are ionic but have partially covalent bond character, but boron and silicon form true covalent carbides, with giant molecular structures. In addition, the transition metals form a range of interstitial carbides in which the carbon atoms occupy interstitial positions in the metal lattice. These substances are generally hard materials with metallic conductivity. Some transition metals (e.g. Cr, Mn, Fe, Co, and Ni) have atomic radii that are too small to allow individual carbon atoms in the interstitial holes. These form carbides in which the metal lattice is distorted and chains of carbon atoms exist (e.g. Cr_3C_2, Fe_3C). Such compounds are intermediate in character between interstitial carbides and ionic carbides. They give mixtures of hydrocarbons on hydrolysis with water or acids.

carbocation An ion with a positive charge that is mostly localized on a carbon atom. There are two types:

Carbonium ions have five bonds to the carbon atom and a complete outer shell of eight electrons. A simple example is the ion CH_5^+, which has a trigonal bipyramidal shape. Ions of this type are transient species. They can be produced by electron impact and detected by mass spectroscopy.

Carbenium ions have three bonds to the carbon atom and are planar, with six outer electrons and a vacant *p*-orbital. Ions of this type are intermediates in a number of organic reactions (for example, in the S_N1 mechanism of *nucleophilic substitution). Certain carbenium ions are stabilized by delocalization of the charge. An example is the orange-red salt $(C_6H_5)_3C^+Cl^-$. Carbenium ions can be produced by superacids.

carbocyclic *See* CYCLIC.

carbohydrate One of a group of organic compounds based on the general formula $C_x(H_2O)_y$. The simplest carbohydrates are the *sugars (saccharides), including glucose and sucrose. *Polysaccharides are carbohydrates of much greater molecular weight and complexity; examples are starch, glycogen, and cellulose. Carbohydrates perform many vital roles in living organisms. Sugars, notably glucose, and their derivatives are essential intermediates in the conversion of food to energy. Starch and other polysaccharides serve as energy stores in plants, particularly in seeds, tubers, etc., which provide a major energy source for animals, including man. Cellulose, lignin, and others form the supporting cell walls and woody tissue of plants. Chitin is a structural polysaccharide found in the body shells of many invertebrate animals. Carbohydrates also occur in the surface coat of animal cells and in bacterial cell walls.

SEE WEB LINKS

- Information about IUPAC nomenclature

carbolic acid *See* PHENOL.

carbon Symbol C. A nonmetallic element belonging to *group 14 (formerly IVB) of the periodic table; a.n. 6; r.a.m. 12.011; m.p. ~3550°C; b.p. ~4827°C. Carbon has three main allotropic forms (*see* ALLOTROPY).

*Diamond (r.d. 3.52) occurs naturally and can be produced synthetically. It is extremely hard and has highly refractive crystals. The hardness of diamond results from the covalent crystal structure, in which each carbon atom is linked by covalent bonds to four others situated at the corners of a tetrahedron. The C–C bond length is 0.154 nm and the bond angle is 109.5°.

Graphite (r.d. 2.25) is a soft black slippery substance (sometimes called **black lead** or **plumbago**). It occurs naturally and can also be made by the *Acheson process. In graphite the carbon atoms are arranged in layers, in which each carbon atom is surrounded by three others to which it is bound by single or double bonds. The layers are held together by much weaker van der Waals' forces. The carbon–carbon bond length in the layers is 0.142 nm and the layers are 0.34 nm apart. Graphite is a good conductor of heat and electricity. It has a variety of uses including electrical contacts, high-temperature equipment, and as a solid lubricant. Graphite mixed with clay is the 'lead' in pencils (hence its alternative name). The third crystalline allotrope is fullerite (*see* BUCKMINSTERFULLERENE). There are also several amorphous forms of carbon, such as *carbon black and *charcoal.

There are two stable isotopes of carbon (proton numbers 12 and 13) and four radioactive ones (10, 11, 14, 15). Carbon–14 is used in *carbon dating.

Carbon occurs in all organic compounds and is therefore fundamental to the structure of all living organisms. It is an *essential element for plants and animals, being ultimately derived from atmospheric carbon dioxide assimilated by plants during photosynthesis (*see* CARBON CYCLE). The ubiquitous nature of carbon in living organisms is due to its unique ability to form stable covalent bonds with other carbon atoms and also with hydrogen, oxygen, nitrogen, and sulphur atoms, resulting in the formation of a variety of compounds containing chains and rings of carbon atoms.

SEE WEB LINKS

- Information from the WebElements site

carbon assimilation The incorporation of carbon from atmospheric carbon dioxide into organic molecules. This process occurs during *photosynthesis. *See* CARBON CYCLE.

carbonate A salt of carbonic acid containing the carbonate ion, CO_3^{2-}. The free ion has a plane triangular structure. Metal carbonates may be ionic or may contain covalent metal–carbonate bonds (complex carbonates) via one or two oxygen atoms. The carbonates of the alkali metals are all soluble but other carbonates are insoluble; they all react with mineral acids to release carbon dioxide.

carbonate minerals A group of common rock-forming minerals containing the anion CO_3^{2-} as the fundamental unit in their structure. The most important carbonate minerals are *calcite, *dolomite, and *magnesite. *See also* ARAGONITE.

carbonation The solution of carbon dioxide in a liquid under pressure.

carbon bisulphide *See* CARBON DISULPHIDE.

carbon black A fine carbon powder made by burning hydrocarbons in insufficient air. It is used as a pigment and a filler (e.g. for rubber).

carbon capture and storage (CCS) The removal of carbon dioxide from a point source of pollution and its subsequent transfer to a repository so that it does not enter the atmosphere. Methods of CCS are being developed as ways of reducing emissions of greenhouse gases (*see* GREENHOUSE EFFECT) and mitigating the environmental impact of burning coal, natural gas, or oil. For example, it is feasible to remove carbon dioxide from power station flue gases by scrubbing, using activated carbon filters. However, this significantly increases the operating cost of the power station. Once removed from a point source, the carbon dioxide is piped to a suitable storage site, often located in porous underground rock formations, notably depleted oil and gas fields. Other possibilities are storage in deep ocean sites and chemical reaction with metal oxides to create stable carbonates.

carbon cycle **1.** (in biology) One of the major cycles of chemical elements in the environment (*see* BIOGEOCHEMICAL CYCLE). Carbon (as carbon dioxide) is taken up from the atmosphere and incorporated into the tissues of plants in *photosynthesis. It may then pass into the bodies of animals as the plants are eaten (*see* FOOD CHAIN). During the respiration of plants, animals, and organisms that bring about decomposition, carbon dioxide is returned to the atmosphere. The combustion of fossil fuels (e.g. coal and peat) also releases carbon dioxide into the atmosphere. See illustration. *See also* GREENHOUSE EFFECT.

2. (in physics) A series of nuclear reactions in which four hydrogen nuclei combine to form a helium nucleus with the liberation of energy, two positrons, and two neutrinos. The process is believed to be the source of energy in many stars and to take place in six stages. In this series carbon–12 acts as if it were a catalyst, being reformed at the end of the series:

$$^{12}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{13}_{7}\mathrm{N} + \gamma$$

$$^{13}_{7}\mathrm{N} \rightarrow {}^{13}_{6}\mathrm{C} + \mathrm{e}^{+} + \nu_{\mathrm{e}}$$

$$^{13}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{14}_{7}\mathrm{N} + \gamma$$

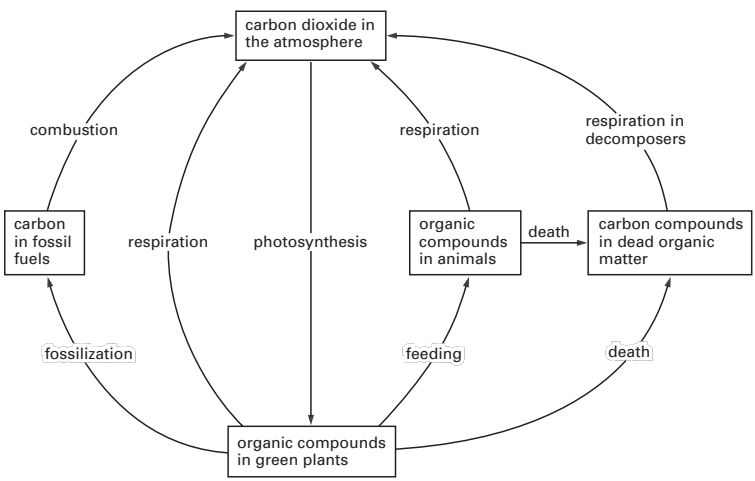
$$^{14}_{7}\mathrm{N} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{15}_{8}\mathrm{O} + \gamma$$

$$^{15}_{8}\mathrm{O} \rightarrow {}^{15}_{7}\mathrm{N} + \mathrm{e}^{+} + \nu_{\mathrm{e}}$$

$$^{15}_{7}\mathrm{N} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{4}_{2}\mathrm{He}.$$

See STELLAR EVOLUTION.

carbon dating (radiocarbon dating) A method of estimating the ages of archaeological specimens of biological origin. As a result of *cosmic radiation a small number of atmospheric nitrogen nuclei are continuously being transformed by neutron



The carbon cycle in nature.

bombardment into radioactive nuclei of carbon–14:

$$^{14}_{7}N + n \rightarrow {}^{14}_{6}C + p$$

Some of these radiocarbon atoms find their way into living trees and other plants in the form of carbon dioxide, as a result of *photosynthesis. When the tree is cut down photosynthesis stops and the ratio of radiocarbon atoms to stable carbon atoms begins to fall as the radiocarbon decays. The ratio $^{14}C/^{12}C$ in the specimen can be measured and enables the time that has elapsed since the tree was cut down to be calculated. The method has been shown to give consistent results for specimens up to some 40 000 years old, though its accuracy depends upon assumptions concerning the past intensity of the cosmic radiation. The technique was developed by Willard F. Libby (1908–80) and his coworkers in 1946–47.

carbon dioxide A colourless odourless gas, CO_2, soluble in water, ethanol, and acetone; d. 1.977 g dm^{-3} (0°C); m.p. –56.6°C; b.p. –78.5°C. It occurs in the atmosphere (0.04% by volume) but has a short residence time in this phase as it is both consumed by plants during *photosynthesis and produced by *respiration and by combustion. It is readily prepared in the laboratory by the action of dilute acids on metal carbonates or of heat on heavy-metal carbonates. Carbon dioxide is a by-product from the manufacture of lime and from fermentation processes.

Carbon dioxide has a small liquid range and liquid carbon dioxide is produced only at high pressures. The molecule CO_2 is linear with each oxygen making a double bond to the carbon. Chemically, it is unreactive and will not support combustion. It dissolves in water to give *carbonic acid.

Large quantities of solid carbon dioxide (**dry ice**) are used in processes requiring large-scale refrigeration. It is also used in fire extinguishers as a desirable alternative to water for most fires, and as a constituent of medical gases as it promotes exhalation. It is also used in carbonated drinks.

The level of carbon dioxide in the atmosphere has increased by some 30% since the Industrial Revolution, mainly because of extensive burning of fossil fuels and the destruction of large areas of rainforest. This has been postulated as the main cause of the average increase of 0.74°C in global temperatures over the last 100 years, through the *greenhouse effect. Atmospheric CO_2 concentration continues to rise, in spite of tentative steps to control emissions, giving the prospect of accelerated *global warming in the foreseeable future.

carbon disulphide (carbon bisulphide) A colourless highly refractive liquid, CS_2, slightly soluble in water and soluble in ethanol and ether; r.d. 1.261; m.p. –110°C; b.p. 46.3°C. Pure carbon disulphide has an ethereal odour but the commercial product is contaminated with a variety of other sulphur compounds and has a most unpleasant smell. It was previously manufactured by heating a mixture of wood, sulphur, and charcoal; modern processes use natural gas and sulphur. Carbon disulphide is an excellent solvent for oils, waxes, rubber, sulphur, and phosphorus, but its use is decreasing because of its high toxicity and its flammability. It is used for the preparation of xanthates in the manufacture of viscose yarns.

carbon fibres Fibres of carbon in which the carbon has an oriented crystal structure. Carbon fibres are made by heating textile fibres and are used in strong composite materials for use at high temperatures.

carbon footprint The total amount of greenhouse gases (GHGs) emitted to the atmosphere as a result of the activities of an individual, household, business, or other entity. It is usually measured as the mass of carbon dioxide, or carbon dioxide equivalent (i.e. including methane, nitrogen oxides, and other GHGs), emitted per year, and indicates the environmental impact of those activities through their contribution to the *greenhouse effect and hence global warming. Calculation of a full carbon footprint involves both direct and indirect emissions. Direct emissions include those arising from activities that are controlled directly by an individual or organization, such as the combustion of fuel for heating or transport. Indirect emissions are those arising from all goods and services used by the individual or organization, but not directly controlled by them, such as the energy used in the extraction and processing of raw materials and manufacture of goods.

carbonic acid A dibasic acid, H_2CO_3, formed in solution when carbon dioxide is dissolved in water:

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

The acid is in equilibrium with dissolved carbon dioxide, and also dissociates as follows:

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

C

$K_a = 4.5 \times 10^{-7}$ mol dm^{-3}

$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$

$K_a = 4.8 \times 10^{-11}$ mol dm^{-3}

The pure acid cannot be isolated, although it can be produced in ether solution at –30°C. Carbonic acid gives rise to two series of salts: the *carbonates and the *hydrogencarbonates.

carbonic anhydrase An enzyme, present in red blood cells and kidney cells, that catalyses the reaction between carbon dioxide with water:

$CO_2 + H_2O \rightleftharpoons H_2CO_3$

$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$.

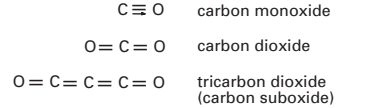
This reaction is one of the fastest known and controls the elimination of carbon dioxide from the body and the pH of urine. It also facilitates the transfer of carbon dioxide from the tissues to the blood and from the blood to the alveoli (air sacs) of the lungs. *See also* CHLORIDE SHIFT.

Carboniferous A geological period in the Palaeozoic era. It began about 360 million years ago, following the Devonian period, and extended until the beginning of the Permian period, about 299 million years ago. In Europe the period is divided into the Lower and Upper Carboniferous, which roughly correspond to the Mississippian and Pennsylvanian periods, respectively, of North America. During the Lower Carboniferous a marine transgression occurred and the characteristic rock of this division – the Carboniferous limestone – was laid down in the shallow seas. Fauna included foraminiferans, corals, bryozoans, brachiopods, blastoids, and other invertebrates. The Upper Carboniferous saw the deposition of the millstone grit, a mixture of shale and sandstone formed in deltaic conditions, followed by the coal measures, alternating beds of coal, sandstone, shale, and clay. The coal was formed from the vast swamp forests composed of seed ferns, lycopsids, and other plants. During the period fishes continued to diversify and amphibians became more common.

carbonium ion *See* CARBOCATION.

carbonize (carburize) To change an organic compound into carbon by heating, or to coat something with carbon in this way.

carbon monoxide A colourless odourless gas, CO, sparingly soluble in water and soluble in ethanol and benzene; d. 1.25 g dm^{-3} (0°C); m.p. –199°C; b.p. –191.5°C. It is flammable and highly toxic. In the laboratory it can be made by the dehydration of methanoic acid (formic acid) using concentrated sulphuric acid. Industrially it is produced by the oxidation of natural gas (methane) or (formerly) by the water-gas reaction. It is formed by the incomplete combustion of carbon and is present in car-exhaust gases.



Carbon monoxide. Oxides of carbon.

It is a neutral oxide, which burns in air to give carbon dioxide, and is a good reducing agent, used in a number of metallurgical processes. It has the interesting chemical property of forming a range of transition metal carbonyls, e.g. $Ni(CO)_4$. Carbon monoxide is able to use vacant *p*-orbitals in bonding with metals; the stabilization of low oxidation states, including the zero state, is a consequence of this. This also accounts for its toxicity, which is due to the binding of the CO to the iron in haemoglobin, thereby blocking the uptake of oxygen.

carbon suboxide *See* TRICARBON DIOXIDE.

carbon tetrachloride *See* TETRACHLOROMETHANE.

carbonyl chloride (phosgene) A colourless gas, $COCl_2$, with an odour of freshly cut hay. It is used in organic chemistry as a chlorinating agent, and was formerly used as a war gas.

carbonyl compound A compound containing the carbonyl group >C=O. Aldehydes, ketones, and carboxylic acids are examples of organic carbonyl compounds. Inorganic carbonyls are complexes in which carbon monoxide has coordinated to a metal atom or ion, as in *nickel carbonyl, $Ni(CO)_4$. *See also* LIGAND.

carbonyl group The group >C=O, found in aldehydes, ketones, carboxylic acids, amides, etc., and in inorganic carbonyl complexes (*see* CARBONYL COMPOUND).

carboranes Compounds similar to the *boranes, but with one or more boron atoms replaced by carbon atoms.

carborundum *See* SILICON CARBIDE.

carboxyhaemoglobin The highly stable product formed when *haemoglobin combines with carbon monoxide. Carbon monoxide competes with oxygen for haemoglobin, with which it binds strongly: the affinity of haemoglobin for carbon monoxide is 250 times greater than that for oxygen. This reduces the availability of haemoglobin for combination with (and transport of) oxygen and accounts for the toxic effects of carbon monoxide on the respiratory system.

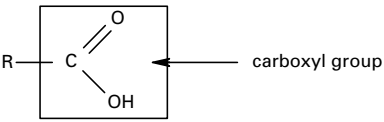
carboxylate An anion formed from a *carboxylic acid. For example, ethanoic acid gives rise to the ethanoate ion, CH_3COO^-.

carboxyl group The organic group –COOH, present in *carboxylic acids.

carboxylic acids Organic compounds containing the group –COOH (the **carboxyl group**; i.e. a carbonyl group attached to a hydroxyl group). In systematic chemical nomenclature carboxylic-acid names end in the suffix *-oic*, e.g. ethanoic acid, CH_3COOH. They are generally weak acids. Many long-chain carboxylic acids occur naturally as esters in fats and oils and are therefore also known as *fatty acids. *See also* GLYCERIDE.

SEE WEB LINKS

- Information about IUPAC nomenclature



Carboxylic acid structure.

carboxypeptidase An *exopeptidase enzyme in pancreatic juice that is secreted into the duodenum. The enzyme is secreted as an inactive precursor, **procarboxypeptidase**, which is activated by another pancreatic protease, *trypsin. *See also* CHYMOTRYPSIN.

carburize *See* CARBONIZE.

carbylamine reaction *See* ISOCYANIDE TEST.

carcerulus A dry fruit that is a type of *schizocarp. It consists of a number of one-seeded fragments (**mericarps**) that adhere to a central axis. It is characteristic of mallow.

carcinogen Any agent that produces *cancer, e.g. tobacco smoke, certain industrial chemicals, and *ionizing radiation (such as X-rays and ultraviolet rays).

carcinoma *See* CANCER.

cardiac **1.** Relating to the heart. **2.** Relating to the part of the stomach nearest to the oesophagus.

cardiac cycle The sequence of events that occurs in the heart during one full heartbeat. These events comprise contraction (*see* SYSTOLE) and relaxation (*see* DIASTOLE) of the chambers of the heart, associated with opening and closing of the heart valves. When both the atria and the ventricles are relaxed, pressure in the heart is low and blood flows from the vena cava and pulmonary vein into the atria and through to the ventricles. The aortic and pulmonary valves, at the junction between the left ventricle and aorta and the right ventricle and pulmonary artery, respectively, are closed; therefore, blood can enter but not leave the heart, which increases the pressure in the chambers. As the pressure in the heart increases, the atria begin to contract, forcing the blood into the ventricles and closing the *tricuspid valve and the *bicuspid valve. A wave of ventricular contraction follows, expelling the blood into the aorta and pulmonary artery to complete the cardiac cycle. At a resting heart rate, the human cardiac cycle lasts approximately 0.85 second.

cardiac muscle A specialized form of *muscle that is peculiar to the vertebrate heart. There are two types of cardiac muscle fibres: contractile fibres, which are striated and contain numerous myofibrils; and conducting fibres, or *Purkyne fibres, which branch extensively and conduct electrical signals throughout the muscle. The muscle itself shows spontaneous contraction and does not need nervous stimulation (*see* PACEMAKER). The vagus nerve to the heart can, however, affect the rate of contraction.

cardiac output The volume of blood pumped per minute by each ventricle, which is also the total blood flow through the pulmonary circuit. At rest, normal human cardiac output is approximately 5 litres per minute, rising to 22 litres per minute during maximum physical exertion. The cardiac output can be calculated from heart rate (number of beats per minute) and stroke volume (volume of blood expelled from the heart per beat).

C

cardiovascular centre One of the areas in the brain that are responsible for the modification of the cardiovascular system based upon the integration of sensory information from the autonomic nervous system. These centres influence the heart rate via the sympathetic and parasympathetic nerves and by the action of certain hormones.

Carius method A method of determining the amount of sulphur and halogens in an organic compound, by heating the compound in a sealed tube with silver nitrate in concentrated nitric acid. The compound is decomposed and silver sulphide and halides are precipitated, separated, and weighed.

carnallite A mineral consisting of a hydrated mixed chloride of potassium and magnesium, $KCl.MgCl_2.6H_2O$.

carnassial teeth Molar and premolar teeth modified for shearing flesh by having cusps with sharp cutting edges. They are typical of animals of the order *Carnivora (e.g. tigers, wolves), in which they are the first molars in the lower jaw and the last premolars in the upper.

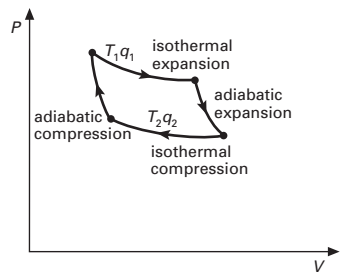
Carnivora An order of mainly flesh-eating mammals that includes the dogs, wolves, bears, badgers, weasels, and cats. Carnivores typically have very keen sight, smell, and hearing. The hinge joint between the lower jaw and skull is very tight, allowing no lateral movement of the lower jaw. This – together with the arrangement of jaw muscles – enables a very powerful bite. The teeth are specialized for stabbing and tearing flesh: canines are large and pointed and some of the cheek teeth are modified for shearing (*see* CARNASSIAL TEETH).

carnivore An animal that eats meat, especially a member of the order *Carnivora (e.g. tigers, wolves). Carnivores are specialized by having strong powerful jaws and well-developed canine teeth. They may be *predators or carrion eaters. *See also* CONSUMER. *Compare* HERBIVORE; OMNIVORE.

carnivorous plant (insectivorous plant) Any plant that supplements its supply of nitrates in conditions of nitrate deficiency by digesting small animals, especially insects. Such plants are adapted in various ways to attract and trap the insects and produce proteolytic enzymes to digest them. Venus' fly trap (*Dionaea*), for example, has spiny-margined hinged leaves that snap shut on an alighting insect. Sundews (*Drosera*) trap and digest insects by means of glandular leaves that secrete a sticky substance, and pitcher plants (families Nepenthaceae and Sarraceniaceae) have leaves modified as pitchers into which insects fall, drowning in the water and digestive enzymes at the bottom.

Carnot, Nicolas Léonard Sadi (1796–1832) French physicist, who first worked as a military engineer. He then turned to scientific research and in 1824 published his analysis of the efficiency of heat engines. The key to this analysis is the thermodynamic *Carnot cycle. He died at an early age of cholera.

Carnot cycle The most efficient cycle of operations for a reversible *heat engine. Published in 1824 by Nicolas Carnot, it consists of four operations on the working substance in the engine (see illustration):
a. Isothermal expansion at thermodynamic temperature T_1 with heat Q_1 taken in.
b. Adiabatic expansion with a fall of temperature to T_2.
c. Isothermal compression at temperature T_2 with heat Q_2 given out.
d. Adiabatic compression with a rise of temperature back to T_1.



Carnot cycle.

According to the **Carnot principle**, the efficiency of any reversible heat engine depends only on the temperature range through which it works, rather than the properties of the working substances. In any reversible engine, the efficiency (η) is the ratio of the work done (W) to the heat input (Q_1), i.e. $\eta = W/Q_1$. As, according to the first law of *thermodynamics, $W = Q_1 - Q_2$, it follows that $\eta = (Q_1 - Q_2)/Q_1$. For the Kelvin temperature scale, $Q_1/Q_2 = T_1/T_2$ and $\eta = (T_1 - T_2)/T_1$. For maximum efficiency T_1 should be as high as possible and T_2 as low as possible.

carnotite A radioactive mineral consisting of hydrated uranium potassium vanadate, $K_2(UO_2)_2(VO_4)_2.nH_2O$. It varies in colour from bright yellow to lemon- or greenish-yellow. It is a source of uranium, radium, and vanadium. The chief occurrences are in the Colorado Plateau, USA; Radium Hill, Australia; and Katanga, Democratic Republic of Congo.

Caro's acid *See* PEROXOSULPHURIC(VI) ACID.

carotene A member of a class of *carotenoid pigments. Examples are β-carotene and lycopene, which colour carrot roots and ripe tomato fruits respectively. α- and β-carotene yield vitamin A when they are broken down during animal digestion.

carotenoid Any of a group of yellow, orange, red, or brown plant pigments chemically related to terpenes. Carotenoids are responsible for the characteristic colour of many plant organs, such as ripe tomatoes, carrots, and autumn leaves. They also function as accessory *photosynthetic pigments in the light-dependent reactions of *photosynthesis. *See* CAROTENE; XANTHOPHYLL.

Carothers, Wallace Hume (1896–1937) US industrial chemist, who joined the Du Pont company where he worked on polymers. In 1931 he produced *neoprene, a synthetic rubber. His greatest success came in 1935 with the discovery of the polyamide that came to be known as *nylon. Carothers, who suffered from depression, committed suicide.

carotid artery The major artery that supplies blood to the head. A pair of **common carotid arteries** arise from the aorta (on the left) and the innominate artery (on the right) and run up the neck; each branches into an **external** and an **internal carotid artery**, which supply the head.

carotid body One of a pair of tissue masses adjacent to the *carotid sinus. Each contains receptors that are sensitive to oxygen and pH levels (acidity) in the blood. High levels of carbon dioxide in the blood lower the pH (i.e. increase the acidity). By responding to fluctuations in pH, the carotid body coordinates reflex changes in respiration rate.

carotid sinus An enlarged region of the *carotid artery at its major branching point in the neck. Its walls contain many receptors that are sensitive to changes in pressure and it regulates blood pressure by initiating reflex changes in heart rate and dilation of blood vessels.

carpal (carpal bone) One of the bones that form the wrist (*see* CARPUS) in terrestrial vertebrates.

carpel The female reproductive organ of a flower. Typically it consists of a *stigma, *style, and *ovary. It is thought to have evolved by the fusion of the two edges of a flattened megasporophyll (*see* SPOROPHYLL). Each flower may have one carpel (**monocarpellary**) or many (**polycarpellary**), either free (**apocarpous**) or fused together (**syncarpous**). *See also* PISTIL.

carpus The wrist (or corresponding part of the forelimb) in terrestrial vertebrates, consisting of a number of small bones (**carpals**). The number of carpal bones varies with the species. The rabbit, for example, has two rows of carpals, the first (proximal) row containing three bones and the second (distal) row five. In humans there are also eight carpals. This large number of bones enables flexibility at the wrist joint, between the hand and forelimb. *See also* PENTADACTYL LIMB.

carrier **1.** (in radio) *See* CARRIER WAVE. **2.** (in physics) *See* CHARGE CARRIER. **3.** (in medicine) An individual who harbours a particular disease-causing microorganism without ill-effects and who can transmit the microorganism to others. *Compare* VECTOR. **4.** (in genetics) An individual with an *allele for some defective condition that is masked by a normal *dominant allele. Such individuals therefore do not suffer from the condition themselves but they may pass on the defective allele to their offspring. In humans, women may be carriers of such conditions as red–green colour blindness and haemophilia, the alleles for which are carried on the X chromosomes (*see* SEX LINKAGE). **5.** (in biochemistry) *See* CARRIER MOLECULE; HYDROGEN CARRIER.

carrier gas The gas that carries the sample in *gas chromatography.

carrier molecule **1.** A molecule that plays a role in transporting electrons through the *electron transport chain. Carrier molecules are usually proteins bound to a nonprotein group; they can undergo oxidation and reduction relatively easily, thus allowing electrons to flow through the system. There are

four types of carrier: flavoproteins (e.g. *FAD), *cytochromes, iron–sulphur proteins (e.g. ferredoxin), and *ubiquinone. **2.** A lipid-soluble molecule that can bind to lipid-insoluble molecules and transport them across membranes. Carrier molecules have specific sites that interact with the molecules they transport. Several different molecules may compete for transport by the same carrier. *See* TRANSPORT PROTEIN.

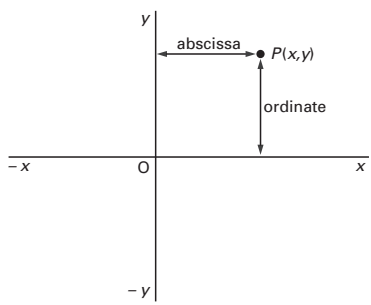
carrier wave An electromagnetic wave of specified frequency and amplitude that is emitted by a radio transmitter in order to carry information. The information is superimposed onto the carrier by means of *modulation.

carrying capacity Symbol *K*. The maximum population of a particular species that can be supported indefinitely by a given habitat or area without damage to the environment. It can be manipulated by human intervention. For example, the carrying capacity for grazing mammals could be increased by boosting the yield of their grassland habitat by the application of fertilizer. *See also* K SELECTION.

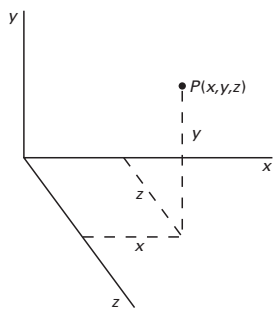
Cartesian coordinates A system used in analytical geometry to locate a point *P*, with reference to two or three **axes** (see graphs). In a two-dimensional system the vertical axis is the *y*-axis and the horizontal axis is the *x*-axis. The point at which the axes intersect each other is called the **origin**, *O*. Values of $y < 0$ fall on the *y*-axis below the origin, values of $x < 0$ fall on the *x*-axis to the left of the origin. Any point *P* is located by its perpendicular distances from the two axes. The distance from the *x*-axis is called the **ordinate**; the distance from the *y*-axis is the **abscissa**. The position is indicated numerically by enclosing the values of the abscissa and the ordinate in parentheses and separating the two by means of a comma, e.g. (*x*,*y*). In three dimensions the system can be used to locate a point with reference to a third, *z*-axis. It is named after René Descartes (1596–1650).

cartilage (gristle) A firm flexible connective tissue that forms the adult skeleton of cartilaginous fish (e.g. sharks). In other vertebrates cartilage forms the skeleton of the embryo, being largely replaced by *bone in mature animals (although it persists in certain areas). Cartilage comprises a matrix consisting chiefly of a glycosaminoglycan (mucopolysaccharide) called **chondroitin sulphate** secreted by cells (**chondroblasts**) that become embedded in the matrix as **chondrocytes**. It also contains collagenous and elastic fibres. **Hyaline cartilage** consists largely of glycosaminoglycan, giving it a shiny glasslike appearance; this type of cartilage gives flexibility and support at the joints. **Fibrocartilage**, in which bundles of collagen fibres predominate, is stronger and less elastic than hyaline cartilage; it is found in such areas as the intervertebral discs. **Elastic cartilage** has a yellow appearance due to the presence of numerous elastic fibres (*see* ELASTIN). This cartilage maintains the shape of certain organs, such as the pinna of the ear.

cartilage bone (replacing bone) *Bone that is formed by replacing the cartilage of an embryo skeleton. The process, called **ossification**, is brought about by the cells (osteoblasts) that secrete bone. *Compare* MEMBRANE BONE.



two-dimensional system



three-dimensional system

Cartesian coordinates.

cartilaginous fishes *See* CHONDRICHTHYES.

cartography The science of the production of maps and charts. Maps may be based on original surveys, aerial photographs (photogrammetry), or compiled from existing maps and records. Computer-based information systems are increasingly used in the production of maps (**digital cartography**) in place of more traditional methods. *See also* MAP PROJECTIONS.

caruncle A small outgrowth from the testa of a seed that develops from the placenta, funicle, or micropyle. Examples include the warty outgrowth from the castor-oil seed and the tuft of hairs on the testa of the seed of willowherb. *See also* ARIL.

caryopsis A dry single-seeded indehiscent fruit that differs from an *achene in that the fruit wall is fused to the testa of the seed. It is the grain of cereals and grasses.

cascade liquefier An apparatus for liquefying a gas of low *critical temperature. Another gas, already below its critical temperature, is liquified and evaporated at a reduced pressure in order to cool the first gas to below its critical temperature. In practice a series of steps is often used, each step enabling the critical temperature of the next gas to be reached.

cascade process Any process that takes place in a number of steps, usually because the single step is too inefficient to produce the desired result. For example, in some uranium-enrichment processes the separation of the desired isotope is only poorly achieved in a single stage; to achieve better separation the process has to be repeated a number of times, in a series, with the enriched fraction of one stage being fed to the succeeding stage for further enrichment. Another example of cascade process is that operating in a *cascade liquefier.

case hardening The hardening of the surface layer of steel, used for tools and certain mechanical components. The commonest method is to carburize the surface layer by heating the metal in a hydrocarbon or by dipping the red hot metal into molten sodium cyanide. Diffusion of nitrogen into the surface layer to form nitrides is also used.

casein One of a group of phosphate-containing proteins (phosphoproteins) found in milk. Caseins are easily digested by the enzymes of young mammals and represent a major source of phosphorus. *See* RENNIN.

CAS registry A database of chemical compounds, certain mixtures, and biological sequences maintained by the Chemical Abstracts Service of the American Chemical Society. In the registry every entry has a unique CAS registry number (**CASRN**). This has three parts: up to six digits, followed by two digits, followed by one digit. For example, the CAS number of water is 7732-18-5. The final digit is a check number. CAS registry numbers are used for searching chemical databases. The size of the registry is immense, with over 32 million substances and 59 million sequences. It identifies every chemical that has been described in the literature since 1957 and around 50 000 new numbers are added each week.

SEE WEB LINKS

- Further information from the CAS site
- A free service for finding CAS numbers from CambridgeSoft

Cassegrainian telescope *See* TELESCOPE.

Cassini, Giovanni Domenico (1625–1712) Italian-born French astronomer, who was professor of astronomy at Bologna. In 1669 he moved to Paris to run the new observatory there, becoming a French citizen in 1673. He is best known for his discovery (1675) of the gap that divides Saturn's ring system into two parts, now called the **Cassini division**. He also discovered four new satellites of Saturn.

cassiterite A yellow, brown, or black form of tin(IV) oxide, SnO_2, that forms tetragonal, often twinned, crystals; the principal ore of tin. It occurs in hydrothermal veins and metasomatic deposits associated with acid igneous rocks and in alluvial (placer) deposits. The chief producers are Malaysia, Indonesia, Democratic Republic of Congo, and Nigeria.

caste A division found in social insects, such as the *Hymenoptera (ants, bees, wasps) and the Isoptera (termites), in which the individuals are structurally and physiologically specialized to perform a particular function. For example, in honeybees there are queens (fertile females), workers (sterile females), and drones (males). There are several different castes of workers (all sterile females) among ants.

C

cast iron A group of iron alloys containing 1.8 to 4.5% of carbon. It is usually cast into specific shapes ready for machining, heat treatment, or assembly. It is sometimes produced direct from the *blast furnace or it may be made from remelted *pig iron.

castor oil A pale-coloured oil extracted from the castor-oil plant. It contains a mixture of glycerides of fatty acids, the predominant acid being ricinoleic acid, $C_{17}H_{32}(OH)COOH$. It is used as a *drying oil in paints and varnishes and medically as a laxative.

catabolism The metabolic breakdown of large molecules in living organisms to smaller ones, with the release of energy. Respiration is an example of a catabolic series of reactions. *See* METABOLISM. *Compare* ANABOLISM.

catalysis The process of changing the rate of a chemical reaction by use of a *catalyst.

catalyst A substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change. Catalysts that have the same phase as the reactants are **homogeneous catalysts** (e.g. *enzymes in biochemical reactions or transition-metal complexes used in the liquid phase for catalysing organic reactions). Those that have a different phase are **heterogeneous catalysts** (e.g. metals or oxides used in many industrial gas reactions). The catalyst provides an alternative pathway by which the reaction can proceed, in which the activation energy is lower. It thus increases the rate at which the reaction comes to equilibrium, although it does not alter the position of the equilibrium. The catalyst itself takes part in the reaction and consequently may undergo physical change (e.g. conversion into powder). In certain circumstances, very small quantities of catalyst can speed up reactions. Most catalysts are also highly specific in the type of reaction they catalyse, particularly enzymes in biochemical reactions. Generally, the term is used for a substance that increases reaction rate (a **positive catalyst**). Some reactions can be slowed down by **negative catalysts** (*see* INHIBITION).

catalytic activity The increase in the rate of a specified chemical reaction caused by an enzyme or other catalyst under specified assay conditions. It is measured in *katals or in moles per second.

catalytic converter A device used in the exhaust systems of motor vehicles to reduce atmospheric pollution. The three main pollutants produced by petrol engines are: unburnt hydrocarbons, carbon monoxide produced by incomplete combustion of hydrocarbons, and nitrogen oxides produced by nitrogen in the air reacting with oxygen at high engine temperatures. Hydrocarbons and carbon monoxide can be controlled by a higher combustion temperature and a weaker mixture. However, the higher temperature and greater availability of oxygen arising from these measures encourage formation of nitrogen oxides. The use of three-way catalytic converters solves this problem by using platinum and palladium catalysts to oxidize the hydrocarbons and the CO and rhodium catalysts to reduce the nitrogen oxides back to nitrogen. These three-way catalysts require that the air–fuel ratio is strictly stochiometric. Some catalytic converters promote oxidation reactions only, leaving the nitrogen oxides unchanged. Three-way converters can reduce hydrocarbons and CO emissions by some 85%, at the same time reducing nitrogen oxides by 62%.

catalytic cracking *See* CRACKING.

catalytic rich gas process *See* CRG PROCESS.

catalytic RNA *See* RIBOZYME.

cataphoresis *See* ELECTROPHORESIS.

catastrophe theory A branch of mathematics dealing with the sudden emergence of discontinuities, in contrast to *calculus, which is concerned with continuous quantities. Catastrophe theory originated in *topology in work by the French mathematician René Thom (1923–2002) and was developed by Thom and the Russian mathematician Vladimir Igorevich Arnold (1937–). There are physical applications of catastrophe theory in *optics and in systems involving *complexity, including biological systems.

catechol *See* 1,2-DIHYDROXYBENZENE.

catecholamine Any of a class of amines that possess a catechol ($C_6H_4(OH)_2$) ring. Including *dopamine, *adrenaline, and *noradrenaline, they function as *neurotransmitters and/or hormones.

category (in taxonomy) *See* RANK.

catenane A type of compound consisting of two or more large rings that are interlocked like the links of a chain. In a cate-

nane, there is no chemical bonding between the rings; the rings are held together by *mechanical bonding.

catenary A curve formed when a chain or rope of uniform density hangs from two fixed points. If the lowest point on the curve passes through the origin, the equation is $y = c(\cosh x/c)$, where c is the distance between the x-axis and the directrix.

catenation **1.** The formation of chains of atoms in chemical compounds. **2.** The formation of a *catenane compound by mechanical bonding.

cathetometer A telescope or microscope fitted with crosswires in the eyepiece and mounted so that it can slide along a graduated scale. Cathetometers are used for accurate measurement of lengths without mechanical contact. The microscope type is often called a **travelling microscope**.

cathine (β-hydroxyamphetamine) An alkaloid, $C_9H_{13}NO$. It may contribute to the stimulant activity of *khat.

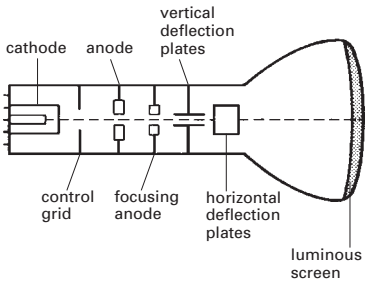
cathinone (β-ketoamphetamine) An alkaloid, $C_9H_{11}NO$. It is the main active ingredient in fresh *khat.

cathode A negative electrode. In *electrolysis cations are attracted to the cathode. In vacuum electronic devices electrons are emitted by the cathode and flow to the *anode. It is therefore from the cathode that electrons flow into these devices. However, in a primary or secondary cell the cathode is the electrode that spontaneously becomes negative during discharge, and from which therefore electrons emerge.

cathode-ray oscilloscope (CRO) An instrument based on the *cathode-ray tube that provides a visual image of electrical signals. The horizontal deflection is usually provided by an internal *timebase, which causes the beam to sweep across the screen at a specified rate. The signal to be investigated is fed to the vertical deflection plates after amplification. Thus the beam traces a graph of the signal amplitude against time.

cathode rays Streams of electrons emitted at the cathode in an evacuated tube containing a cathode and an anode. They were first observed in gas *discharge tubes operated at low pressure. Under suitable conditions electrons produced by secondary emission at the cathode are accelerated down the tube to the anode. In such devices as the *cathode-ray tube the electrons are produced by *thermionic emission from a hot cathode in a vacuum.

cathode-ray tube (CRT) The device that provides the viewing screen in the television tube, the radar viewer, and the *cathode-ray oscilloscope. The cathode-ray tube consists of an evacuated tube containing a heated cathode and two or more ring-shaped anodes through which the cathode rays can pass so that they strike the enlarged end of the tube (see illustration). This end of the tube is coated with fluorescent material so that it provides a screen. Any point on the screen that is struck by the cathode ray becomes luminous. A *control grid between the cathode and the anode enables the intensity of the beam to be varied, thus controlling the brightness of the illumination on the screen. The assembly of cathode, control grid, and anode is called the *electron gun. The beam emerging from the electron gun is focused and deflected by means of plates providing an electric field or coils providing a magnetic field. This enables the beam to be focused to a small point of light and deflected to produce the illusion of an illuminated line as this point sweeps across the tube.



Cathode-ray tube.

The television tube is a form of cathode-ray tube in which the beam is made to scan the screen 625 times to form a frame, with 25 new frames being produced every second. (These are the figures for standard television tubes in the UK). Each frame creates a picture by variations in the intensity of the beam as it forms each line.

cathodic protection *See* SACRIFICIAL PROTECTION.

cation A positively charged ion, i.e. an ion

that is attracted to the cathode in *electrolysis. *Compare* ANION.

cationic detergent *See* DETERGENT.

cationic dye *See* DYES.

cationic resin *See* ION EXCHANGE.

catkin A type of flowering shoot (*see* RACEMOSE INFLORESCENCE) in which the axis, which is often long, bears many small stalkless unisexual flowers. Usually the male catkins hang down from the stem; the female catkins are shorter and often erect. Examples include birch and hazel. Most plants with catkins are adapted for wind pollination, the male flowers producing large quantities of pollen; willows are an exception, having nectar-secreting flowers and being pollinated by insects.

caudal vertebrae The bones (*see* VERTEBRA) of the tail, which articulate with the *sacral vertebrae. The number of caudal vertebrae varies with the species. Rabbits, for example, have 15 caudal vertebrae, while in humans these vertebrae are fused to form a single bone, the *coccyx.

causality The principle that effect cannot precede cause. The principle is particularly useful when combined with the principle that the highest attainable speed in the universe is the *speed of light in a vacuum. Causality is used to analyse the results of scattering experiments and in optics.

caustic **1.** (in chemistry) Describing a substance that is strongly alkaline (e.g. caustic soda). **2.** (in optics) The curve or surface formed by the reflection of parallel rays of light in a large-aperture concave mirror. The apex of the caustic lies at the principal focus of the mirror. Such a curve can sometimes be seen on the surface of the liquid in a cup as a result of reflection by the curved walls of the cup. A similar curve is formed by a convex lens with spherical surfaces refracting parallel rays of light.

caustic potash *See* POTASSIUM HYDROXIDE.

caustic soda *See* SODIUM HYDROXIDE.

Cavendish, Henry (1731–1810) British chemist and physicist, born in France. Although untrained, his inheritance from his grandfather, the Duke of Devonshire, enabled him to live as a recluse and study science. In his experiments with gases (1766), he correctly distinguished between hydrogen and carbon dioxide, and in 1781 synthesized water by exploding hydrogen in oxygen. He also constructed a torsion balance in 1798, with which he measured the mean density (and hence mass) of the earth.

cavitation The formation of gas- or vapour-filled cavities in liquids in motion when the pressure is reduced to a critical value while the ambient temperature remains constant. If the velocity of the flowing liquid exceeds a certain value, the pressure can be reduced to such an extent that the *Bernoulli theorem breaks down. It is at this point that cavitation occurs, causing a restriction on the speed at which hydraulic machinery can be run without noise, vibration, erosion of metal parts, or loss of efficiency.

cavity resonator *See* RESONANT CAVITY.

C cell (parafollicular cell) Any one of a group of calcium-secreting cells in vertebrates that are derived from the terminal pair of gill pouches. In mammals these cells are incorporated into the *thyroid gland and the *parathyroid gland.

c.c.p. Cubic close packing. *See* CLOSE PACKING.

CD **1. (cluster of differentiation)** Any group of antigens that is associated with a specific subpopulation of human *T cells. The differentiation antigens expressed by a T cell vary with its stage of development and thus with its role in the immune response. Hence, for example, CD4 antigens are expressed by helper T cells, whereas CD8 antigens are expressed by cytotoxic T cells. The antigens are glycoproteins and are characterized using *monoclonal antibodies. **2.** *See* COMPACT DISK. **3.** *See* CIRCULAR DICHROISM.

CD-I CD interactive. A variant of *CD-ROM in which data, sound, and images can be interleaved on the same disk, i.e. it is a *multimedia disk. It was designed as a 'buy and play' system for the home.

cDNA *See* COMPLEMENTARY DNA.

CD-ROM CD read-only memory. A device that is based on the audio *compact disk and provides read-only access to a large amount of data (up to 640 megabytes) for use on computer systems. The term also refers to the medium in general. A **CD-ROM drive** must be used with the computer system to read the data from disk; the data cannot normally be rewritten. Most drives can also play CD audio disks, but audio disk players can-

not handle CD-ROMs. The data may be in any form – text, sound, images, or binary data, or a mixture – and various CD-ROM format standards exist to handle these. CD-ROM is widely used for the distribution of data, images, and software and for archiving data.

CD-RW CD-rewritable, a CD format launched around 1997 that enabled recording and re-use of CDs. CD-RW uses a phase change to record data. The recording layer is a special alloy (typically silver/indium/antimony/tellurium). The laser in the CD drive has three power levels. The highest level melts small regions of the recording layer and these cool quickly to an amorphous form, thereby creating small pits in the recording surface. This level is used for writing data to the disk. The intermediate power level heats the surface to a temperature below the melting point, but high enough to cause recrystallization of the amorphous pits. This is used for erasing data. The lowest power level is used for reading data from the disk in the same way that data is read from a CD-ROM.

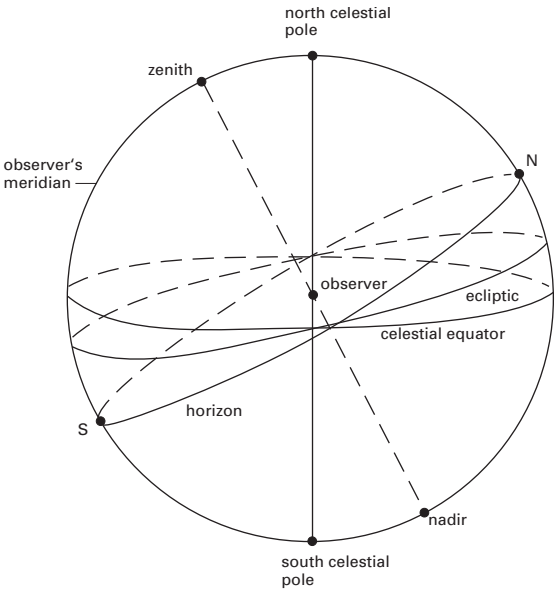
CD spectrum (circular dichroism spectrum) The spectrum obtained by plotting the variable $I_R - I_L$ against frequency of the incident electromagnetic radiation, where I_R and I_L are the absorption intensities for right- and left-circularly polarized light, respectively. One application of CD spectroscopy is to determine the configurations of complexes of transition metals in inorganic chemistry.

CE *See* CAPILLARY ELECTROPHORESIS.

celestial equator *See* EQUATOR.

celestial mechanics The study of the motions of and forces between the celestial bodies. It is based on *Newton's laws of motion and *Newton's law of gravitation. Refinements based on the general theory of *relativity are also included in the study, although the differences between the two theories are only important in a few cases.

celestial sphere The imaginary sphere on the inside of which all celestial bodies appear to be projected. The earth, and the observer, are visualized as being at the centre of the sphere and the sphere as rotating from east to west once every sidereal *day (see illustration). The sphere is used to describe



Celestial sphere.

the position of celestial bodies with respect to the earth.

celestine A mineral form of strontium sulphate, $SrSO_4$.

C

cell (in physical chemistry) **1.** A system in which two electrodes are in contact with an electrolyte. The electrodes are metal or carbon plates or rods or, in some cases, liquid metals (e.g. mercury). In an *electrolytic cell a current from an outside source is passed through the electrolyte to produce chemical change (*see* ELECTROLYSIS). In a *voltaic cell, spontaneous reactions between the electrodes and electrolyte(s) produce a potential difference between the two electrodes.

Voltaic cells can be regarded as made up of two *half cells, each composed of an electrode in contact with an electrolyte. For instance, a zinc rod dipped in zinc sulphate solution is a $Zn|Zn^{2+}$ half cell. In such a system zinc atoms dissolve as zinc ions, leaving a negative charge on the electrode

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e$$

The solution of zinc continues until the charge build-up is sufficient to prevent further ionization. There is then a potential difference between the zinc rod and its solution. This cannot be measured directly, since measurement would involve making contact with the electrolyte, thereby introducing another half cell (*see* ELECTRODE POTENTIAL). A rod of copper in copper sulphate solution comprises another half cell. In this case the spontaneous reaction is one in which copper ions in solution take electrons from the electrode and are deposited on the electrode as copper atoms. In this case, the copper acquires a positive charge.

The two half cells can be connected by using a porous pot for the liquid junction (as in the *Daniell cell) or by using a salt bridge. The resulting cell can then supply current if the electrodes are connected through an external circuit. The cell is written

$$Zn(s)|Zn^{2+}(aq)||Cu^{2+}(aq)|Cu$$

$$E = 1.10 \text{ V}$$

Here, E is the e.m.f. of the cell equal to the potential of the right-hand electrode minus that of the left-hand electrode for zero current. Note that 'right' and 'left' refer to the cell as written. Thus, the cell could be written

$$Cu(s)|Cu^{2+}(aq)||Zn^{2+}(aq)|Zn(s)$$

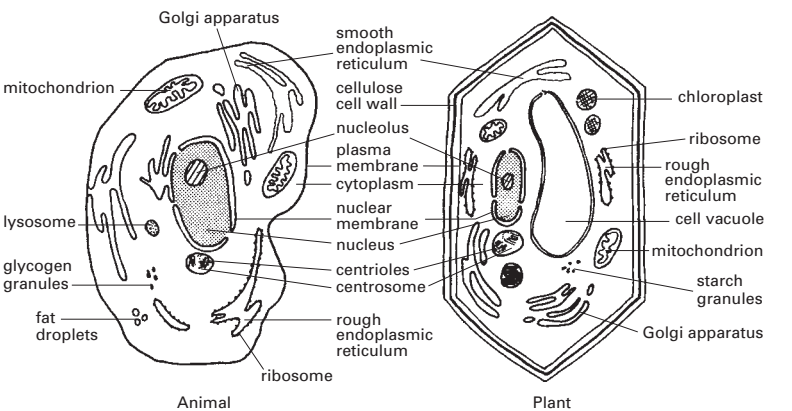
$$E = -1.10 \text{ V}$$

The overall reaction for the cell is

$$Zn(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Zn^{2+}(aq)$$

This is the direction in which the cell reaction occurs for a positive e.m.f.

The cell above is a simple example of a **chemical cell**; i.e. one in which the e.m.f. is produced by a chemical difference. **Concentration cells** are cells in which the e.m.f. is caused by a difference of concentration. This may be a difference in concentration of the electrolyte in the two half cells. Alternatively,



Cell. Generalized eukaryotic cells.

it may be an electrode concentration difference (e.g. different concentrations of metal in an amalgam, or different pressures of gas in two gas electrodes). Cells are also classified into cells **without transport** (having a single electrolyte) and **with transport** (having a liquid junction across which ions are transferred). Various types of voltaic cell exist, used as sources of current, standards of potential, and experimental set-ups for studying electrochemical reactions. *See also* DRY CELL; PRIMARY CELL; SECONDARY CELL; LITHIUM BATTERY.

2. *See* PHOTOELECTRIC CELL. **3.** *See* SOLAR CELL. **4.** *See* KERR EFFECT (for Kerr cell).

cell (in biology) The structural and functional unit of most living organisms (*compare* COENOCYTE; SYNCYTIUM). Cell size varies, but most cells are microscopic (average diameter 0.01–0.1 mm). Cells may exist as independent units of life, as in bacteria and certain protoctists, or they may form colonies or tissues, as in all plants and animals. Each cell consists of a mass of protein material that is differentiated into *cytoplasm and a *nucleus, which contains DNA. The cell is bounded by a *plasma membrane, which in the cells of plants, fungi, algae, and bacteria is surrounded by a *cell wall. There are two main types of cell. **Prokaryotic cells** (bacteria) are the more primitive. The nuclear material is not bounded by a membrane and chemicals involved in cell metabolism are associated with the plasma membrane. The shape and internal organization of cells depends on the *cytoskeleton. Reproduction is generally asexual and involves simple cell cleavage. In **eukaryotic cells** the nucleus is bounded by a nuclear envelope and the cytoplasm is divided by membranes into a system of interconnected cavities and separate compartments (**organelles**), e.g. *mitochondria, *endoplasmic reticulum, *Golgi apparatus, *lysosomes, and *ribosomes (see illustration). The shape and internal organization of cells depends on the *cytoskeleton. Reproduction can be either asexual (*see* MITOSIS) or sexual (*see* MEIOSIS). Plants and animals consist of eukaryotic cells but plant cells possess *chloroplasts and other *plastids and bear a rigid cellulose cell wall. See Chronology: Cell Biology.

SEE WEB LINKS

- Describes a wide range of topics in cell biology; developed for the University of Texas Cell Biology Graduate Program

cell body (perikaryon) The part of a *neuron that contains the nucleus. The cell processes that are involved in the transmission and reception of nervous impulses (the axon and the dendrites respectively) develop as extensions from the cell body.

cell cycle The sequence of stages that a cell passes through between one cell division and the next. The cell cycle can be divided into four main stages: (1) the **M phase**, which consists of *mitosis (nuclear division) and **cytokinesis** (cytoplasmic division); (2) the **G_1 phase**, in which there is a high rate of biosynthesis and growth; (3) the **S phase**, in which the DNA content of the cell doubles and the chromosomes replicate; (4) the **G_2 phase**, during which the final preparations for cell division are made. *Interphase consists of the G_1, S, and G_2 phases, which comprise about 90% (16–24 hours) of the total time of the cell cycle in rapidly dividing cells. The M phase lasts about 1–2 hours. A point is reached in the G_1 phase, known as the **restriction point**, after which the cell becomes committed to passing through the remainder of the cell cycle regardless of the external conditions.

cell division The formation of two or more daughter cells from a single mother cell. The nucleus divides first and this is followed by the formation of a plasma membrane between the daughter nuclei. *Mitosis produces two daughter nuclei that are identical to the original nucleus; *meiosis results in four daughter nuclei each with half the number of chromosomes in the mother cell nucleus. *See also* CELL CYCLE.

SEE WEB LINKS

- Animation comparing mitosis with meiosis

cell fusion (somatic cell hybridization) The technique of combining two cells from different tissues or species in a cell culture. The cells fuse and coalesce but their nuclei generally remain separate. However, during cell division a single spindle is formed so that each daughter cell has a single nucleus containing sets of chromosomes from each parental line. Subsequent division of the hybrid cells often results in the loss of chromosomes (and therefore genes), so that absence of a gene product in the culture can be related to the loss of a particular chromosome. Thus the technique is used to determine the control of characteristics exerted by specific chromosomes. Hybrid cells resulting from

CELL BIOLOGY

1665	English physicist Robert Hooke (1635–1703) coins the word 'cell'.
1831	Robert Brown discovers the nucleus in plant cells.
1838	German botanist Matthias Schleiden (1804–81) proposes that plants are composed of cells.
1839	Theodor Schwann states that animals are composed of cells and concludes that all living things are made up of cells.
1846	German botanist Hugo von Mohl (1805–72) coins the word 'protoplasm' for the living material of cells.
1858	German pathologist Rudolf Virchow (1821–1902) postulates that all cells arise from other cells.
1865	German botanist Julius von Sachs (1832–97) discovers the chlorophyll-containing bodies in plant cells later named chloroplasts.
1876–80	German cytologist Eduard Strasburger (1844–1912) describes cell division in plants and states that new nuclei arise from division of existing nuclei.
1882	German cytologist Walther Flemming (1843–1905) describes the process of cell division in animal cells, for which he coins the term 'mitosis'.
	Strasburger coins the words 'cytoplasm' and 'nucleoplasm'.
1886	German biologist August Weismann (1834–1914) proposes his theory of the continuity of the germ plasm.
1887	Belgian cytologist Edouard van Beneden (1846–1910) discovers that the number of chromatin-containing threadlike bodies (subsequently named chromosomes) in the cells of a given species is always the same and that the sex cells contain half this number.
1888	German anatomist Heinrich von Waldeyer (1836–1921) coins the word 'chromosome'.
1898	Camillo Golgi discovers the Golgi apparatus.
1901	US biologist Clarence McClung (1870–1946) discovers the sex chromosomes.
1911	Thomas Hunt Morgan produces the first chromosome map.
1949	Canadian geneticist Murray Barr (1908–95) discovers Barr bodies.
1955	Belgian biochemist Christian de Duve (1917–) discovers lysosomes and peroxisomes.
1956	Romanian-born US physiologist George Palade (1912–2008) discovers the role of microsomes (later renamed ribosomes).
1956	US biochemist Arthur Kornberg (1918–2007) discovers DNA polymerase.
1957	US biochemist Melvin Calvin (1911–97) publishes details of the photosynthetic carbon-fixation cycle (Calvin cycle).

cell fusion are used to produce *monoclonal antibodies.

cell junction Any of various kinds of connection between cells. **Tight junctions** form a seal between adjacent cells, particularly in epithelia, to prevent the passage of materials between cells. A primarily structural bond between cells is provided by **adherens junctions** and **desmosomes**, whereas communication between adjacent cells is facilitated by **gap junctions** in animal cells and *plasmodesmata in plant cells.

1961	South African-born British biochemist Sydney Brenner (1927–) discovers messenger RNA, in conjunction with François Jacob (1920–) and Mathew S. Meselson (1930–).
1964	US microbiologists Keith Porter and Thomas F. Roth discover the first cell receptors.
1970	US biologist Lynn Margulis (1938–) proposes the endosymbiont theory for the origin of eukaryote cellular organelles.
1971	German-born US cell biologist Günter Blobel (1936–) proposes the signal hypothesis to explain how proteins are delivered to their correct destinations within cells.
1975	British biologists J. A. Lucy and E. C. Cocking achieve successful fusion of plant and animal cells.
1979	The first 'test-tube baby', Louise Brown, is born in the UK using *in vitro* fertilization.
1982	British cell biologist Timothy Hunt (1943–) discovers cyclins, proteins that control the cell cycle. US neurologist Stanley Pruisner (1942–) discovers prions.
1983	A mouse embryo is engineered to include the gene for human growth hormone, creating a 'supermouse'.
1984	Sheep embryos are cloned for the first time.
1986	US cell biologist Robert Horvitz (1947–) identifies genes involved in programmed cell death in the nematode *Caenorhabditis elegans*. First licence granted in USA for marketing a genetically engineered organism.
1993	First successful cloning of human embryos.
1997	Birth of Dolly the sheep, the first mammal to be cloned from adult body cells.
1998	Approval given in USA for therapeutic use of a synthetic skin containing live cultured human tissue cells.
2000	The embryo of a gaur, an endangered mammal, is cloned from skin cells of an adult and develops inside the womb of a cow.
2002	A pluripotent stem cell is isolated from adult human bone marrow. Discovery of new mechanism for regulating gene expression, called a riboswitch.
2004	World's first bank for stem cells opens in north London.
2005	First cloned dog (an Afghan hound called Snuppy) is created, using somatic cell transfer, by Korean researchers led by Woo Suk Huang.

cell membrane Any membrane that is found in a living cell, especially the *plasma membrane, which forms the cell boundary. Other cell membranes include the nuclear envelope (*see* NUCLEUS); the *tonoplast, which encloses the vacuole of plant cells; and the membranes of the various cell organelles, such as the endoplasmic reticulum, Golgi apparatus, mitochondria, chloroplasts, and lysosomes.

cell sap The solution that fills the vacuoles of plant cells. It contains sugars, amino

acids, waste substances (such as tannins), and mineral salts.

cell theory The theory that was born of the findings of Matthias Schleiden (1804–81) in 1838 and Theodor *Schwann in 1839, who postulated, respectively, that plants and animals were made up of cells and that these units were basic to the structure and function of all organisms. Previously, in 1665, Robert Hooke, while examining cork under the microscope, had observed that its structure consisted of hollow boxlike units, which he called 'cells'. At the time, however, he did not realize the significance of these units, which were in fact dead cells.

cellular plastic *See* EXPANDED PLASTIC.

cellulase A carbohydrate-digesting enzyme (a **carbohydrase**) that hydrolyses cellulose to sugars, including **cellobiose** (a disaccharide consisting of two β-(1,4) linked molecules of glucose) and glucose. Cellulase breaks the β-glycosidic links that join the constituent sugar units of cellulose. *See also* RUMINANTIA.

celluloid A transparent highly flammable substance made from cellulose nitrate with a camphor plasticizer. It was formerly widely used as a thermoplastic material, especially for film (a use now discontinued owing to the flammability of celluloid).

cellulose A polysaccharide that consists of a long unbranched chain of glucose units. It is the main constituent of the cell walls of all plants, many algae, and some fungi and is responsible for providing the rigidity of the cell wall. It is an important constituent of dietary *fibre. The fibrous nature of extracted cellulose has led to its use in the textile industry for the production of cotton, artificial silk, etc.

cellulose acetate *See* CELLULOSE ETHANOATE.

cellulose ethanoate (cellulose acetate) A compound prepared by treating cellulose (cotton linters or wood pulp) with a mixture of ethanoic anhydride, ethanoic acid, and concentrated sulphuric acid. Cellulose in the cotton is ethanoylated and when the resulting solution is treated with water, cellulose ethanoate forms as a flocculent white mass. It is used in lacquers, nonshatterable glass, varnishes, and as a fibre (*see also* RAYON).

cellulose nitrate A highly flammable material made by treating cellulose (wood pulp) with concentrated nitric acid. Despite the alternative name **nitrocellulose**, the compound is in fact an ester (containing $CONO_2$ groups), not a nitro compound (which would contain $C–NO_2$). It is used in explosives (as **guncotton**) and celluloid.

cell wall A rigid outer layer that surrounds the plasma membrane of plant, fungal, algal and bacterial (but not animal) cells. It protects and/or gives shape to a cell, and in herbaceous plants provides mechanical support for the plant body. Most plant cell walls are composed of the polysaccharide *cellulose and may be strengthened by the addition of *lignin. The cell walls of fungi consist mainly of *chitin. Bacterial cell walls consist of complex polymers of polysaccharides and amino acids.

Celsius scale A *temperature scale in which the fixed points are the temperatures at standard pressure of ice in equilibrium with water (0°C) and water in equilibrium with steam (100°C). The scale, between these two temperatures, is divided in 100 degrees. The degree Celsius (°C) is equal in magnitude to the *kelvin. This scale was formerly known as the **centigrade scale**; the name was officially changed in 1948 to avoid confusion with a hundredth part of a grade. It is named after the Swedish astronomer Anders Celsius (1701–44), who devised the inverted form of this scale (ice point 100°, steam point 0°) in 1742.

cement **1.** Any of various substances used for bonding or setting to a hard material. Portland cement is a mixture of calcium silicates and aluminates made by heating limestone ($CaCO_3$) with clay (containing aluminosilicates) in a kiln. The product is ground to a fine powder. When mixed with water it sets in a few hours and then hardens over a longer period of time due to the formation of hydrated aluminates and silicates. **2. (cementum)** A thin layer of bony material that fixes teeth to the jaw. It covers the dentine of the root of a *tooth, below the level of the gum, and is attached to the *periodontal membrane lining the tooth socket in the jawbone.

cementation Any metallurgical process in which the surface of a metal is impregnated by some other substance, especially an obsolete process for making steel by heating bars of wrought iron to red heat for several days in a bed of charcoal. *See also* CASE HARDENING.

cementite *See* STEEL.

Cenozoic (Cainozoic; Kainozoic) The geological era that began about 65 million years ago and extends to the present. It followed the *Mesozoic era and is subdivided into the *Palaeogene and *Neogene periods. The Cenozoic is often known as the **Age of Mammals** as these animals evolved to become an abundant, diverse, and dominant group. Birds and flowering plants also flourished. The era saw the formation of the major mountain ranges of the Himalayas and the Alps.

centaur Any of a class of *minor planets that appear to be half-way between an asteroid and a comet and follow an unstable eccentric solar orbit between Jupiter and Neptune. Centaurs are probably *scattered disc objects that have been perturbed into their present orbits.

centi- Symbol c. A prefix used in the metric system to denote one hundredth. For example, 0.01 metre = 1 centimetre (cm).

centigrade scale *See* CELSIUS SCALE.

centipedes *See* CHILOPODA.

Central Dogma The basic belief originally held by molecular geneticists, that flow of genetic information can only occur from *DNA to *RNA to proteins. It is now known, however, that information contained within RNA molecules can also flow back to DNA, for example during the replication of *retroviruses. *See also* GENETIC CODE.

central nervous system (CNS) The part of the nervous system that coordinates all neural functions. In invertebrates it may comprise simply a few *nerve cords and their associated *ganglia. In vertebrates it consists of the *brain and the *spinal cord. The vertebrate CNS contains *reflex arcs, which produce automatic and rapid responses to particular stimuli.

central processing unit *See* CPU; COMPUTER.

centre (in neurology) A part of the nervous system, consisting of a group of nerve cells, that coordinates a particular process. An example is the respiratory centre in the vertebrate brainstem, which controls breathing movements. The stimulation of a centre will initiate the process, while destruction of the centre will prevent or impair it.

centre of curvature The centre of the sphere of which a *lens surface or curved *mirror forms a part. The **radius of curvature** is the radius of this sphere.

centre of gravity *See* CENTRE OF MASS.

centre of mass The point at which the whole mass of a body may be considered to be concentrated. This is the same as the **centre of gravity**, the point at which the whole weight of a body may be considered to act, if the body is situated in a uniform gravitational field.

centrifugal force *See* CENTRIPETAL FORCE.

centrifugal pump *See* PUMP.

centrifuge A device in which solid or liquid particles of different densities are separated by rotating them in a tube in a horizontal circle. The denser particles tend to move along the length of the tube to a greater radius of rotation, displacing the lighter particles to the other end.

centriole A cylindrical structure associated with the *centrosome in animal cells but not normally found in plant cells. Centrioles occur in pairs, orientated at right angles to each other, and are composed of *microtubules. During cell division the pair separates: a centriole migrates with each centrosome to opposite poles of the cell. Centrioles seem to act as an orientational device in the assembly of centrosomes; they are also essential for the assembly of *undulipodia.

centripetal force A force acting on a body causing it to move in a circular path. If the mass of the body is m, its constant speed v, and the radius of the circle r, the magnitude of the force is mv^2/r and it is directed towards the centre of the circle. Even though the body is moving with a constant speed v, its velocity is changing, because its direction is constantly changing. There is therefore an acceleration v^2/r towards the centre of the circle. For example, when an object is tied to a string and swung in a horizontal circle there is a tension in the string equal to mv^2/r. If the string breaks, this restraining force disappears and the object will move off in a straight line along the tangent to the circle in which it was previously moving.

In the case of a satellite (mass m) orbiting the earth (mass M), the centripetal force holding the satellite in orbit is the gravitational force, GmM/d^2, where G is the gravitational constant and d is the height of the

satellite above the centre of the earth. Therefore $GmM/d^2 = mv^2/d$. This equation enables the height of the orbit to be calculated for a given orbital velocity.

Another way of looking at this situation, which was once popular, is to assume that the centripetal force is balanced by an equal and opposite force, acting away from the centre of the circle, called the **centrifugal force**. One could then say that the satellite stays in orbit when the centrifugal force balances the gravitational force. This is, however, a confusing and misleading argument because the centrifugal force is fictitious – it does not exist. The gravitational force is not balanced by the centrifugal force: it *is* the centripetal force.

Another example is that of a car rounding a bend. To an observer in the car, a tennis ball lying on the back shelf will roll across the shelf as if it was acted on by an outward centrifugal force. However, to an observer outside the car it can be seen that the ball, because of its almost frictionless contact with the car, is continuing in its straight line motion, uninfluenced by the centripetal force. Occasionally the concept of a centrifugal force can be useful, as long as it is recognized as a fictitious force. A true centrifugal force is exerted, as a *reaction, by the rotating object on whatever is providing its centripetal force.

centroid The point within an area or volume at which the centre of mass would be if the surface or body had a uniform density. For a symmetrical area or volume it coincides with the centre of mass. For a nonsymmetrical area or volume it has to be found by integration.

centromere (kinomere; spindle attachment) The part of a *chromosome that attaches to the *spindle during cell division (*see* MEIOSIS; MITOSIS), attachment being via a platelike structure called the *kinetochore. The centromere usually appears as a constriction when chromosomes contract during cell division. The position of the centromere is a distinguishing feature of individual chromosomes.

centrosome (cell centre; centrosphere) A specialized region of all eukaryote cells except fungi, situated next to the nucleus, that organizes the microtubules of the *spindle during cell division. In animal cells it is also the main region of the cell from which the microtubules of the *cytoskeleton radiate. The centrosomes of most animal cells contain a pair of *centrioles. During *metaphase of mitosis and meiosis, the centrosome separates into two regions, each containing one of the centrioles (where present). The two regions move to opposite ends of the cell and a spindle forms between them. *See also* ASTER.

centrum *See* VERTEBRA.

cephalization The tendency among animal groups for the major sense organs, mouth, and brain to be grouped together at the front (anterior) end of the body. These are usually contained in a specialized cephalic region – the head.

Cephalopoda The most advanced class of molluscs, containing the squids, cuttlefishes, octopuses, and the extinct *ammonites. Cephalopods have a highly concentrated central nervous system within a protective cartilaginous case. The eye has a well-developed retina and is comparable to that of vertebrates. All cephalopods are predacious carnivores capable of swimming by jet propulsion; they have highly mobile tentacles for catching and holding prey.

cephalothorax The fused head and thorax of crustaceans and arachnids (spiders, scorpions), which is connected to the abdomen.

Cepheid variable A type of pulsating star that has departed from the main sequence (*see* HERTZSPRUNG–RUSSELL DIAGRAM) and is either a young star belonging to population I, (the **classical cepheids**) or an old star belonging to population II (the **W Virginis stars**). Cepheids contract and expand with great regularity over periods that range from 1 to 50 days. There is a direct correlation between a cepheid's period and its luminosity: those with the longest periods are intrinsically the brightest. This fact has allowed astronomers to use these stars to determine stellar and galactic distances with great accuracy. Most Cepheids are yellow supergiants destined to become *red giants. There are more than 700 known Cepheids within the Milky Way Galaxy and thousands more in the galaxies of the Local Group. Cepheids take their name from their prototype, Delta Cephei in the northern constellation Cepheus. *See also* POPULATION TYPE.

ceramics Inorganic materials, such as pottery, enamels, and refractories. Ceramics are metal silicates, oxides, nitrides, etc.

cerebellum The part of the vertebrate *brain concerned with the coordination and regulation of muscle activity and the maintenance of muscle tone and balance. In mammals it consists of two connected hemispheres, composed of a core of white matter and a much-folded outer layer of grey matter, and is situated above the medulla oblongata and partly beneath the cerebrum.

cerebral cortex (pallium) The layer of *grey matter that forms the outer layer of the hemispheres of the *cerebrum in many vertebrates. It is most highly developed in mammals. The cortex is responsible for the control and integration of voluntary movement and the senses of vision, hearing, touch, etc.; it also contains centres concerned with memory, language, thought, and intellect.

cerebral hemisphere Either of the two halves of the vertebrate *cerebrum.

cerebrospinal fluid (CSF) The fluid, similar in composition to *lymph, that bathes the central nervous system of vertebrates. It is secreted by the *choroid plexus into the *ventricles of the brain, filling these and other cavities in the brain and spinal cord, and is reabsorbed by veins on the brain surface. Its function is to protect the central nervous system from mechanical injury.

cerebrum The largest part of the vertebrate *brain. It consists of two **cerebral hemispheres**, which develop from the embryonic *forebrain. The hemispheres have an outer convoluted layer of grey matter – the *cerebral cortex – which contains an estimated ten billion nerve cells. Underneath this is *white matter. The two halves of the cerebrum are linked by the *corpus callosum. The function of the cerebrum is to integrate complex sensory and neural functions. The cerebrum plays a critical role in the process of learning, which involves both short-term and long-term memory.

Cerenkov, Pavel Alekseyevich (1904–90) Soviet physicist, who became a professor at the Lebedev Institute of Physics in Moscow. In 1934, while observing radioactive radiation underwater, he discovered *Cerenkov radiation. The explanation of the phenomenon was provided by Igor Tamm (1895–1971) and Ilya Frank (1908–90), and in 1958 the three scientists shared the Nobel Prize for physics.

Cerenkov counter (Cerenkov detector) A type of *counter for detecting and counting high-energy charged particles. The particles pass through a liquid and the light emitted as *Cerenkov radiation is registered by a *photomultiplier tube.

Cerenkov radiation Electromagnetic radiation, usually bluish light, emitted by a beam of high-energy charged particles passing through a transparent medium at a speed greater than the speed of light in that medium. It was discovered in 1934 by Pavel Cerenkov. The effect is similar to that of a *sonic boom when an object moves faster than the speed of sound; in this case the radiation is a shock wave set up in the electromagnetic field. Cerenkov radiation is used in the *Cerenkov counter.

cerium Symbol Ce. A silvery metallic element belonging to the *lanthanoids; a.n. 58; r.a.m. 140.12; r.d. 6.77 (20°C); m.p. 799°C; b.p. 3426°C. It occurs in allanite, bastnasite, cerite, and monazite. Four isotopes occur naturally: cerium–136, –138, –140, and –142; fifteen radioisotopes have been identified. Cerium is used in mischmetal, a rare-earth metal containing 25% cerium, for use in lighter flints. The oxide is used in the glass industry. It was discovered by Martin Klaproth (1743–1817) in 1803.

SEE WEB LINKS

- Information from the WebElements site

cermet A composite material consisting of a ceramic in combination with a sintered metal, used when a high resistance to temperature, corrosion, and abrasion is needed.

CERN (Conseil Européen pour la Recherche Nucléaire) The European Laboratory for Particle Physics, formerly known as the European Organization for Nuclear Research, which is situated close to Geneva in Switzerland and is supported by a number of European nations. It runs the **Super Proton Synchrotron** (**SPS**), which has a 7-kilometre underground tunnel enabling protons to be accelerated to 400 GeV, and the **Large Electron-Positron Collider** (**LEP**), in which 50 GeV electron and positron beams are collided. The *Large Hadron Collider began operation in September 2008.

SEE WEB LINKS

- The CERN public website

certificate (public key certificate; digital certificate) In computing, a means of authenticating public keys. *Public key encryp-

C

tion is a very powerful system but has an important security hole: there is no intrinsic guarantee that the people or organizations distributing public keys are who they claim to be. A certificate is a file issued by a trusted third party – a certificate authority – that contains both a public key and details of the person or organization to whom it belongs, which the third party declares to be correct. Crucially, the certificate is digitally signed by the third party. A recipient can verify that the certificate itself is genuine by using the third party's public key, and can then be confident in using the public key it contains. Certificate files comply with the X509 standard and their use on the Internet is governed by RFC 3280.

SEE WEB LINKS

- The Internet X509 specification

cerussite An ore of lead consisting of lead carbonate, $PbCO_3$. It is usually of secondary origin, formed by the weathering of *galena. Pure cerussite is white but the mineral may be grey due to the presence of impurities. It forms well-shaped orthorhombic crystals. It occurs in the USA, Spain, and SW Africa.

cervical vertebrae The *vertebrae of the neck. The number of cervical vertebrae varies with the vertebrate group: most mammals (including humans) have seven. Their main functions are to support the head and to provide articulating surfaces against which it can move relative to the backbone. *See* ATLAS; AXIS.

cervix A narrow or necklike part of an organ. The cervix of the uterus (**cervix uteri**) leads to the vagina. Glands in its walls produce mucus, whose viscosity changes according to the oestrous cycle. During labour, the cervix enlarges greatly to allow passage of the fetus.

Cestoda A class of flatworms (*see* PLATYHELMINTHES) comprising the tapeworms – ribbon-like parasites within the gut of vertebrates. Tapeworms are surrounded by partially digested food in the host gut so they are able to absorb nutrients through their whole body surface. The body consists of a **scolex** (head), bearing suckers and hooks for attachment, and a series of **proglottids**, which contain male and female reproductive systems. The life cycle of a tapeworm requires two hosts, the primary host usually being a predator of the secondary host. *Taenia solium* has humans for its primary host and the pig as its secondary host. Mature proglottids, containing thousands of fertilized eggs, leave the primary host with its faeces and develop into embryos and then larvae that continue the life cycle in the gut of a secondary host.

Cetacea An order of marine mammals comprising the whales, which includes what is probably the largest known animal – the blue whale (*Balaenoptera musculus*), over 30 m long and over 150 tonnes in weight. The forelimbs of whales are modified as short stabilizing flippers and the skin is very thin and almost hairless. A thick layer of blubber insulates the body against heat loss and is an important food store. Whales breathe through a dorsal blowhole, which is closed when the animal is submerged. The toothed whales (suborder Odontoceti), such as the dolphins and killer whale, are carnivorous; whalebone whales (suborder Mysticeti), such as the blue whale, feed on plankton filtered by *whalebone plates. Molecular systematics now indicates that whales are closely related to hippos and should be classified with them and other artiodactyls in the superorder Cetartiodactyla.

cetane *See* HEXADECANE.

cetane number A number that provides a measure of the ignition characteristics of a Diesel fuel when it is burnt in a standard Diesel engine. It is the percentage of cetane (hexadecane) in a mixture of cetane and 1-methylnaphthalene that has the same ignition characteristics as the fuel being tested. *Compare* OCTANE NUMBER.

Cetartiodactyla *See* ARTIODACTYLA.

CFC *See* CHLOROFLUOROCARBON.

CGE Capillary gel electrophoresis. *See* CAPILLARY ELECTROPHORESIS.

c.g.s. units A system of *units based on the centimetre, gram, and second. Derived from the metric system, it was not well suited for use with thermal quantities (based on the inconsistently defined *calorie) and with electrical quantities (in which two systems, based respectively on unit permittivity and unit permeability of free space, were used). For many scientific purposes c.g.s. units have now been replaced by *SI units.

Chadwick, Sir James (1891–1974) British physicist. After working at Manchester University under *Rutherford, he went to work with Hans *Geiger in Leipzig in 1913. In-

terned for the duration of World War I, he joined Rutherford in Cambridge after the war. In 1932 he discovered the *neutron, as predicted by Rutherford. In 1935 he was awarded the Nobel Prize, the same year in which he built Britain's first *cyclotron at Liverpool University.

chaeta A bristle, made of *chitin, occurring in annelid worms. In the earthworm they occur in small groups projecting from the skin in each segment and function in locomotion. The chaetae of polychaete worms (e.g. ragworm) are borne in larger groups on paddle-like appendages (**parapodia**).

chain A line of atoms of the same type in a molecule. In a **straight chain** the atoms are attached only to single atoms, not to groups. Propane, for instance, is a straight-chain alkane, $CH_3CH_2CH_3$, with a chain of three carbon atoms. A **branched chain** is one in which there are side groups attached to the chain. Thus, 3-ethyloctane, $CH_3CH_2CH(C_2H_5)C_5H_{11}$, is a branched-chain alkane in which there is a **side chain** (C_2H_5) attached to the third carbon atom. A **closed chain** is a *ring of atoms in a molecule; otherwise the molecule has an **open chain**.

Chain, Sir Ernst Boris (1906–79) German-born British biochemist, who began his research career at Cambridge University in 1933. Two years later he joined *Florey at Oxford, where they isolated and purified *penicillin. They also developed a method of producing the drug in large quantities and carried out its first clinical trials. The two men shared the 1945 Nobel Prize for physiology or medicine with penicillin's discoverer, Alexander *Fleming.

chain reaction A reaction that is self-sustaining as a result of the products of one step initiating a subsequent step.

In nuclear chain reactions the succession depends on production and capture of neutrons. Thus, one nucleus of the isotope uranium–235 can disintegrate with the production of two or three neutrons, which cause similar fission of adjacent nuclei. These in turn produce more neutrons. If the total amount of material exceeds a *critical mass, the chain reaction may cause an explosion.

Chemical chain reactions usually involve free radicals as intermediates. An example is the reaction of chlorine with hydrogen initiated by ultraviolet radiation. A chlorine molecule is first split into atoms:

$$Cl_2 \rightarrow Cl\cdot + Cl\cdot$$

These react with hydrogen as follows

$$Cl\cdot + H_2 \rightarrow HCl + H\cdot$$

$$H\cdot + Cl_2 \rightarrow HCl + Cl\cdot, \text{ etc.}$$

Combustion and explosion reactions involve similar free-radical chain reactions.

chair conformation *See* CONFORMATION.

chalaza **1.** A twisted strand of fibrous albumen in a bird's egg that is attached to the membrane at either end of the yolk and thus holds the yolk in position in the albumen. **2.** The part of a plant *ovule where the nucellus and integuments merge.

chalcedony A mineral consisting of a microcrystalline variety of *quartz. It occurs in several forms, including a large number of semiprecious gemstones; for example, sard, carnelian, jasper, onyx, chrysoprase, agate, and tiger's-eye.

chalcogens *See* GROUP 16 ELEMENTS.

chalconides Binary compounds formed between metals and group 16 elements; i.e. oxides, sulphides, selenides, and tellurides.

chalcopyrite (copper pyrites) A brassy yellow mineral consisting of a mixed copper–iron sulphide, $CuFeS_2$, crystallizing in the tetragonal system; the principal ore of copper. It is similar in appearance to pyrite and gold. It crystallizes in igneous rocks and hydrothermal veins associated with the upper parts of acid igneous intrusions. Chalcopyrite is the most widespread of the copper ores, occurring, for example, in Cornwall (UK), Sudbury (Canada), Chile, Tasmania (Australia), and Rio Tinto (Spain).

chalk A very fine-grained white rock composed of the fossilized skeletal remains of marine plankton known as **coccoliths** and consisting largely of *calcium carbonate ($CaCO_3$). It is used in toothpaste and cosmetics and is the characteristic rock of the *Cretaceous period. It should not be confused with blackboard 'chalk', which is made from calcium sulphate.

Chandrasekhar limit The maximum possible mass of a star that is prevented from collapsing under its own gravity by the *degeneracy pressure of electrons. For white dwarfs the **Chandrasekhar mass** is about 1.4 times the mass of the sun. There is an ana-

logue of the Chandrasekhar limit for neutron stars. For neutron stars its value is less precisely known because of uncertainties regarding the equation of state of neutron matter, but it is generally taken to be in the range of 1.5 to 3 (and almost certainly no more than 5) times the mass of the sun. It is named after Subrahmanyan Chandrasekhar (1910–95).

change of phase (change of state) A change of matter in one physical *phase (solid, liquid, or gas) into another. The change is invariably accompanied by the evolution or absorption of energy, even if it takes place at constant temperature (*see* LATENT HEAT).

channel **1.** The region between the source and the drain in a field-effect *transistor. The conductivity of the channel is controlled by the voltage applied to the gate. **2.** A path, or a specified frequency band, along which signals, information, or data flow. **3.** A pore formed by a protein molecule in a plasma membrane that aids the diffusion of certain substances into and out of the cell. These substances are usually charged ions (*see* ION CHANNEL) or lipid-insoluble molecules. *See also* TRANSPORT PROTEIN.

chaos Unpredictable and seemingly random behaviour occurring in a system that should be governed by deterministic laws. In such systems, the equations that describe the way the system changes with time are nonlinear and involve several variables. Consequently, they are very sensitive to the initial conditions, and a very small initial difference may make an enormous change to the future state of the system. Originally, the theory was introduced to describe unpredictability in meteorology, as exemplified by the **butterfly effect**. It has been suggested that the dynamical equations governing the weather are so sensitive to the initial data that whether or not a butterfly flaps its wings in one part of the world may make the difference between a tornado occurring or not occurring in some other part of the world. Chaos theory has subsequently been extended to other branches of science; for example to turbulent flow, planetary dynamics, and electrical oscillations in physics, and to combustion processes and *oscillating reactions in chemistry. *See also* ATTRACTOR; FRACTAL.

chaotic reaction A type of chemical reaction in which the concentrations of reactants show chaotic behaviour. This may occur when the reaction involves a large number of complex interlinked steps. Under such conditions, it is possible for the reaction to display unpredictable changes with time. *See also* OSCILLATING REACTION.

character (trait) A distinctive inherited feature of an organism. Organisms in a population may display different aspects of a particular character, e.g. the A, B, and O human blood groups (*see* ABO SYSTEM) are different aspects of the blood group character.

characteristic *See* LOGARITHM.

charcoal A porous form of carbon produced by the destructive distillation of organic material. Charcoal from wood is used as a fuel. All forms of charcoal are porous and are used for adsorbing gases and purifying and clarifying liquids. There are several types depending on the source. Charcoal from coconut shells is a particularly good gas adsorbent. **Animal charcoal** (or **bone black**) is made by heating bones and dissolving out the calcium phosphates and other mineral salts with acid. It is used in sugar refining. **Activated charcoal** is charcoal that has been activated for adsorption by steaming or by heating in a vacuum.

charge A property of some *elementary particles that gives rise to an interaction between them and consequently to the host of material phenomena described as electrical. Charge occurs in nature in two forms, conventionally described as **positive** and **negative** in order to distinguish between the two kinds of interaction between particles. Two particles that have similar charges (both negative or both positive) interact by repelling each other; two particles that have dissimilar charges (one positive, one negative) interact by attracting each other. The size of the interaction is determined by *Coulomb's law.

The natural unit of negative charge is the charge on an *electron, which is equal but opposite in effect to the positive charge on the proton. Large-scale matter that consists of equal numbers of electrons and protons is electrically neutral. If there is an excess of electrons the body is negatively charged; an excess of protons results in a positive charge. A flow of charged particles, especially a flow of electrons, constitutes an electric current. Charge is measured in coulombs, the charge on an electron being 1.602×10^{-19} coulombs.

charge carrier The entity that transports electric charge in an electric current. The nature of the carrier depends on the type of conductor: in metals, the charge carriers are electrons; in *semiconductors the carriers are electrons (*n*-type) or positive *holes (*p*-type); in gases the carriers are positive ions and electrons; in electrolytes they are positive and negative ions.

charge conjugation Symbol *C*. A property of elementary particles that determines the difference between a particle and its *antiparticle. The property is not restricted to electrically charged particles (i.e. it applies to neutral particles such as the neutron). *See* CP INVARIANCE.

charge density **1.** The electric charge per unit volume of a medium or body (**volume charge density**). **2.** The electric charge per unit surface area of a body (**surface charge density**).

charge-transfer complex A chemical compound in which there is weak coordination involving the transfer of charge between two molecules. An example is phenoquinone, in which the phenol and quinone molecules are not held together by formal chemical bonds but are associated by transfer of charge between the compounds' aromatic ring systems.

Charles, Jacques Alexandre César (1746–1823) French chemist and physicist, who became professor of physics at the Paris Conservatoire des Arts et Métiers. He is best remembered for discovering *Charles' law (1787), relating to the volume and temperature of a gas. In 1783 he became the first person to make an ascent in a hydrogen balloon.

Charles' law The volume of a fixed mass of gas at constant pressure expands by a constant fraction of its volume at 0°C for each Celsius degree or kelvin its temperature is raised. For any *ideal gas the fraction is approximately 1/273. This can be expressed by the equation

$$V = V_0(1 + t/273),$$

where V_0 is the volume at 0°C and V is its volume at t°C. This is equivalent to the statement that the volume of a fixed mass of gas at constant pressure is proportional to its thermodynamic temperature, $V = kT$, where k is a constant. The law resulted from experiments begun around 1787 by Jacques Charles but was properly established only by the more accurate results published in 1802 by the French scientist Joseph Gay-Lussac (1778–1850). Thus the law is also known as **Gay-Lussac's law**. An equation similar to that given above applies to pressures for ideal gases:

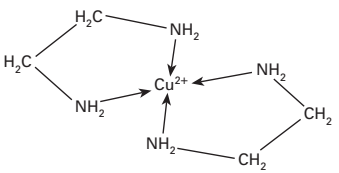
$$p = p_0(1 + t/273),$$

a relationship known as **Charles' law of pressures**. *See also* GAS LAWS.

charm A property of certain *elementary particles that is expressed as a quantum number and is used in the quark model. It was originally suggested to account for the unusually long lifetime of the *psi particle. In this theory the three original quark–antiquark pairs were supplemented by a fourth pair – the charmed quark and its antiquark. The psi particle itself is a meson having zero charm as it consists of the charmed pair. However, charmed *hadrons do exist; they are said to possess **naked charm**. Charm is thought to be conserved in strong and electromagnetic interactions.

cheddite Any of a group of high explosives made from nitro compounds mixed with sodium or potassium chlorate.

chelate An inorganic complex in which a *ligand is coordinated to a metal ion at two (or more) points, so that there is a ring of atoms including the metal (see formula). The process is known as **chelation**. A ligand such as diaminoethane, which coordinates at two points, is said to be **bidentate** ('having two teeth'). Other ligands are **tridentate**, **tetradentate**, etc. The angle made by two bonds coordinating to the metal atom is the **bite angle** of the ligand. *See also* SEQUESTRATION.



Chelate. Chelate formed by coordination of two molecules of $H_2N(CH_2)2NH_2$.

chelate effect The effect in which a chelate complex is generally more stable than the analogous complex formed with monodentate ligands. For example, the complex ion $[Cu(en)(OH_2)_4]^{2+}$ is more stable

than the complex ion $[Cu(NH_3)_2(OH_2)_4]^{2+}$. Here, en denotes the bidentate ethylene diamine (1,2-diaminoethane) ligand. The main cause of the chelate effect is the effect of reaction entropy when the complex is formed. Thus, the reaction

$$[Cu(OH_2)_6]^{2+} + en \rightarrow [Cu(en)(OH_2)_4 + 2H_2O$$

results in a net increase in the number of molecules (from 2 to 3). The reaction

$$[Cu(OH_2)_6]^{2+} + 2NH_3 \rightarrow Cu(NH_3)2(OH_2)_4 + 2H_2O$$

involves no net increase in the number of molecules. As a result, the chelate reaction has a larger reaction entropy and is more favourable.

chelicerae The first pair of appendages on the head of arachnids and other *arthropods of the phylum Chelicerata. These appendages take the form of pincers or claws and are used for grasping or tearing food.

ChemDraw A widely used chemical drawing and modelling program produced by CambridgeSoft.

SEE WEB LINKS

- The CambridgeSoft website, giving details about ChemDraw and associated software

chemical bond A strong force of attraction holding atoms together in a molecule or crystal. Typically chemical bonds have energies of about 1000 kJ mol^{-1} and are distinguished from the much weaker forces between molecules (*see* VAN DER WAALS' FORCE). There are various types.

Ionic (or **electrovalent**) bonds can be formed by transfer of electrons. For instance, the calcium atom has an electron configuration of $[Ar]4s^2$, i.e. it has two electrons in its outer shell. The chlorine atom is $[Ne]3s^23p^5$, with seven outer electrons. If the calcium atom transfers two electrons, one to each chlorine atom, it becomes a Ca^{2+} ion with the stable configuration of an inert gas [Ar]. At the same time each chlorine, having gained one electron, becomes a Cl^- ion, also with an inert-gas configuration [Ar]. The bonding in calcium chloride is the electrostatic attraction between the ions.

Covalent bonds are formed by sharing of valence electrons rather than by transfer. For instance, hydrogen atoms have one outer electron ($1s^1$). In the hydrogen molecule, H_2, each atom contributes 1 electron to the bond. Consequently, each hydrogen atom has control of 2 electrons – one of its own and the second from the other atom – giving it the electron configuration of an inert gas [He]. In the water molecule, H_2O, the oxygen atom, with six outer electrons, gains control of an extra two electrons supplied by the two hydrogen atoms. This gives it the configuration [Ne]. Similarly, each hydrogen atom gains control of an extra electron from the oxygen, and has the [He] electron configuration.

A particular type of covalent bond is one in which one of the atoms supplies both the electrons. These are known as **coordinate** (**semipolar** or **dative**) bonds, and written A→B, where the direction of the arrow denotes the direction in which electrons are donated.

Covalent or coordinate bonds in which one pair of electrons is shared are **electron-pair bonds** and are known as **single bonds**. Atoms can also share two pairs of electrons to form **double bonds** or three pairs in **triple bonds**. *See* ORBITAL.

In a compound such as sodium chloride, Na^+Cl^-, there is probably complete transfer of electrons in forming the ionic bond (the bond is said to be **heteropolar**). Alternatively, in the hydrogen molecule H–H, the pair of electrons is equally shared between the two atoms (the bond is **homopolar**). Between these two extremes, there is a whole range of **intermediate bonds**, which have both ionic and covalent contributions. Thus, in hydrogen chloride, H–Cl, the bonding is predominantly covalent with one pair of electrons shared between the two atoms. However, the chlorine atom is more electronegative than the hydrogen and has more control over the electron pair; i.e. the molecule is polarized with a positive charge on the hydrogen and a negative charge on the chlorine, forming a *dipole. *See also* BANANA BOND; HYDROGEN BOND; METALLIC BOND; MULTICENTRE BOND; MULTIPLE BOND.

chemical cell *See* CELL.

chemical combination The combination of elements to give compounds. There are three laws of chemical combination.
(1) The **law of constant composition** states that the proportions of the elements in a compound are always the same, no matter how the compound is made. It is also called the **law of constant proportions** or **definite proportions**.
(2) The **law of multiple proportions** states that when two elements A and B combine to form more than one compound, then the

masses of B that combine with a fixed mass of A are in simple ratio to one another. For example, carbon forms two oxides. In one, 12 grams of carbon is combined with 16 grams of oxygen (CO); in the other 12 grams of carbon is combined with 32 grams of oxygen (CO_2). The oxygen masses combining with a fixed mass of carbon are in the ratio 16:32, i.e. 1:2.
(3) The **law of equivalent proportions** states that if two elements A and B each form a compound with a third element C, then a compound of A and B will contain A and B in the relative proportions in which they react with C. For example, sulphur and carbon both form compounds with hydrogen. In methane 12 g of carbon react with 4 g of hydrogen. In hydrogen sulphide, 32 g of sulphur react with 2 g of hydrogen (i.e. 64 g of S for 4 g of hydrogen). Sulphur and carbon form a compound in which the C:S ratio is 12:64 (i.e. CS_2). The law is sometimes called the law of **reciprocal proportions**.

chemical control The use of chemicals to kill pests (*see* PESTICIDE). *Compare* BIOLOGICAL CONTROL.

chemical dating An absolute *dating technique that depends on measuring the chemical composition of a specimen. Chemical dating can be used when the specimen is known to undergo slow chemical change at a known rate. For instance, phosphate in buried bones is slowly replaced by fluoride ions from the ground water. Measurement of the proportion of fluorine present gives a rough estimate of the time that the bones have been in the ground. Another, more accurate, method depends on the fact that amino acids in living organisms are L-optical isomers. After death, these racemize and the age of bones can be estimated by measuring the relative amounts of D- and L-amino acids present.

chemical engineering The study of the design, manufacture, and operation of plant and machinery in industrial chemical processes.

chemical equation A way of denoting a chemical reaction using the symbols for the participating particles (atoms, molecules, ions, etc.); for example,

$$xA + yB \rightarrow zC + wD$$

The single arrow is used for an irreversible reaction; double arrows ($\rightleftharpoons$) are used for reversible reactions. When reactions involve different phases it is usual to put the phase in brackets after the symbol (s = solid; l = liquid; g = gas; aq = aqueous). The numbers *x*, *y*, *z*, and *w*, showing the relative numbers of molecules reacting, are called the **stoichiometric coefficients**. The sum of the coefficients of the reactants minus the sum of the coefficients of the products ($x + y - z - w$ in the example) is the **stoichiometric sum**. If this is zero the equation is balanced. Sometimes a generalized chemical equation is considered

$$\nu_1A_1 + \nu_2A_2 + \ldots \rightarrow \ldots \nu_nA_n + \nu_{n+1}A_{n+1} \ldots$$

In this case the reaction can be written $\Sigma\nu_iA_i = 0$, where the convention is that stoichiometric coefficients are positive for reactants and negative for products. The stoichiometric sum is $\Sigma\nu_i$.

chemical equilibrium A reversible chemical reaction in which the concentrations of reactants and products are not changing with time because the system is in thermodynamic equilibrium. For example, the reversible reaction

$$3H_2 + N_2 \rightleftharpoons 2NH_3$$

is in chemical equilibrium when the rate of the **forward reaction**

$$3H_2 + N_2 \rightarrow 2NH_3$$

is equal to the rate of the **back reaction**

$$2NH_3 \rightarrow 3H_2 + N_2$$

See also EQUILIBRIUM CONSTANT.

chemical equivalent *See* EQUIVALENT WEIGHT.

chemical fossil Any of various organic compounds found in ancient geological strata that appear to be biological in origin and are assumed to indicate that life existed when the rocks were formed. The presence of chemical fossils in Archaean strata indicates that life existed over 3500 million years ago.

chemical potential Symbol: μ. For a given component in a mixture, the coefficient $\partial G/\partial n$, where G is the Gibbs free energy and n the amount of substance of the component. The chemical potential is the change in Gibbs free energy with respect to change in amount of the component, with pressure, temperature, and amounts of other components being constant. Components are in equilibrium if their chemical potentials are equal.

chemical reaction A change in which one

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or more chemical elements or compounds (the **reactants**) form new compounds (the **products**). All reactions are to some extent **reversible**; i.e. the products can also react to give the original reactants. However, in many cases the extent of this back reaction is negligibly small, and the reaction is regarded as **irreversible**.

chemical shift A change in the normal wavelength of absorption or emission of electromagnetic wavelength in a process in which there is a nuclear energy change (as in the *Mössbauer effect and *nuclear magnetic resonance) or a change in electron energy levels in the inner shells of an atom (as in X-ray *photoelectron spectroscopy).

chemical warfare The use of toxic chemical substances in warfare or military operations. A large number of chemicals have been designed or used for warfare, including pulmonary agents (chlorine, *carbonyl chloride, *diphosgene), blister agents (lewisite, *sulphur mustard, *nitrogen mustard), and the *nerve agents. Chemical warfare agents are classified as weapons of mass destruction by the United Nations.

chemiluminescence *See* LUMINESCENCE.

chemiosmotic theory A theory postulated by the British biochemist Peter Mitchell (1920–92) to explain the formation of ATP in the mitochondrial *electron transport chain. As electrons are transferred along the electron carrier system in the inner mitochondrial membrane, hydrogen ions (protons) are actively transported (via *hydrogen carriers) into the space between the inner and outer mitochondrial membranes, which thus contains a higher concentration of protons than the matrix. This creates an electrochemical gradient across the inner membrane, down which protons move back into the matrix. This movement occurs through special channels associated with ATP synthetase, the enzyme that catalyses the conversion of ADP to ATP, and is coupled with the phosphorylation of ADP. A similar gradient is created across the thylakoid membranes of chloroplasts during the light-dependent reactions of *photosynthesis (*see* PHOTOPHOSPHORYLATION).

chemisorption *See* ADSORPTION.

chemistry The study of the elements and the compounds they form. Chemistry is mainly concerned with effects that depend on the outer electrons in atoms. *See* BIOCHEMISTRY; GEOCHEMISTRY; INORGANIC CHEMISTRY; ORGANIC CHEMISTRY; PHYSICAL CHEMISTRY.

chemoautotroph *See* AUTOTROPHIC NUTRITION; CHEMOSYNTHESIS.

chemoinformatics The branch of chemistry concerned with methods of representing molecules and reactions and with the design and use of databases for storing chemical information.

chemoorganotroph An organism, especially a microorganism, that obtains its energy by the oxidation of organic compounds.

chemoreceptor A *receptor that detects the presence of particular chemicals and (in multicellular organisms) transmits this information to sensory nerves. Examples include the *taste buds and the receptors in the *carotid body.

chemosynthesis A type of *autotrophic nutrition in which organisms (called **chemoautotrophs**) synthesize organic materials using energy derived from the oxidation of inorganic chemicals, rather than from sunlight. Most chemoautotrophs are bacteria, including *Nitrosomonas*, which oxidizes ammonium to nitrite, and *Thiobacillus*, which oxidizes sulphur to sulphate.

chemosystematics *See* SYSTEMATICS.

chemotaxis *See* TAXIS.

chemotaxonomy The *classification of plants and microorganisms based on similarities and differences in their natural products and the biochemical pathways involved in their manufacture. *See also* TAXONOMY.

chemotherapy The use of chemicals, especially drugs, in the treatment of disease. The term is often used specifically to denote drug therapy for cancer, as distinct from treatments with radiation (radiotherapy).

chemotropism The growth or movement of a plant or plant part in response to a chemical stimulus. An example is the growth of a pollen tube down the style during fertilization in response to the presence of sugars in the style.

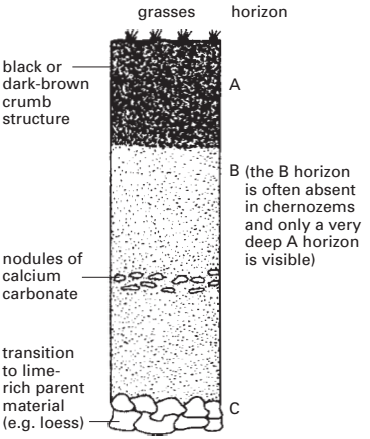
ChemSketch A commonly used chemical drawing program for 2D and 3D structures, copyright of Advanced Chemistry Development, Inc. The program has certain additional features including calculation of molecular weight, calculation of percentages

of elements present, IUPAC name generation, and viewing in RasMol.

SEE WEB LINKS

- Details and download from Advanced Chemistry Development website

chernozem (black earth) A type of soil that is characteristic of the continental interiors of the mid-latitudes, in which grassland formed the natural vegetation. Chernozems occur across the Russian steppes and parts of Romania and Hungary; these soils also occur in North America. The deep surface layer (A horizon) of a chernozem is black and rich in alkaline humus derived from the decomposition of the natural grassland vegetation. The underlying horizon contains calcium carbonate concretions. Chernozems are important agriculturally and most have been ploughed up for cereal production.



Chernozem soil profile.

chert *See* FLINT.

chiasma (*pl.* **chiasmata**) The point at which paired *homologous chromosomes remain in contact as they begin to separate during the first prophase of *meiosis, forming a cross shape. A number of chiasmata can usually be identified and at these points *crossing over occurs.

Chile saltpetre A commercial mineral largely composed of *sodium nitrate from the caliche deposits in Chile. Before the ammonia-oxidation process for nitrates most imported Chilean saltpetre was used by the chemical industry; its principal use today is as an agricultural source of nitrogen.

Chilopoda A class of terrestrial *arthropods belonging to the subphylum *Myriapoda and comprising the centipedes, characterized by a distinct head bearing one pair of poison jaws and 15–177 body segments, each bearing one pair of similar legs. Centipedes are fast-moving predators.

chimaera An organism composed of tissues that are genetically different. Chimaeras can develop if a *mutation occurs in a cell of a developing embryo. All the cells arising from it have the mutation and therefore produce tissue that is genetically different from adjacent tissue, e.g. brown patches in otherwise blue eyes in humans. *Graft hybrids are examples of plant chimaeras.

Chime A plug-in that allows chemical structures to be displayed within a web page. The structures, which are embedded as mol files, can be viewed interactively; i.e. they can be rotated, expanded, exported, and rendered in *RasMol. The program is the copyright of MDL Information Systems, Inc., and is available free (subject to a license agreement).

SEE WEB LINKS

- A downloadable version of Chime at the MDL website (free registration required)

china clay *See* KAOLIN.

Chinese white *See* ZINC OXIDE.

chip *See* SILICON CHIP.

chirality The property of existing in left- and right-handed structural forms. *See* OPTICAL ACTIVITY.

chirality element The part of a molecule that makes it exist in left- and right-handed forms. In most cases this is a **chirality centre** (i.e. an asymmetric atom). In certain cases the element is a **chirality axis**. For example, in allenenes of the type $R_1R_2C{=}C{=}CR_3R_4$ the C=C=C chain is a chirality axis. Certain ring compounds may display chirality as a result of a **chirality plane** in the molecule.

Chiron A minor planet discovered in 1977. It has an orbit of 50.68 years that, unlike other known minor planets, lies almost entirely outside that of Saturn. Its diameter is uncertain, but appears to be of the order of 300 km.

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chirooptical spectroscopy Spectroscopy making use of the properties of chiral substances when they interact with polarized light of various wavelengths. **Optical rotatory dispersion** (the change of optical rotation with wavelength) and circular dichroism are old examples of chirooptical spectroscopy. More recent types of chirooptical spectroscopy involve infrared radiation and Raman spectroscopy. Chirooptical spectroscopy is used in the analysis of the structure of molecules.

Chiroptera An order of flying mammals comprising the bats. Their membranous wings are supported by very elongated forelimbs and digits and stretch along the sides of the body to the hindlimbs and tail. Whenever bats rest they allow their body temperature to fall, hibernating in winter when food is scarce. Most bats are nocturnal; their ears are enlarged and specialized for *echolocation, which they use to hunt prey and avoid obstacles. Bats feed variously on insects, fruit, nectar, or blood.

chi-square distribution The distribution of the sum of the squares of random variables with standard normal distributions. For example, if x_1, x_2, …, x_i, … are independent variables with standard normal distribution, then

$$\chi^2 = \Sigma x_i^2$$

has a chi-square distribution with n degrees of freedom, written $\chi_n^{\,r}$. The mean and variance are n and $2n$, respectively. The values $\chi_n^{\,2}(\alpha)$ for which

$$P(\chi^2 \leq \chi_n^{\,2}(\alpha)) = \alpha$$

are tabulated for various values of n.

chi-squared test A procedure in *statistics to test how well a frequency distribution matches one predicted theoretically. Statistical tables are used to assess the significance of the result obtained by calculating $\chi^2 = \Sigma(O - E)2/E$, where O are the observed frequencies and E are the predicted frequencies.

chitin A *polysaccharide comprising chains of *N*-acetyl-D-glucosamine, a derivative of glucose. Chitin is structurally very similar to cellulose and serves to strengthen the supporting structures of various invertebrates. It also occurs in fungi.

chloral *See* TRICHLOROETHANAL.

chloral hydrate *See* 2,2,2-TRICHLOROETHANEDIOL.

chlorates Salts of the chloric acids; i.e. salts containing the ions ClO^- (chlorate(I) or **hypochlorite**), ClO_2^- (chlorate(III) or **chlorite**), ClO_3^- (chlorate(V)), or ClO_4^- (chlorate(VII) or **perchlorate**). When used without specification of an oxidation state the term 'chlorate' refers to a chlorate(V) salt.

chlorenchyma *Parenchyma tissue that contains chloroplasts and is photosynthetic. Chlorenchyma makes up the mesophyll tissue of plant leaves and is also found in the stems of certain plant species. *Compare* COLLENCHYMA (*see* GROUND TISSUES); SCLERENCHYMA.

chloric acid Any of the oxoacids of chlorine: *chloric(I) acid, *chloric(III) acid, *chloric(V) acid, and *chloric(VII) acid. The term is commonly used without specification of the oxidation state of chlorine to mean chloric(V) acid, $HClO_3$.

chloric(I) acid (hypochlorous acid) A liquid acid that is stable only in solution, HOCl. It may be prepared by the reaction of chlorine with an agitated suspension of mercury(II) oxide. Because the disproportionation of the ion ClO^- is slow at low temperatures chloric(I) acid may be produced, along with chloride ions by the reaction of chlorine with water at 0°C. At higher temperatures disproportionation to the chlorate(V) ion, ClO_3^-, takes place. Chloric(I) acid is a very weak acid but is a mild oxidizing agent and is widely used as a bleaching agent.

chloric(III) acid (chlorous acid) A pale-yellow acid known only in solution, $HClO_2$. It is formed by the reaction of chlorine dioxide and water and is a weak acid and an oxidizing agent.

chloric(V) acid (chloric acid) A colourless unstable liquid, $HClO_3$; r.d. 1.2; m.p. <–20°C; decomposes at 40°C. It is best prepared by the reaction of barium chlorate with sulphuric acid although chloric(V) acid is also formed by the disproportionation of chloric(I) acid in hot solutions. It is both a strong acid and a powerful oxidizing agent; hot solutions of the acid or its salts have been known to detonate in contact with readily oxidized organic material.

chloric(VII) acid (perchloric acid) An unstable liquid acid, $HClO_4$; r.d. 1.76; m.p. –112°C; b.p. 39°C (50 mmHg); explodes at about 90°C at atmospheric pressure. There is

also a monohydrate (r.d. 1.88 (solid), 1.77 (liquid); m.p. 48°C; explodes at about 110°C) and a dihydrate (r.d. 1.65; m.p. –17.8°C; b.p. 200°C). Commercial chloric(VII) acid is a water azeotrope, which is 72.5% $HClO_4$, boiling at 203°C. The anhydrous acid may be prepared by vacuum distillation of the concentrated acid in the presence of magnesium perchlorate as a dehydrating agent. Chloric(VII) acid is both a strong acid and a strong oxidizing agent. It is widely used to decompose organic materials prior to analysis, e.g. samples of animal or vegetable matter requiring heavy-metal analysis.

chloride *See* HALIDE.

chloride shift The movement of chloride ions (Cl^-) into red blood cells. Carbon dioxide reacts with water to form carbonic acid in the red blood cells (*see* CARBONIC ANHYDRASE). The carbonic acid then dissociates into hydrogencarbonate ions (HCO_3^-) and hydrogen ions (H^+). The plasma membrane is relatively permeable to negative ions. Therefore the hydrogencarbonate ions diffuse out of the cell into the blood plasma, leaving the hydrogen ions, which create a net positive charge; this is neutralized by the diffusion of chloride ions from the plasma into the cell.

chlorinating agent A chemical reagent that introduces chlorine atoms into a compound or substitutes chlorine for some other group. Examples include phosphorus pentachloride, PCl_5, and sulphur dichloride oxide (thionyl chloride, $SOCl_2$).

chlorination **1.** A chemical reaction in which a chlorine atom is introduced into a compound. *See* HALOGENATION. **2.** The treatment of water with chlorine to disinfect it.

chlorine Symbol Cl. A *halogen element; a.n. 17; r.a.m. 35.453; d. 3.214 g dm^{-3}; m.p. –100.98°C; b.p. –34.6°C. It is a poisonous greenish-yellow gas and occurs widely in nature as sodium chloride in seawater and as halite (NaCl), carnallite ($KCl.MgCl_2.6H_2O$), and sylvite (KCl). It is manufactured by the electrolysis of brine and also obtained in the *Downs process for making sodium. It has many applications, including the chlorination of drinking water, bleaching, and the manufacture of a large number of organic chemicals.

It reacts directly with many elements and compounds and is a strong oxidizing agent. Chlorine compounds contain the element in the 1, 3, 5, and 7 oxidation states. It was discovered by Karl Scheele in 1774 and Humphry Davy confirmed it as an element in 1810.

SEE WEB LINKS

- Information from the WebElements site

chlorine dioxide A yellowish-red explosive gas, ClO_2; d. 3.09 g dm^{-3}; m.p. –59.5°C; b.p. 9.9°C. It is soluble in cold water but decomposed by hot water to give chloric(VII) acid, chlorine, and oxygen. Because of its high reactivity, chlorine dioxide is best prepared by the reaction of sodium chlorate and moist oxalic acid at 90°–100°C, as the product is then diluted by liberated carbon dioxide. Commercially the gas is produced by the reaction of sulphuric acid containing chloride ions with sulphur dioxide. Chlorine dioxide is widely used as a bleach in flour milling and in wood pulping and also finds application in water purification.

chlorine monoxide *See* DICHLORINE OXIDE.

chlorite **1.** *See* CHLORATES. **2.** A group of layered silicate minerals, usually green or white in colour, that are similar to the micas in structure and crystallize in the monoclinic system. Chlorites are composed of complex silicates of aluminium, magnesium, and iron in combination with water, with the formula $(Mg,Al,Fe)_{12}(Si,Al)_8O_{20}(OH)_{16}$. They are most common in low-grade metamorphic rocks and also occur as secondary minerals in igneous rocks as alteration products of pyroxenes, amphiboles, and micas. The term is derived from *chloros*, the Greek word for green.

chloroacetic acids *See* CHLOROETHANOIC ACIDS.

chlorobenzene A colourless highly flammable liquid, C_6H_5Cl; r.d. 1.106; m.p. –45.43°C; b.p. 131.85°C. It is prepared by the direct chlorination of benzene using a halogen carrier (*see* FRIEDEL–CRAFTS REACTION), or manufactured by the *Raschig process. It is used mainly as an industrial solvent.

2-chlorobuta-1,3-diene (chloroprene) A colourless liquid chlorinated diene, CH_2:CClCH:CH_2; r.d. 0.96; b.p. 59°C. It is polymerized to make synthetic rubbers (e.g. neoprene).

chloroethane (ethyl chloride) A colourless flammable gas, C_2H_5Cl; m.p. –136.4°C; b.p. 12.3°C. It is made by reaction of ethene

and hydrogen chloride and used in making lead tetraethyl for petrol.

chloroethanoic acids (chloroacetic acids) Three acids in which hydrogen atoms in the methyl group of ethanoic acid have been replaced by chlorine atoms. They are: **monochloroethanoic acid** ($CH_2ClCOOH$); **dichloroethanoic acid** ($CHCl_2COOH$); **trichloroethanoic acid** (CCl_3COOH). The presence of chlorine atoms in the methyl group causes electron withdrawal from the COOH group and makes the chloroethanoic acids stronger acids than ethanoic acid itself. The K_a values (in moles dm^{-3} at 25°C) are

CH_3COOH 1.7×10^{-5}

$CH_2ClCOOH$ 1.3×10^{-3}

$CHCl_2COOH$ 5.0×10^{-2}

CCl_3COOH 2.3×10^{-1}

chloroethene (vinyl chloride) A gaseous compound, CH_2:CHCl; r.d. 0.911; m.p. –153.8°C; b.p. –13.37°C. It is made by chlorinating ethene to give dichloroethane, then removing HCl:

$$C_2H_4 + Cl_2 \rightarrow CH_2ClCH_2Cl \rightarrow CH_2CHCl$$

The compound is used in making PVC.

chlorofluorocarbon (CFC) A type of compound in which some or all of the hydrogen atoms of a hydrocarbon (usually an alkane) have been replaced by chlorine and fluorine atoms (*see* HALOCARBONS). CFCs are used in oils, polymers, and solvents, and in the manufacture of rigid packaging foam. A commonly encountered commercial name for these compounds is **freon**. Most chlorofluorocarbons are chemically unreactive and are stable at high temperatures. Because of this, they can diffuse unchanged into the upper atmosphere. Their former widespread use in aerosols and refrigerator coolants led to increased concentrations in the upper atmosphere, where photochemical reactions cause them to break down and react with ozone (*see* OZONE LAYER). They also contribute to the greenhouse effect. For these reasons, CFCs have now largely been replaced by less damaging alternatives, such as hydrofluorcarbons. *See also* POLLUTION.

chloroform *See* TRICHLOROMETHANE.

chloromethane (methyl chloride) A colourless flammable gas, CH_3Cl; r.d. 0.916; m.p. –97.1°C; b.p. –24.2°C. It is a *haloalkane, made by direct chlorination of methane and used as a local anaesthetic and refrigerant.

chlorophyll One of two pigments (**chlorophyll a** and **chlorophyll b**) responsible for the green colour of most plants. Chlorophyll molecules are the principal sites of light absorption in the light-dependent reactions of *photosynthesis. They are magnesium-containing *porphyrins, chemically related to *cytochrome and *haemoglobin. *See also* BACTERIOCHLOROPHYLL.

Chlorophyta (green algae) A large phylum of *algae, the members of which possess chlorophylls *a* and *b*, store food reserves as starch, and have cellulose cell walls. In these respects, and on the basis of molecular studies, they resemble plants more closely than do any of the other algal phyla and are placed with them in the supergroup Archaeplastida (*see* PLANT). The Chlorophyta are widely distributed and diverse in form. Unicellular forms may occur singly (sometimes with *flagella for motility) or in colonies, while multicellular forms may be filamentous (e.g. *Spirogyra*) or platelike (e.g. *Ulva*).

chloroplast Any of the chlorophyll-containing organelles (*see* PLASTID) that are found in large numbers in those plant cells undergoing *photosynthesis. Chloroplasts are typically lens-shaped and bounded by a double membrane. They contain membranous structures called **thylakoids**, which are piled up into stacks (*see* GRANUM), surrounded by a gel-like matrix (**stroma**). The light-dependent reactions of photosynthesis occur on the thylakoid membranes, while the light-independent reactions take place in the stroma.

chloroplatinic acid A reddish crystalline compound, H_2PtCl_6, made by dissolving platinum in aqua regia.

chloroprene *See* 2-CHLOROBUTA-1,3-DIENE.

chlorosis The abnormal condition in plant stems and leaves in which synthesis of the green pigment chlorophyll is inhibited, resulting in a pale yellow coloration. This may be caused by lack of light, mineral deficiency, infection (particularly by viruses), or genetic factors.

chlorosulphanes *See* DISULPHUR DICHLORIDE.

chlorous acid *See* CHLORIC(III) ACID.

chloroxybacteria (grass-green bacteria) *See* CYANOBACTERIA.

choanae (internal nares) *See* NARES.

choke A coil of wire with high inductance and low resistance. It is used in radio circuits to impede the passage of audio-frequency or radio-frequency currents or to smooth the output of a rectifying circuit.

choke damp *See* BLACKDAMP.

cholecalciferol *See* VITAMIN D.

cholecystokinin (CCK; pancreozymin) A hormone, produced by the duodenal region of the small intestine, that induces the gall bladder to contract and eject bile into the intestine and stimulates the pancreas to secrete its digestive enzymes. Cholecystokinin output is stimulated by contact with the contents of the stomach.

cholesteric crystal *See* LIQUID CRYSTAL.

cholesterol A *sterol (*see also* STEROID) occurring widely in animal tissues and also in some plants and algae. It can exist as a free sterol or esterified with a long-chain fatty acid. Cholesterol is absorbed through the intestine or manufactured in the liver. It serves principally as a constituent of blood plasma *lipoproteins and of the lipid–protein complexes that form plasma membranes. It is also important as a precursor of various steroids, especially the bile acids, sex hormones, and adrenocorticoid hormones. The derivative 7-dehydrocholesterol is converted to vitamin D_3 by the action of sunlight on skin. Increased levels of dietary and blood cholesterol have been associated with **atherosclerosis**, a condition in which lipids accumulate on the inner walls of arteries and eventually obstruct blood flow. It is now thought that this damage to blood vessels is caused by high concentrations of low-density lipoproteins in the blood.

choline An amino alcohol, $CH_2OHCH_2N(CH_3)_3OH$. It occurs widely in living organisms as a constituent of certain types of phospholipids – the *lecithins and sphingomyelins – and in the neurotransmitter *acetylcholine. It is sometimes classified as a member of the *vitamin B complex.

cholinergic Describing a nerve fibre that either releases *acetylcholine when stimulated or is itself stimulated by acetylcholine. *Compare* ADRENERGIC.

cholinesterase (acetylcholinesterase) An enzyme that hydrolyses the neurotransmitter *acetylcholine to choline and acetate. Cholinesterase is secreted by nerve cells at *synapses and by muscle cells at *neuromuscular junctions. Organophosphorus insecticides (*see* PESTICIDE) act as *anticholinesterases by inhibiting the action of cholinesterase.

Chondrichthyes A class of vertebrates comprising the fishes with cartilaginous skeletons. The majority belong to the subclass Elasmobranchii (skates, rays, and sharks – *see* SELACHII). Most cartilaginous fishes are marine carnivores with powerful jaws. Unlike bony fishes, they have no swim bladder, and therefore avoid sinking only by constant swimming with the aid of an asymmetrical (**heterocercal**) tail. There is no operculum covering the gill slits, the first of which is modified as a *spiracle. Fertilization is internal so the few eggs produced are consequently yolky, large, and well-protected. Some cartilaginous fishes show viviparous development of the young (*see* VIVIPARITY).

chondrin The matrix of *cartilage, which is made up of chondrocytes embedded in chondroitin sulphate.

chondrocyte Any of the cells that make up the matrix of *cartilage.

Chordata A phylum of animals characterized by a hollow dorsal nerve cord and, at some stage in their development, a flexible skeletal rod (the *notochord) and *gill slits opening from the pharynx. There are three subphyla: the Urochordata (sea squirts), Cephalochordata (lancelets), and *Craniata.

chorion **1.** A membrane enclosing the embryo, yolk sac, and allantois of reptiles, birds, and mammals. In mammals a section of the chorion becomes the embryonic part of the *placenta. *See* EXTRAEMBRYONIC MEMBRANES. **2.** The protective shell of an insect egg, produced by the ovary. It is pierced by a small pore (**micropyle**) that allows the entry of spermatozoa for fertilization. *See also* EGG MEMBRANE.

chorionic gonadotrophin *See* GONADOTROPHIN.

choroid A pigmented layer, rich in blood vessels, that lies between the retina and the sclerotic of the vertebrate eye. At the front of the eye the choroid is modified to form the *ciliary body and the *iris.

choroid plexus A membrane rich in

blood vessels that lines the *ventricles of the brain. It is an extension of the *pia mater and secretes *cerebrospinal fluid into the ventricles; it also controls exchange of materials between the blood and cerebrospinal fluid.

C

chromate A salt containing the ion CrO_4^{2-}.

chromatic aberration *See* ABERRATION.

chromaticity An objective description of the colour quality of a visual stimulus that does not depend on its luminance but which, together with its luminance, completely specifies the colour. The colour quality is defined in terms of **chromaticity coordinates**, *x*,*y*, and *z*, where

$x = X/(X + Y + Z)$

$y = Y/(X + Y + Z)$

and $z = Z/(X + Y + Z)$

X, *Y*, and *Z* are the **tristimulus values** of a light, i.e. they are the amounts of three reference stimuli needed to match exactly the light under consideration in a trichromatic system.

chromatid A threadlike strand formed from a *chromosome during the early stages of cell division. Each chromosome divides along its length into two chromatids, which are at first held together at the centromere. They separate completely at a later stage. The DNA of the chromosome reproduces itself exactly so that each chromatid has the complete amount of DNA and becomes a daughter chromosome with exactly the same genes as the original chromosome from which it was formed.

chromatin The substance of which eukaryotic *chromosomes are composed. It consists of proteins (principally histones), DNA, and small amounts of RNA and can be observed microscopically in two forms. In the *interphase of the cell cycle, chromatin is mainly in a condensed form, **heterochromatin**, which stains densely with basic stains and cannot undergo transcription. During the *metaphase of cell division most of the chromatin is in an expanded, lighter staining form, **euchromatin**, in which genes are available for transcription.

chromatogram A record obtained by chromatography. The term is applied to the developed records of *paper chromatography and *thin-layer chromatography and also to the graphical record produced in *gas chromatography.

chromatography A technique for analysing or separating mixtures of gases, liquids, or dissolved substances. The original technique (invented by the Russian botanist Mikhail Tsvet (1872–1919) in 1906) is a good example of **column chromatography**. A vertical glass tube is packed with an adsorbing material, such as alumina. The sample is poured into the column and continuously washed through with a solvent (a process known as **elution**). Different components of the sample are adsorbed to different extents and move down the column at different rates. In Tsvet's original application, plant pigments were used and these separated into coloured bands in passing down the column (hence the name chromatography). The usual method is to collect the liquid (the **eluate**) as it passes out from the column in fractions.

In general, all types of chromatography involve two distinct phases – the **stationary phase** (the adsorbent material in the column in the example above) and the **moving phase** (the solution in the example). The separation depends on competition for molecules of sample between the moving phase and the stationary phase. The form of column chromatography above is an example of **adsorption chromatography**, in which the sample molecules are adsorbed on the alumina. In **partition chromatography**, a liquid (e.g. water) is first absorbed by the stationary phase and the moving phase is an immiscible liquid. The separation is then by *partition between the two liquids. In ion-exchange chromatography (*see* ION EXCHANGE), the process involves competition between different ions for ionic sites on the stationary phase. *Gel filtration is another chromatographic technique in which the size of the sample molecules is important.

See also GAS CHROMATOGRAPHY; HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY; PAPER CHROMATOGRAPHY; R_F VALUE; THIN-LAYER CHROMATOGRAPHY.

chromatophore **1.** A pigment-containing cell found in the skin of many lower vertebrates (e.g. chameleon) and in the integument of crustaceans. Concentration or dispersion of the pigment granules in the cytoplasm of the cell causes the colour of the animal to alter to match its surroundings. A common type of chromatophore is the **melanophore**, which contains the pigment *melanin. **2.** A membrane-bound structure

in photosynthetic bacteria that contains photosynthetic pigments.

chrome alum *See* POTASSIUM CHROMIUM SULPHATE.

chrome iron ore A mixed iron–chromium oxide, $FeO.Cr_2O_3$, used to make ferrochromium for chromium steels.

chrome red A basic lead chromate, $PbO.PbCrO_4$, used as a red pigment.

chrome yellow Lead chromate, $PbCrO_4$, used as a pigment.

chromic acid A hypothetical acid, H_2CrO_4, known only in chromate salts.

chromic anhydride *See* CHROMIUM(VI) OXIDE.

chromic compounds Compounds containing chromium in a higher (+3 or +6) oxidation state; e.g. chromic oxide is chromium(VI) oxide (CrO_3).

chromite A spinel mineral, $FeCr_2O_4$; the principal ore of chromium. It is black with a metallic lustre and usually occurs in massive form. It is a common constituent of peridotites and serpentines. The chief producing countries are Turkey, South Africa, Russia, the Philippines, and Zimbabwe.

chromium Symbol Cr. A hard silvery *transition element; a.n. 24; r.a.m. 52.00; r.d. 7.19; m.p. 1857°C; b.p. 2672°C. The main ore is chromite ($FeCr_2O_4$). The metal has a body-centred-cubic structure. It is extracted by heating chromite with sodium chromate, from which chromium can be obtained by electrolysis. Alternatively, chromite can be heated with carbon in an electric furnace to give ferrochrome, which is used in making alloy steels. The metal is also used as a shiny decorative electroplated coating and in the manufacture of certain chromium compounds.

At normal temperatures the metal is corrosion-resistant. It reacts with dilute hydrochloric and sulphuric acids to give chromium(II) salts. These readily oxidize to the more stable chromium(III) salts. Chromium also forms compounds with the +6 oxidation state, as in chromates, which contain the CrO_4^{2-} ion. The element was discovered in 1797 by Vauquelin.

SEE WEB LINKS

- Information from the WebElements site

chromium(II) oxide A black insoluble powder, CrO. Chromium(II) oxide is prepared by oxidizing chromium amalgam with air. At high temperatures hydrogen reduces it to the metal.

chromium(III) oxide (chromium sesquioxide) A green crystalline water-insoluble salt, Cr_2O_3; r.d. 5.21; m.p. 2435°C; b.p. 4000°C. It is obtained by heating chromium in a stream of oxygen or by heating ammonium dichromate. The industrial preparation is by reduction of sodium dichromate with carbon. Chromium(III) oxide is amphoteric, dissolving in acids to give chromium(III) ions and in concentrated solutions of alkalis to give **chromites**. It is used as a green pigment in glass, porcelain, and oil paint.

chromium(IV) oxide (chromium dioxide) A black insoluble powder, CrO_2; m.p. 300°C. It is prepared by the action of oxygen on chromium(VI) oxide or chromium(III) oxide at 420–450°C and 200–300 atmospheres. The compound is unstable.

chromium(VI) oxide (chromium trioxide; chromic anhydride) A red compound, CrO_3; rhombic; r.d. 2.70; m.p. 196°C. It can be made by careful addition of concentrated sulphuric acid to an ice-cooled concentrated aqueous solution of sodium dichromate with stirring. The mixture is then filtered through sintered glass, washed with nitric acid, then dried at 120°C in a desiccator.

Chromium(VI) oxide is an extremely powerful oxidizing agent, especially to organic matter; it immediately inflames ethanol. It is an acidic oxide and dissolves in water to form 'chromic acid', a powerful oxidizing agent and cleansing fluid for glassware. At 400°C, chromium(VI) oxide loses oxygen to give chromium(III) oxide.

chromium potassium sulphate A red crystalline solid, $K_2SO_4.Cr_2(SO_4)_3.24H_2O$; r.d. 1.91. It is used as a mordant. *See also* ALUMS.

chromium sesquioxide *See* CHROMIUM(III) OXIDE.

chromium steel Any of a group of *stainless steels containing 8–25% of chromium. A typical chromium steel might contain 18% of chromium, 8% of nickel, and 0.15% of carbon. Chromium steels are highly resistant to corrosion and are used for cutlery, chemical plant, ball bearings, etc.

chromophore A group causing coloration

in a *dye. Chromophores are generally groups of atoms having delocalized electrons.

C

chromoplast Any of various pigment-containing *plastids in plant cells. Red, orange, and yellow chromoplasts contain carotenoid pigments and are responsible for the coloration of fruits and flowers. *See also* PLASTOGLOBULUS. *Compare* CHLOROPLAST; LEUCOPLAST.

chromosome A threadlike structure several to many of which are found in the nucleus of plant and animal (eukaryotic) cells. Chromosomes are composed of *chromatin and carry the *genes in a linear sequence; these determine the individual characteristics of an organism. When the nucleus is not dividing, individual chromosomes cannot be identified with a light microscope. During the first stage of nuclear division, however, the chromosomes contract and, when stained, can be clearly seen under a microscope. Each consists of two *chromatids held together at the *centromere (*see also* MEIOSIS; MITOSIS). The number of chromosomes in each cell is constant for and characteristic of the species concerned. In the normal body cells of *diploid organisms the chromosomes occur in pairs (*see* HOMOLOGOUS CHROMOSOMES); in the gamete-forming germ cells, however, the diploid number is halved and each cell contains only one member of each chromosome pair. Thus in man each body cell contains 46 chromosomes (22 matched pairs and one pair of *sex chromosomes) and each germ cell 23. Abnormalities in the number or structure of chromosomes may give rise to abnormalities in the individual; *Down's syndrome is the result of one such abnormality. *See* CHROMOSOME MUTATION.

Bacterial cells contain only a single circular chromosome, aggregated into a *nucleoid. Viral chromosomes can consist of one or several single- or double-stranded nucleic acid molecules. *See also* ARTIFICIAL CHROMOSOME.

chromosome map Any plan that shows the positions of genes, genetic markers, or other landmarks along the length of a chromosome. There are essentially two complementary types of map: *linkage maps, which give the relative positions of genetic sites (loci) determined by studies of how frequently recombination occurs between the loci; and *physical maps, which show the arrangement of the chromosomal material. Accumulated data for the chromosomes of many species of organism are now held in databases and available freely via the Internet for geneticists and others worldwide.

chromosome mutation A change in the gross structure of a chromosome, which usually causes severely deleterious effects in the organism. Chromosome mutations often occur due to an error in pairing during the *crossing over stage of meiosis. The main types of chromosome mutation include *translocation, *duplication, *deletion, and *inversion. *Compare* POINT MUTATION. *See also* MUTATION.

chromosome painting A technique based on *fluorescence in situ hybridization (FISH) that uses a palette of fluorescently labelled probes to identify specific chromosomes or chromosomal regions by 'painting' them in different colours. It is used diagnostically in clinical cytogenetics to screen for translocations or other structural aberrations, for example in hereditary diseases and cancer, and in comparative cytogenetics to determine the structural changes in genomes occurring during evolution.

chromosphere The layer of the *sun's atmosphere immediately above the *photosphere. The chromosphere is normally only visible when the photosphere is totally eclipsed by the moon. The chromosphere is about 10 000 kilometres thick and the temperature in it rises from 4000 K, where it merges with the photosphere, to about 50 000 K, where it reaches the transition region below the *corona.

chromous compounds Compounds containing chromium in its lower (+2) oxidation state; e.g. chromous chloride is chromium(II) chloride ($CrCl_2$).

chromyl chloride (chromium oxychloride) A dark red liquid, CrO_2Cl_2; r.d. 1.911; m.p. –96.5°C; b.p. 117°C. It is evolved as a dark-red vapour on addition of concentrated sulphuric acid to a mixture of solid potassium dichromate and sodium chloride; it condenses to a dark-red covalent liquid, which is immediately hydrolysed by solutions of alkalis to give the yellow chromate. Since bromides and iodides do not give analogous compounds this is a specific test for chloride ions. The compound is a powerful oxidizing agent, exploding on contact with phosphorus and inflaming sulphur and many organic compounds.

chronology protection conjecture A conjecture put forward by Stephen *Hawking in the early 1990s that asserts that the fundamental laws of physics should forbid time travel. There is some theoretical evidence in favour of this idea.

chrysalis *See* PUPA.

chrysotile *See* SERPENTINE.

chyle A milky fluid consisting of *lymph that contains absorbed food materials (especially emulsified fats). Most chyle occurs in the lymphatic ducts (*lacteals) in the *villi of the small intestine during the absorption of fat.

chyme The semisolid and partly digested food that is discharged from the stomach into the duodenum.

chymosin *See* RENNIN.

chymotrypsin An *endopeptidase enzyme in pancreatic juice that is secreted into the duodenum. The enzyme is secreted as an inactive precursor, **chymotrypsinogen**, which is activated by another pancreatic protease, *trypsin.

chymotrypsinogen *See* CHYMOTRYPSIN.

ciliary body The circular band of tissue surrounding and supporting the *lens of the vertebrate eye. It contains the **ciliary muscles**, which bring about changes in the shape of the lens (*see also* ACCOMMODATION). The ciliary body produces the *aqueous humour.

ciliary feeding A method of feeding used by lancelets and many other aquatic invertebrates. The movement of cilia causes a current of water to be drawn towards and through the animal, and microorganisms in the water are filtered out by the cilia.

ciliary muscle *See* CILIARY BODY.

cilium A short minute hairlike structure (up to 10 μm long) present on the surface of many cells, notably in certain protozoans and some types of vertebrate *epithelium. Cilia usually occur in large groups. Beating of cilia can produce cell movement or create a current in fluid surrounding a cell. Cilia and eukaryotic flagella have the same structure and are collectively called undulipodia (*see* UNDULIPODIUM).

cinnabar A bright red mineral form of mercury(II) sulphide, HgS, crystallizing in the hexagonal system; the principal ore of mercury. It is deposited in veins and impregnations near recent volcanic rocks and hot springs. The chief sources include Spain, Italy, and the former Yugoslavia.

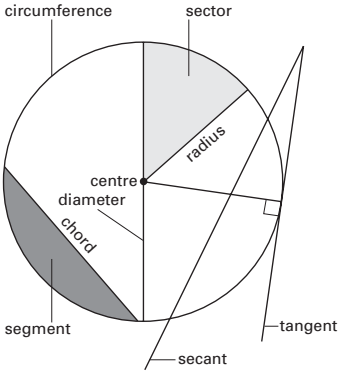
cinnamic acid (3-phenylpropenoic acid) A white crystalline aromatic *carboxylic acid, $C_6H_5CH{:}CHCOOH$; r.d. 1.248 (trans isomer); m.p. 135–136°C; b.p. 300°C. Esters of cinnamic acid occur in some essential oils.

CIP system (Cahn–Ingold–Prelog system) A system for the unambiguous description of stereoisomers used in the *R*–*S* convention (*see* ABSOLUTE CONFIGURATION) and in the **E*–*Z* convention. The system involves a **sequence rule** for determining a conventional order of ligands. The rule is that the atom bonded directly to the chiral centre or double bond is considered and the ligand in which this atom has the highest proton number takes precedence. So, for example, I takes precedence over Cl. If two ligands have bonding atoms with the same proton number, then substituents are taken into account (with the substituent of highest proton number taking precedence). Thus, $–C_2H_5$ has a higher precedence than $–CH_3$. If a double (or triple) bond occurs to a substituent, then the substituent is counted twice (or three times). An isotope of high nucleon number takes precedence over one of lower nucleon number. Hydrogen always has lowest priority in this system. For example, the sequence for some common ligands is I, Br, Cl, SO_3H, $OCOCH_3$, OCH_3, OH, NO_2, NH_2, $COOCH_3$, $CONH_2$, $COCH_3$, CHO, CH_2OH, C_6H_5, C_2H_5, CH_3, H. The system was jointly developed by the British chemists Robert Sidney Cahn (1899–1981) and Sir Christopher Kelk Ingold (1893–1970) and the Bosnian–Swiss chemist Vladimir Prelog (1906–98).

circadian rhythm (diurnal rhythm) Any 24-hour periodicity in the behaviour or physiology of animals or plants. Examples are the sleep/activity cycle in many animals and the growth movements of plants. Circadian rhythms are generally controlled by *biological clocks.

circle A closed curve every point on which is a fixed distance (the **radius**) from a point (the **centre**) within the curve (see illustration). The **diameter** is a line that joins two points on the **circumference** and passes through the centre: the diameter is twice the radius (*r*). The circumference of a circle is equal to $2\pi r$; the area is πr^2, where π is a constant with the value 3.141 592. In analytical

geometry the equation of a circle, centred at the origin, is $x^2 + y^2 = r^2$.



A circle.

circular birefringence A phenomenon in which there is a difference between the refractive indices of the molecules of a substance for right- and left-circularly polarized light. Circular birefringence depends on the way in which the electromagnetic field interacts with the molecule, and is affected by the handedness of the molecule, and hence its polarizability. If a molecule has the shape of a helix, the polarizability is dependent on whether or not the electric field of the electromagnetic field rotates in the same sense as the helix, thus giving rise to circular birefringence.

circular dichroism (CD) The production of an elliptically polarized wave when a linearly polarized light wave passes through a substance that has differences in the extinction coefficients for left- and right-handed polarized light. The size of this effect is given by $\phi = \pi/\lambda(\eta_l - \eta_r)$, where ϕ is the ellipticity of the beam that emerges (in radians), λ is the wavelength of the light, and η_l and η_r are the absorption indices of the left- and right-handed circularly polarized light, respectively. Circular dichroism is a property of optically active molecules and is used to obtain information about proteins. *See also* CD SPECTRUM.

circular measure A method of measuring angles by treating them as the angle formed by a sector of a circle at the circle's centre. The unit of measure is the **radian**, the angle subtended at the centre of a circle by an arc of equal length to the radius. Since an arc of length r subtends an angle of 1 radian, the whole circumference, length $2\pi r$, will subtend an angle of $2\pi r/r = 2\pi$ radians. Thus, $360° = 2\pi$ radians; 1 radian = 57.296°.

circular polarization *See* POLARIZATION OF LIGHT.

circulation The mass flow of fluid (e.g. blood or lymph) through the tissues and organs of an animal, allowing the transport and exchange of such materials as oxygen, nutrients, and waste products (*see also* VASCULAR SYSTEM; LYMPHATIC SYSTEM). Smaller animals (e.g. arthropods and most molluscs) have an **open circulation**, i.e. the blood is pumped into the body cavity, in which the internal organs are suspended. In open circulatory systems the tissues are in direct contact with the blood and materials are exchanged directly by diffusion. In a **closed circulation**, found in larger animals, the blood flows in vessels, which usually contain a series of one-way valves to maintain the flow in one direction. *See also* DOUBLE CIRCULATION; SINGLE CIRCULATION.

circulatory system The heart, blood vessels, blood, lymphatic vessels, and lymph, which together serve to transport materials throughout the body. *See also* DOUBLE CIRCULATION; SINGLE CIRCULATION; VASCULAR SYSTEM.

circumnutation *See* NUTATION.

cirque A steep semicircular hollow formed high on a mountain slope by the erosive action of a glacier. Many cirques fill with water to form lakes (called tarns). In Britain cirques are also called corries or cwms.

cis-isomer *See* ISOMERISM.

cisplatin A platinum complex, *cis*-$[PtCl_2(NH_3)_2]$, used in cancer treatment to inhibit the growth of tumours. It acts by binding between strands of DNA.

cis–trans isomerism *See* ISOMERISM.

citrate A salt or ester of citric acid.

citric acid A white crystalline hydroxycarboxylic acid, $HOOCCH_2C(OH)(COOH)CH_2COOH$; r.d. 1.54; m.p. 153°C. It is present in citrus fruits and is an intermediate in the *Krebs cycle in plant and animal cells.

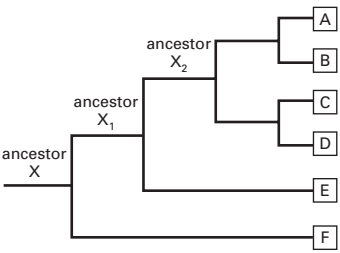
citric-acid cycle *See* KREBS CYCLE.

CJD *See* CREUTZFELDT–JAKOB DISEASE.

CL20 *See* HNIW.

cladding **1.** A thin coating of an expensive metal rolled on to a cheaper one. **2.** A thin covering of a metal around a fuel element in a nuclear reactor to prevent corrosion of the fuel elements by the coolant.

clade A group of organisms that share a common ancestor. *See* CLADISTICS.



Cladistics. A cladogram showing the relationships of six species (A–F).

cladistics A method of classification in which animals and plants are placed into taxonomic groups called **clades** strictly according to their evolutionary relationships. These relationships are deduced on the basis of certain shared *homologous characters that are thought to indicate common ancestry (*see* MONOPHYLETIC). Implicit in this is the assumption that two new species are formed suddenly, by splitting from a common ancestor, and not by gradual evolutionary change. A diagram indicating these relationships (called a **cladogram**) therefore consists of a system of dichotomous branches: each point of branching represents divergence from a common ancestor, as shown in the diagram. Thus the species A to F form a clade as they share the common ancestor X, and species A to D form a clade of a different taxonomic rank, sharing the ancestor X_2. Species C to F do not form a clade, since the latter must include *all* the descendants of a common ancestor.

cladode A flattened stem or internode that resembles and functions as a leaf. It is an adaptation to reduce water loss, since it contains fewer *stomata than a leaf. An example of a plant with cladodes is asparagus.

cladogram *See* CLADISTICS.

Claisen condensation A reaction of esters in which two molecules of the ester react to give a keto ester, e.g.

$$2CH_3COOR \rightarrow CH_3COCH_2COOR + ROH$$

The reaction is catalysed by sodium ethoxide, the mechanism being similar to that of the *aldol reaction. It is named after Ludwig Claisen (1851–1930).

Clapeyron–Clausius equation A differential equation that describes the relationship between variables when there is a change in the state of a system. In a system that has two *phases of the same substance, for example solid and liquid, heat is added or taken away very slowly so that one phase can change reversibly into the other while the system remains at equilibrium. If the two phases are denoted A and B, the Clapeyron–Clausius equation is:

$$\mathrm{d}p/\mathrm{d}T = L/T(V_B - V_A),$$

where p is the pressure, T is the thermodynamic *temperature, L is the heat absorbed per mole in the change from A to B, and V_B and V_A are the volumes of B and A respectively. In the case of a transition from liquid to vapour, the volume of the liquid can be ignored. Taking the vapour to be an *ideal gas, the Clapeyron–Clausius equation can be written:

$$\mathrm{d}\log_e p / \mathrm{d}T = L/RT^2.$$

The Clapeyron–Clausius equation is named after the French engineer Benoit-Pierre-Émile Clapeyron (1799–1864) and Rudolf *Clausius.

Clark cell A type of *voltaic cell consisting of an anode made of zinc amalgam and a cathode of mercury both immersed in a saturated solution of zinc sulphate. The Clark cell was formerly used as a standard of e.m.f.; the e.m.f. at 15°C is 1.4345 volts. It is named after the British scientist Hosiah Clark (d. 1898).

Clark process *See* HARDNESS OF WATER.

class A category used in the *classification of organisms that consists of similar or closely related orders. Similar classes are grouped into a phylum. Examples include Mammalia (mammals), Aves (birds), and Dicotyledoneae (dicots).

classical field theory A theory that describes a *field in terms of *classical physics rather than *quantum mechanics. Examples of classical field theories include classical *electrodynamics, described by *Maxwell's equations, and the general theory of *relativ-

ity, describing classical gravitation. A classical field theory emerges as a limit of the corresponding *quantum field theory. In order for a classical field theory to apply on a macroscopic scale it is necessary for the interactions to be long range, as they are in electrodynamics and gravitation, rather than short range, as in nuclear forces. Classical field theory is also used for mathematical convenience to describe the physics of continuous media, such as fluids.

classical physics Theoretical physics up to approximately the end of the 19th century, before the concepts of *quantum theory (1900) and special *relativity (1905). Classical physics relied largely on Newton's mechanics and James Clerk Maxwell's theory of electromagnetism. It may still be applied with high precision to large-scale phenomena involving no very rapid relative motion.

classification The arrangement of organisms into a series of groups based on physiological, biochemical, anatomical, or other relationships. An **artificial classification** is based on one or a few characters simply for ease of identification or for a specific purpose; for example, birds are often arranged according to habit and habitat (seabirds, songbirds, birds of prey, etc.) while fungi may be classified as edible or poisonous. Such systems do not reflect evolutionary relationships. A **natural classification** is based on resemblances and is a hierarchical arrangement. The smallest group commonly used is the *species. Species are grouped into genera (*see* GENUS), the hierarchy continuing up through *tribes, *families, *orders, *classes, and phyla (*see* PHYLUM) to *kingdoms and – in some systems – *domains. (In traditional systems of plant classification the phylum was replaced by the *division.) Higher up in the hierarchy the similarities between members of a group become fewer. Present-day natural classifications try to take into account as many features as possible and in so doing aim to reflect evolutionary relationships (*see* CLADISTICS). Natural classifications are also predictive. Thus if an organism is placed in a particular genus because it shows certain features characteristic of the genus, then it can be assumed it is very likely to possess most (if not all) of the other features of that genus. *See also* BINOMIAL NOMENCLATURE; MOLECULAR SYSTEMATICS; TAXONOMY.

clastic rock A rock composed of fragments (clasts) of other older rocks or their minerals. The fragments, generally the products of erosion, may vary in size from large boulders to the tiny particles in silt. They have often been transported from their previous location, and are commonly found as sedimentary rocks along coastlines. Typical consolidated clastic rocks include sandstone and shale.

clathrate A solid mixture in which small molecules of one compound or element are trapped in holes in the crystal lattice of another substance. Clathrates are sometimes called **enclosure compounds** or **cage compounds**, but they are not true compounds (the molecules are not held by chemical bonds). Quinol and ice both form clathrates with such substances as sulphur dioxide and xenon.

Claude process A process for liquefying air on a commercial basis. Air under pressure is used as the working substance in a piston engine, where it does external work and cools adiabatically. This cool air is fed to a counter-current *heat exchanger, where it reduces the temperature of the next intake of high-pressure air. The same air is recompressed and used again, and after several cycles eventually liquefies. The process was perfected in 1902 by the French scientist Georges Claude (1870–1960).

claudetite A mineral form of *arsenic(III) oxide, As_4O_6.

Clausius, Rudolf Julius Emmanuel (1822–88) German physicist, who held teaching posts in Berlin and Zurich, before going to Würzburg in 1869. He is best known for formulating the second law of *thermodynamics in 1850, independently of William Thomson (Lord *Kelvin). In 1865 he introduced the concept of *entropy, and later contributed to electrochemistry and electrodynamics.

Clausius–Mossotti equation A relation between the *polarizability α of a molecule and the dielectric constant ε of a dielectric substance made up of molecules with this polarizability. The Clausius–Mossotti equation can be written in the form $\alpha = (3/4\pi N)/[(\varepsilon - 1)/(\varepsilon - 2)]$, where N is the number of molecules per unit volume. The equation provides a link between a microscopic quantity (the polarizability) and a macroscopic quantity (the dielectric constant); it

was derived using macroscopic electrostatics by the Italian physicist Ottaviano Fabrizio Mossotti (1791–1863) in 1850 and independently by Rudolf Clausius in 1879. It works best for gases and is only approximately true for liquids or solids, particularly if the dielectric constant is large. *Compare* LORENTZ–LORENZ EQUATION.

Claus process A process for obtaining sulphur from hydrogen sulphide (from natural gas or crude oil). It involves two stages. First, part of the hydrogen sulphide is oxidized to sulphur dioxide:

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O.$$

Subsequently, the sulphur dioxide reacts with hydrogen sulphide to produce sulphur:

$$SO_2 + 2H_2S \rightarrow 3S + 2H_2O.$$

The second stage occurs at 300°C and needs an iron or aluminium oxide catalyst.

clavicle A bone that forms part of the *pectoral (shoulder) girdle, linking the *scapula (shoulder blade) to the sternum (breastbone). In man it forms the collar bone and serves as a brace for the shoulders.

clay A fine-grained deposit consisting chiefly of *clay minerals. It is characteristically plastic and virtually impermeable when wet and cracks when it dries out. In geology the size of the constituent particles is usually taken to be less than 1/256 mm. In soil science clay is regarded as a soil with particles less than 0.002 mm in size.

clay minerals Very small particles, chiefly hydrous silicates of aluminium, sometimes with magnesium and/or iron substituting for all or part of the aluminium, that are the major constituents of clay materials. The particles are essentially crystalline (either platy or fibrous) with a layered structure, but may be amorphous or metalloidal. The clay minerals are responsible for the plastic properties of clay; the particles have the property of being able to hold water. The chief groups of clay minerals are:
kaolinite, $Al_4Si_4O_{10}(OH)_8$, the chief constituent of *kaolin;
halloysite, $Al_4Si_4(OH)_8O_{10}.4H_2O$;
illite, $KAl_4(Si,Al)_8O_{18}.2H_2O$;
montmorillonite,

$$(Na,Ca)_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2.nH_2O,$$

formed chiefly through alteration of volcanic ash;
vermiculite,

$$(Mg,Fe,Al)_3(Al,Si)_4O_{10}(OH)_2.4H_2O,$$

used as an insulating material and potting soil.

cleavage **1.** (in embryology) The series of cell divisions by which a single fertilized egg cell is transformed into a multicellular body, the *blastula. Characteristically no growth occurs during cleavage, the shape of the embryo is unchanged except for the formation of a central cavity (the blastocoel), and the ratio of nuclear material (DNA) to cytoplasm increases. **2.** (in crystallography) The splitting of a crystal along planes of atoms in the lattice.

Clemmensen reduction A method of reducing a *carbonyl group (C=O) to CH_2, using zinc amalgam and concentrated hydrochloric acid. It is used as a method of ascending a homologous series. The reaction is named after Erik Clemmensen (1876–1941).

climate The characteristic pattern of weather elements in an area over a period. The main weather elements include temperature, precipitation, humidity, solar insolation, and wind. The climate of a large area is determined by several climatic controls: (1) the latitude of the area, which accounts for the amount of solar radiation it receives; (2) the distribution of land and sea masses; (3) the altitude and topography of the area; and (4) the location of the area in relation to the ocean currents. Climates may be classified into groups; the classification devised by the meteorologist Vladimir Köppen (1846–1940) in 1918, with subsequent modifications, is the most frequently used today. The scientific study of climate is **climatology.**

climate change A long-term change in the elements of climate, such as temperature, precipitation, wind, and pressure, measured over a period of time of at least several decades. Throughout the geological history of the earth there have been periodic fluctuations between warmer and cooler periods on a wide range of time scales. The causes of climate change are complex. Factors include the external processes of variations of solar emissions, variations of the earth's orbit, volcanic eruptions, mountain building, and tectonic movements; anthropogenic (human-induced) processes include the increase of greenhouse gases as a result of activities that include the burning of fossil fuels, changes in land use, and the emission of aerosols. Internal processes, natural interactions within the climate system, are also

factors. The term climate change is also used synonymously with *global warming.

SEE WEB LINKS

- Overview of climate science and the mechanisms of climate change, from the UK Met Office.

C

climax community A relatively stable ecological *community that is achieved at the end of a *succession.

cline A gradual variation in the characteristics of a species or population over its geographical range. It occurs in response to varying environmental factors, such as soil type or climate.

clinostat A mechanical device that rotates whole plants (usually seedlings), so removing the effect of any stimulus that normally acts in one particular direction. It is most often used to study the growth of plant organs when the influence of gravity has been removed.

clitoris An erectile rod of tissue in female mammals (and also some reptiles and birds) that is the equivalent of the male penis. It lies in front of the *urethra and *vagina.

cloaca The cavity in the pelvic region into which the terminal parts of the alimentary canal and the urinogenital ducts open in most vertebrates. Placental mammals, however, have a separate anus and urinogenital opening.

clock reaction *See* OSCILLATING REACTION.

clonal selection theory A theory explaining how the cells of the immune system produce large quantities of the right antibody at the right time, i.e. when the appropriate antigen is encountered. It proposes that there is a pre-existing pool of lymphocytes (*B cells) consisting of numerous small subsets. Each subset carries a unique set of surface antibody molecules with its own particular binding characteristics. If a cell encounters and binds the corresponding antigen it is 'selected' – stimulated to divide repeatedly and produce a large clone of identical cells, all secreting the antibody. The involvement of helper T cells (*see* T CELL) is essential for activation of the B cell.

clone **1.** A group of cells, an organism, or a population of organisms arising from a single ancestral cell. All members of a particular clone are genetically identical. In nature clones are produced by asexual reproduction, for example by the formation of bulbs and tubers in plants or by *parthenogenesis in certain animals. New techniques of cell manipulation and tissue culture have enabled the cloning of many plants and some animals. A wide range of commercially important plant species, including potatoes, tulips, and certain forest trees, are now cloned by *micropropagation, resulting in more uniform crops. Cloning in animals is more complex, but has been accomplished successfully in several species. The first mammal to be cloned experimentally from the body cell of an adult was a sheep ('Dolly') born in 1997. The nucleus containing DNA was extracted from an udder cell (which had been deprived of nutrients) and inserted into an 'empty' egg cell (from which the nucleus had been removed) using the technique of *nuclear transfer. This reconstituted egg cell was then stimulated to divide by an electric shock and implanted into the uterus of a surrogate mother ewe, which subsequently gave birth to a clone of the original sheep. This breakthrough has led to the production of exact replicas of animals with certain genetically engineered traits, for example to manufacture drugs in their milk or provide organs for human transplantation. **2. (gene clone)** An exact replica of a gene. *See* GENE CLONING.

cloning vector *See* VECTOR.

closed chain *See* CHAIN; RING.

close packing The packing of spheres so as to occupy the minimum amount of space. In a single plane, each sphere is surrounded by six close neighbours in a hexagonal arrangement. The spheres in the second plane fit into depressions in the first layer, and so on. Each sphere has 12 other touching spheres. There are two types of close packing. In **hexagonal close packing** the spheres in the third layer are directly over those in the first, etc., and the arrangement of planes is ABAB…. In **cubic close packing** the spheres in the third layer occupy a different set of depressions than those in the first. The arrangement is ABCABC…. *See also* CUBIC CRYSTAL.

SEE WEB LINKS

- An interactive version of cubic close packing
- An interactive version of hexagonal close packing

closo-structure *See* BORANE.

clotting factors (coagulation factors) A group of substances present in blood plasma that, under certain circumstances, undergo a

series of chemical reactions leading to the conversion of blood from a liquid to a solid state (*see* BLOOD CLOTTING). Although they have specific names, most coagulation factors are referred to by an agreed set of Roman numerals (e.g. *Factor VIII, Factor IX). Lack of any of these factors in the blood results in the inability of the blood to clot. *See also* HAEMOPHILIA.

cloud A mass of minute water droplets or ice crystals held in suspension in the atmosphere that appears as an opaque drifting body. The droplets or crystals are formed by the condensation of water vapour in the atmosphere in the presence of condensation nuclei – minute particles, such as smoke or salt. A number of cloud classifications have been devised; that most commonly used is based on cloud appearance and height. The high clouds (above 5000 metres) comprise cirrocumulus, cirrostratus, and cirrus (mares' tails) clouds; the medium clouds (approximately 2000–5000 metres) comprise altocumulus and altostratus; and the low clouds (below 2000 metres) are nimbostratus, stratocumulus, and stratus. Some clouds with great vertical development cannot be confined to these height categories; these are cumulus and cumulonimbus clouds.

cloud chamber A device for making visible the paths of particles of *ionizing radiation. The **Wilson** (**expansion**) **cloud chamber** consists of a container containing air and ethanol vapour, which is cooled suddenly by adiabatic expansion, causing the vapour to become supersaturated. The excess moisture in the vapour is then deposited in drops on the tracks of ions created by the passage of the ionizing radiation. The resulting row of droplets can be photographed. If the original moving particle was being deflected by electric or magnetic fields, the extent of the deflection provides information on its mass and charge. This device was invented in 1911 by C. T. R. Wilson.

A simpler version of this apparatus is the **diffusion cloud chamber**, developed by Cowan, Needels, and Nielsen in 1950, in which supersaturation is achieved by placing a row of felt strips soaked in a suitable alcohol at the top of the chamber. The lower part of the chamber is cooled by solid carbon dioxide. The vapour continuously diffuses downwards, and that in the centre (where it becomes supersaturated) is almost continuously sensitive to the presence of ions created by the radiation.

club drug A drug typically used by young people at clubs, parties, etc. Examples are ecstasy, gammahydroxybutyric acid (GHB), and methamphetamines.

clubmoss *See* LYCOPHYTA.

Clusius column A device for separating isotopes by *thermal diffusion. One form consists of a vertical column some 30 metres high with a heated electric wire running along its axis. The lighter isotopes in a gaseous mixture of isotopes diffuse faster than the heavier isotopes. Heated by the axial wire, and assisted by natural convection, the lighter atoms are carried to the top of the column, where a fraction rich in lighter isotopes can be removed for further enrichment.

cluster *See* GALAXY CLUSTER; STAR CLUSTER.

cluster compound A compound in which groups of metal atoms are joined together by metal–metal bonds. The formation of such compounds is a feature of the chemistry of certain transition elements, particularly molybdenum and tungsten, but also vanadium, tantalum, niobium, and uranium. **Isopoly compounds** are ones in which the cluster contains atoms of the same element; **heteropoly compounds** contain a mixture of different elements.

cluster model A model of atomic nuclei in which nuclei are regarded as being made up of clusters of nucleons, particularly alpha particles, with the clusters having a brief existence before splitting. Cluster models have had considerable success in describing nuclear structure and reactions.

cluster of differentiation *See* CD.

CMR *See* COLOSSAL MAGNETORESISTANCE.

CNB *See* COSMIC NEUTRINO BACKGROUND.

Cnidaria A phylum of aquatic invertebrates (sometimes known as coelenterates) that includes *Hydra*, jellyfish, sea anemones, and *corals. A cnidarian's body is *diploblastic, with two cell layers of the body wall separated by *mesoglea, and shows *radial symmetry. The body cavity (**gastrovascular cavity**) is sac-shaped, with one opening acting as both mouth and anus. This opening is surrounded by tentacles bearing *thread cells. Cnidarians exist both as free-swimming *medusae (e.g. jellyfish) and as sedentary *polyps. The latter may be colonial (e.g. corals) or solitary (e.g. sea anemones and

C

Hydra). In many cnidarians the life cycle alternates between these two forms (*see* ALTERNATION OF GENERATIONS).

SEE WEB LINKS

- Part of the comprehensive website of the University of California Museum of Paleontology, providing a useful summary of cnidarian biology and systematics

cnidoblast *See* THREAD CELL.

CNS *See* CENTRAL NERVOUS SYSTEM.

CoA *See* COENZYME A.

coacervate An aggregate of macromolecules, such as proteins, lipids, and nucleic acids, that form a stable *colloid unit with properties that resemble living matter. Many are coated with a lipid membrane and contain enzymes that are capable of converting such substances as glucose into more complex molecules, such as starch. Coacervate droplets arise spontaneously under appropriate conditions and have been suggested as possible prebiological systems from which living organisms originated.

coadaptation The mutual adaptation of two species that occurs during *coevolution.

coagulation The process in which colloidal particles come together irreversibly to form larger masses. Coagulation can be brought about by adding ions to change the ionic strength of the solution and thus destabilize the colloid (*see* FLOCCULATION). Ions with a high charge are particularly effective (e.g. alum, containing Al^{3+}, is used in styptics to coagulate blood). Another example of ionic coagulation is in the formation of river deltas, which occurs when colloidal silt particles in rivers are coagulated by ions in sea water. Alum and iron (III) sulphate are also used for coagulation in sewage treatment. Heating is another way of coagulating certain colloids (e.g. boiling an egg coagulates the albumin). *See also* BLOOD CLOTTING.

coal A brown or black carbonaceous deposit derived from the accumulation and alteration of ancient vegetation, which originated largely in swamps or other moist environments. As the vegetation decomposed it formed layers of peat, which were subsequently buried (for example, by marine sediments following a rise in sea level or subsidence of the land). Under the increased pressure and resulting higher temperatures the peat was transformed into coal. Two types of coal are recognized: **humic** (or **woody**) **coals**, derived from plant remains; and **sapropelic coals**, which are derived from algae, spores, and finely divided plant material.

As the processes of coalification (i.e. the transformation resulting from the high temperatures and pressures) continue, there is a progressive transformation of the deposit: the proportion of carbon relative to oxygen rises and volatile substances and water are driven out. The various stages in this process are referred to as the **ranks** of the coal. In ascending order, the main ranks of coal are: **lignite** (or **brown coal**), which is soft, brown, and has a high moisture content; **subbituminous coal**, which is used chiefly by generating stations; **bituminous coal**, which is the most abundant rank of coal; **semibituminous coal**; **semianthracite coal**, which has a fixed carbon content of between 86% and 92%; and **anthracite coal**, which is hard and black with a fixed carbon content of between 92% and 98%.

Most deposits of coal were formed during the Carboniferous and Permian periods. More recent periods of coal formation occurred during the early Jurassic and Palaeogene periods. Coal deposits occur in all the major continents, and coal is used as a fuel and in the chemical industry; by-products include coke and coal tar. Combustion of coal is a major source of greenhouse gases worldwide, and efforts are underway to develop 'clean coal' technology.

coal gas A fuel gas produced by the destructive distillation of coal. In the late 19th and early 20th centuries coal gas was a major source of energy and was made by heating coal in the absence of air in local gas works. Typically, it contained hydrogen (50%), methane (35%), and carbon monoxide (8%). By-products of the process were *coal tar and coke. The use of this type of gas declined with the increasing availability of natural gas, although since the early 1970s interest has developed in using coal in making *SNG.

coal tar A tar obtained from the destructive distillation of coal. Formerly, coal tar was obtained as a by-product in manufacturing *coal gas. Now it is produced in making coke for steel making. The crude tar contains a large number of organic compounds, such as benzene, naphthalene, methylbenzene, phenols, etc., which can be obtained by distillation. The residue is **pitch**. Coal tar was once the major source of or-

ganic chemicals, most of which are now derived from petroleum and natural gas.

coaxial cable A cable consisting of a central conductor surrounded by an insulator, which is in turn contained in an earthed sheath of another conductor. The central conductor and the outer conductor are coaxial (i.e. have the same axis). They are used to transmit high-frequency signals as they produce no external fields and are not influenced by them.

cobalamin (vitamin B_{12}) *See* VITAMIN B COMPLEX.

cobalt Symbol Co. A light-grey *transition element; a.n. 27; r.a.m. 58.933; r.d. 8.9; m.p. 1495°C; b.p. 2870°C. Cobalt is ferromagnetic below its Curie point of 1150°C. Small amounts of metallic cobalt are present in meteorites but it is usually extracted from ore deposits worked in Canada, Morocco, and the Democratic Republic of Congo. It is present in the minerals cobaltite, smaltite, and erythrite but also associated with copper and nickel as sulphides and arsenides. Cobalt ores are usually roasted to the oxide and then reduced with carbon or water gas. Cobalt is usually alloyed for use. Alnico is a well-known magnetic alloy and cobalt is also used to make stainless steels and in high-strength alloys that are resistant to oxidation at high temperatures (for turbine blades and cutting tools).

The metal is oxidized by hot air and also reacts with carbon, phosphorus, sulphur, and dilute mineral acids. Cobalt salts, usual oxidation states II and III, are used to give a brilliant blue colour in glass, tiles, and pottery. Anhydrous cobalt(II) chloride paper is used as a qualitative test for water and as a heat-sensitive ink. Small amounts of cobalt salts are essential in a balanced diet for mammals (*see* ESSENTIAL ELEMENT). Artificially produced cobalt–60 is an important radioactive tracer and cancer-treatment agent. The element was discovered by Georg Brandt (1694–1768) in 1737.

SEE WEB LINKS

- Information from the WebElements site

cobalt(II) oxide A pink solid, CoO; cubic; r.d. 6.45; m.p. 1935°C. The addition of potassium hydroxide to a solution of cobalt(II) nitrate gives a bluish-violet precipitate, which on boiling is converted to pink impure cobalt(II) hydroxide. On heating this in the absence of air, cobalt(II) oxide is formed. The compound is readily oxidized in air to form tricobalt tetroxide, Co_3O_4, and is readily reduced by hydrogen to the metal.

cobalt(III) oxide (cobalt sesquioxide) A black grey insoluble solid, Co_2O_3; hexagonal or rhombic; r.d. 5.18; decomposes at 895°C. It is produced by the ignition of cobalt nitrate; the product however never has the composition corresponding exactly to cobalt(III) oxide. On heating it readily forms Co_3O_4, which contains both Co(II) and Co(III), and is easily reduced to the metal by hydrogen. Cobalt(III) oxide dissolves in strong acid to give unstable brown solutions of trivalent cobalt salts. With dilute acids cobalt(II) salts are formed.

cobalt steel Any of a group of alloy *steels containing 5–12% of cobalt, 14–20% of tungsten, usually with 4% of chromium and 1–2% of vanadium. They are very hard but somewhat brittle. Their main use is in high-speed tools.

cobalt thiocyanate test *See* SCOTT'S TEST.

COBE Cosmic Background Explorer; an orbiting satellite launched in November 1989 for cosmological research. In 1992, statistical studies of measurements on the *microwave background radiation indicated the presence of weak temperature fluctuations thought to be imprints of quantum fluctuations in the *early universe. *See also* WMAP.

SEE WEB LINKS

- The NASA website for the COBE project

COBOL A high-level computer language developed in the early 1960s. The name is short for *co*mmon *b*usiness-*o*riented *l*anguage. COBOL is employed widely for data processing in commerce and government. Although programs in COBOL tend to be long and wordy, they are easy to read and easy to modify (even by someone who is not the original author).

cocaine A powerful drug present in the leaves of the coca plant (*Erythroxylon coca*). It stimulates the central nervous system and has effects similar to the amphetamines. It was originally used as a local anaesthetic. The illegal drug is usually the soluble hydrochloride. This can be converted into the free-base form (known as **crack cocaine**) by dissolving in water and heating with sodium bicarbonate. Cocaine is a class A drug in the UK. It can be detected by *Scott's test.

C

coccus Any spherical bacterium. Cocci may occur singly, in pairs, in groups of four or more, in cubical packets, in grapelike clusters (**Staphylococcus*), or in chains (**Streptococcus*). Staphylococci and streptococci include pathogenic species. They are generally nonmotile and do not form spores.

coccyx The last bone in the *vertebral column in apes and man (i.e. tailless primates). It is formed by the fusion of 3–5 *caudal vertebrae.

cochlea Part of the *inner ear of mammals, birds, and some reptiles that transforms sound waves into nerve impulses. In mammals it is coiled, resembling a snail shell. The cochlea is lined with sensitive cells that bear tiny hairs; it is filled with fluid (**endolymph**) and surrounded by fluid (**perilymph**). Sound-induced vibrations of the *oval window are transmitted through the perilymph and endolymph and stimulate the hair cells that line the cochlea. These in turn stimulate nerve cells that transmit information, via the *auditory nerve, to the brain for interpretation of the sounds.

Cockcroft, Sir John Douglas (1897–1967) British physicist, who joined *Rutherford at the Cavendish Laboratory in Cambridge, where with Ernest Walton (1903–95) he built a linear accelerator (*see* COCKCROFT–WALTON GENERATOR). In 1932, using the apparatus to bombard lithium nuclei with protons, they produced the first artificial nuclear transformation. For this work they were awarded the 1951 Nobel Prize.

Cockcroft–Walton generator The first proton accelerator; a simple *linear accelerator producing a potential difference of some 800 kV (d.c.) from a circuit of rectifiers and capacitors fed by a lower (a.c.) voltage. The experimenters, Sir John Cockcroft and E. T. S. Walton (1903–95), used this device in 1932 to achieve the first artificially induced nuclear reaction by bombarding lithium with protons to produce helium:

$$^{1}_{1}\mathrm{H} + ^{7}_{3}\mathrm{Li} = ^{4}_{2}\mathrm{He} + ^{4}_{2}\mathrm{He}$$

cockroaches *See* DICTYOPTERA.

cocoon A protective covering for eggs and/or larvae produced by many invertebrates. For example, the larvae of many insects spin a cocoon in which the pupae develop (that of the silkworm moth produces silk), and earthworms secrete a cocoon for the developing eggs.

cocurrent flow Flow of two fluids in the same direction with transfer of matter or heat between them. *Compare* COUNTERCURRENT FLOW.

codominance The condition that arises when both alleles in a *heterozygous organism are dominant and are fully expressed in the *phenotype. For example, the human blood group AB is the result of two alleles, A and B, both being expressed. A is not dominant to B, nor vice versa. *Compare* INCOMPLETE DOMINANCE.

codon A triplet of nucleotides within a molecule of messenger *RNA that functions as a unit of genetic coding (the **triplet code**), usually by specifying a particular amino acid during the synthesis of proteins in a cell (*see* GENETIC CODE). A few codons specify instructions during this process (*see* START CODON; STOP CODON). The term codon may also refer to any of the corresponding nucleotide triplets of DNA that are transcribed into codons. *See also* READING FRAME. *Compare* ANTICODON.

coefficient **1.** (in mathematics) A number or other known factor by which a variable quantity is multiplied, e.g. in $ax^2 + bx + c = 0$, a is the coefficient of x^2 and b is the coefficient of x. **2.** (in physics) A measure of a specified property of a particular substance under specified conditions, e.g. the coefficient of *friction of a substance.

coefficient of expansion *See* EXPANSIVITY.

coefficient of friction *See* FRICTION.

coelacanth A bony fish of the genus *Latimeria*, thought to be extinct until the first modern specimen of *L. chalumnae* was discovered in 1938 in the Indian Ocean around the Comoros Islands, off the SE coast of Africa. A second species, *L. menadoensis*, was discovered in 1999 in the Celebes Sea, SE Asia. The coelacanth belongs to the same order (Crossopterygii – lobe-finned fishes) as the ancestors of the amphibians. It is a large fish, 1–2 m long and weighing 80 kg or more, with a three-lobed tail fin. The body is covered in rough heavy scales and the pectoral fins can be used like crutches to help movement across the sea bed. The young are born alive. Fossil coelacanths are most abundant in deposits about 400 million years old and

no fossils less than 70 million years old have been found.

coelenterates *See* CNIDARIA.

coelom A fluid-filled cavity that forms the main *body cavity of vertebrate and most invertebrate animals. It is formed by the splitting of the *mesoderm. Ciliated ducts (**coelomoducts**) connect the coelom to the exterior allowing the exit of waste products and gametes; in higher animals these are specialized as oviducts, etc. The coelom is large and often subdivided in annelid worms (in which it functions as a hydrostatic skeleton) and vertebrates. In arthropods it is restricted to the cavities of the gonads and excretory organs, the body cavity being a blood-filled *haemocoel.

coelomoduct *See* COELOM.

coelostat A device that enables light from the same area of the sky (i.e., from a selected celestial object, such as the sun) to be continuously reflected into the field of view of an astronomical telescope or other instrument. It consists of a plane mirror driven by a clockwork or electrical mechanism so that it rotates from east to west to compensate for the west-to-east rotation of the earth.

coenocyte A mass of cytoplasm surrounding many nuclei and enclosed by a cell wall. It is found in certain algae and fungi. *Compare* CELL; SYNCYTIUM.

coenzyme An organic nonprotein molecule that associates with an enzyme molecule in catalysing biochemical reactions. Coenzymes usually participate in the substrate–enzyme interaction by donating or accepting certain chemical groups. Many vitamins are precursors of coenzymes. *See also* COFACTOR.

coenzyme A (CoA) A complex organic compound that acts in conjunction with enzymes involved in various biochemical reactions, notably the oxidation of pyruvate via the *Krebs cycle and fatty-acid oxidation and synthesis. It comprises principally the B vitamin *pantothenic acid, the nucleotide *adenine, and a ribose–phosphate group.

coenzyme Q *See* UBIQUINONE.

coercive force (coercivity) The magnetizing force necessary to reduce the flux density in a magnetic material to zero. *See* HYSTERESIS.

coevolution The evolution of complementary adaptations in two species caused by the *selection pressures that each exerts on the other. It is common in symbiotic associations (*see* SYMBIOSIS). For example, many insect-pollinated plants have evolved flowers whose shapes, colours, etc., make them attractive to particular insects; at the same time the pollinating insects have evolved sense organs and mouthparts specialized for quickly locating, and extracting nectar from, particular species of plants.

cofactor A nonprotein component essential for the normal catalytic activity of an enzyme. Cofactors may be organic molecules (*coenzymes) or inorganic ions. They may activate the enzyme by altering its shape or they may actually participate in the chemical reaction.

coherent radiation Electromagnetic radiation in which two or more sets of waves have a constant phase relationship, i.e. with peaks and troughs always similarly spaced.

coherent scattering Scattering for which there is a well-defined relationship between the phase of the incoming wave and the phase of the outgoing wave. Scattering for which there is no well-defined such relationship is called **incoherent scattering**.

coherent state The quantum-mechanical state of a system that most closely resembles the corresponding classical state of the system. An example of a coherent state is the quantum state of a harmonic oscillator or of an electromagnetic field. The concept of a coherent state is very important in quantum optics.

coherent units A system of *units of measurement in which derived units are obtained by multiplying or dividing base units without the use of numerical factors. *SI units form a coherent system; for example the unit of force is the newton, which is equal to 1 kilogram metre per second squared (kg m s^{-2}), the kilogram, metre, and second all being base units of the system.

cohesion **1.** The force of attraction between like molecules. Cohesion provides the force that holds up a column of water in the xylem tissue of plants without it breaking. The **cohesion–tension theory** is the most widely accepted explanation for the continual flow of water upwards through the xylem of a plant. Water is removed from the plant by the process of *transpiration, which creates a tension that pulls the water in the

xylem upwards as a single column held together by cohesive forces. **2.** (in botany) The union of like parts, such as the fusion of petals that occurs in some flowers.

C

coinage metals A group of three malleable ductile transition metals forming group 11 (formerly IB) of the *periodic table: copper (Cu), silver (Ag), and gold (Au). Their outer electronic configurations have the form $nd^{10}(n+1)s^1$. Although this is similar to that of alkali metals, the coinage metals all have much higher ionization energies and higher (and positive) standard electrode potentials. Thus, they are much more difficult to oxidize and are more resistant to corrosion. In addition, the fact that they have *d*-electrons makes them show variable valency (Cu^{I}, Cu^{II}, and Cu^{III}; Ag^{I} and Ag^{II}; Au^{I} and Au^{III}) and form a wide range of coordination compounds. They are generally classified with the *transition elements.

coincidence circuit An electronic logic device that gives an output only if two input signals are fed to it simultaneously or within a specified time of each other. A **coincidence counter** is an electronic counter incorporating such a device.

coitus *See* SEXUAL INTERCOURSE.

coke A form of carbon made by the destructive distillation of coal. Coke is used for blast-furnaces and other metallurgical and chemical processes requiring a source of carbon. Lower-grade cokes, made by heating the coal to a lower temperature, are used as smokeless fuels for domestic heating.

colchicine An *alkaloid derived from the autumn crocus, *Colchicum autumnale*. It inhibits *spindle formation in cells during mitosis so that chromosomes cannot separate during anaphase, thus inducing multiple sets of chromosomes (*see* POLYPLOID). Colchicine is used in genetics, cytology, and plant breeding research and also in cancer therapy to inhibit cell division.

cold-blooded animal *See* ECTOTHERM.

cold emission The emission of electrons by a solid without the use of high temperature, either as a result of field emission (*see* FIELD-EMISSION MICROSCOPE) or *secondary emission.

cold front *See* FRONT.

cold fusion *See* NUCLEAR FUSION.

Coleoptera An order of insects comprising the beetles and weevils and containing about 330 000 known species – the largest order in the animal kingdom. The forewings are hardened and thickened to form **elytra**, which meet at a precise mid-dorsal line and protect the underlying pair of hindwings and abdomen. The mouthparts are generally modified for biting and in some species assume antler-like proportions. Beetles occur in a wide variety of terrestrial and aquatic habitats; many feed on decaying organic matter, some eat living vegetation, while others prey on other arthropods. A number of beetles and weevils are economically important pests of stored grain, timber, and crops. The young emerge as larvae and generally undergo metamorphosis via a pupal stage to form the adult beetle.

coleoptile A protective sheath that covers the young shoot of the embryo in plants of the grass family. It bursts open when the first leaves develop. Experiments investigating growth movements of the oat coleoptile led to the discovery of the plant growth substance indoleacetic acid (IAA).

coleorhiza A protective sheath that covers the young root of the embryo in plants of the grass family.

collagen An insoluble fibrous protein found extensively in the connective tissue of skin, tendons, and bone. The polypeptide chains of collagen (containing the amino acids glycine and proline predominantly) form triple-stranded helical coils that are bound together to form fibrils, which have great strength and limited elasticity. Collagen accounts for over 30% of the total body protein of mammals.

collapsar A *neutron star, *white dwarf, or any other star composed of degenerate matter: *black holes are also regarded as collapsars. They share the property that they have all collapsed under the effect of a strong gravitational field and ceased to produce energy within their cores.

collecting duct Any of the ducts in the mammalian *kidney that drains into the renal pelvis, which leads to the ureter. They are the main sites of water reabsorption from the glomerular filtrate, which drains into the ducts from the *distal convoluted tubules of the *nephrons. The cells of the collecting ducts are relatively impermeable to water. However, the influence of *antidiuretic hormone increases the permeability of

the collecting ducts, allowing the reabsorption of water and controlling the final urine concentration according to the body's state of hydration.

collective excitation A quantized mode in a many-body system, occurring because of cooperative motion of the whole system as a result of interactions between particles. *Plasmons and *phonons in solids are examples of collective excitations. Collective excitations obey Bose–Einstein statistics (*see* QUANTUM STATISTICS).

collector *See* TRANSISTOR.

collenchyma *See* GROUND TISSUES.

colligative properties Properties that depend on the concentration of particles (molecules, ions, etc.) present in a solution, and not on the nature of the particles. Examples of colligative properties are osmotic pressure (*see* OSMOSIS), *lowering of vapour pressure, *depression of freezing point, and *elevation of boiling point.

collimator **1.** Any device for producing a parallel beam of particle or wave radiation. A common arrangement used for light consists of a convex achromatic lens fitted to one end of a tube with an adjustable slit at the other end, the slit being at the principal focus of the lens. Light rays entering the slit leave the lens as a parallel beam. Collimators for particle beams and other types of electromagnetic radiation utilize a system of slits or apertures. **2.** A small fixed telescope attached to a large astronomical telescope to assist in lining up the large one onto the desired celestial body.

collision density The number of collisions that occur in unit volume in unit time when a given neutron flux passes through matter.

collision quenching *See* EXTERNAL CONVERSION.

collodion A thin film of cellulose nitrate made by dissolving the cellulose nitrate in ethanol or ethoxyethane, coating the surface, and evaporating the solvent.

colloids As originally defined by Thomas Graham in 1861, substances, such as starch or gelatin, that will not diffuse through a membrane. Graham distinguished colloids from **crystalloids** (e.g. inorganic salts), which would pass through membranes. Later it was recognized that colloids were distinguished from true solutions by the presence of particles that were too small to be observed with a normal microscope yet were much larger than normal molecules. Colloids are now regarded as systems in which there are two or more phases, with one (the **dispersed phase**) distributed in the other (the **continuous phase**). Moreover, at least one of the phases has small dimensions (in the range 10^{-9}–10^{-6} m). Colloids are classified in various ways.

Sols are dispersions of small solid particles in a liquid. The particles may be macromolecules or may be clusters of small molecules. **Lyophobic sols** are those in which there is no affinity between the dispersed phase and the liquid. An example is silver chloride dispersed in water. In such colloids the solid particles have a surface charge, which tends to stop them coming together. Lyophobic sols are inherently unstable and in time the particles aggregate and form a precipitate. **Lyophilic sols**, on the other hand, are more like true solutions in which the solute molecules are large and have an affinity for the solvent. Starch in water is an example of such a system. **Association colloids** are systems in which the dispersed phase consists of clusters of molecules that have lyophobic and lyophilic parts. Soap in water is an association colloid (*see* MICELLE).

Emulsions are colloidal systems in which the dispersed and continuous phases are both liquids, e.g. oil-in-water or water-in-oil. Such systems require an emulsifying agent to stabilize the dispersed particles.

Gels are colloids in which both dispersed and continuous phases have a three-dimensional network throughout the material, so that it forms a jelly-like mass. Gelatin is a common example. One component may sometimes be removed (e.g. by heating) to leave a rigid gel (e.g. silica gel).

Other types of colloid include *aerosols (dispersions of liquid or solid particles in a gas, as in a mist or smoke) and foams (dispersions of gases in liquids or solids). Colloids are analysed theoretically in terms of intermolecular forces.

cologarithm The logarithm of the reciprocal of a number.

colon The section of the vertebrate *large intestine that lies between the *caecum and the *rectum. Its prime function is to absorb water and minerals from indigestible food residues passing from the small intestine, which results in the formation of *faeces.

C

colony **1.** (in zoology) A group of animals of the same species living together and dependent upon each other. Some, such as the corals and sponges, are physically connected and function as a single unit. Others, such as insect colonies, are not physically joined but show a high level of social organization with members specialized for different functions (*see* CASTE). **2.** (in microbiology) A group of microorganisms, usually bacteria or yeasts, that are considered to have developed from a single parent cell. Colonies that grow on *agar plates differ in shape, colour, surface texture, and translucency and can therefore be used as a means of identification.

colony-stimulating factor (CSF) Any of several *cytokines that stimulate development of certain types of blood cells from haemopoietic *stem cells. They include **GM-CSF**, a glycoprotein that causes the stem cells to develop into mixed colonies of granulocytes and monocytes/macrophages (hence the name); **G-CSF**, which stimulates production of granulocytes only; and **M-CSF**, which promotes only monocyte/macrophage cell production. *Interleukin-3 (IL-3) is sometimes called the 'multi-CSF' because it stimulates the production of all types of lymphocytes and also erythrocytes.

colorimeter Any instrument for comparing or reproducing colours. Monochromatic colorimeters match a *colour with a mixture of monochromatic and white lights. Trichromatic colorimeters use a mixture of three *primary colours.

colorimetric analysis Quantitative analysis of solutions by estimating their colour, e.g. by comparing it with the colours of standard solutions.

colossal magnetoresistance (CMR) A property of certain materials in which electrical resistance can change by several orders of magnitude in a magnetic field. It is observed particularly in certain manganese oxides and is likely to have applications in magnetic storage and spintronics. At present, there is no complete quantitative theory of the phenomenon. *See also* GIANT MAGNETORESISTANCE; MAGNETORESISTANCE.

colostrum A liquid with a high content of nitrogen, antibodies, and vitamins that is secreted from the mammary glands before and just after giving birth. The change of secretion from colostrum to proper milk takes place gradually during the days after birth.

colour The sensation produced when light of different wavelengths falls on the human eye. Although the visible spectrum covers a continuously varying range of colours from red to violet it is usually split into seven colours (the **visible spectrum**) with the following approximate wavelength ranges:

red 740–620 nm
orange 620–585 nm
yellow 585–575 nm
green 575–500 nm
blue 500–445 nm
indigo 445–425 nm
violet 425–390 nm

A mixture of all these colours in the proportions encountered in daylight gives white light; other colours are produced by varying the proportions or omitting components.

A coloured light has three attributes: its **hue**, depending on its wavelength; its **saturation**, depending on the degree to which it departs from white light; and its *luminosity. Coloured objects that owe their colour to pigments or dyes absorb some components of white light and reflect the rest. For example, a red book seen in white light absorbs all the components except the red, which it reflects. This is called a **subtractive process** as the final colour is that remaining after absorption of the rest. This is the basis of the process used in *colour photography. Combining coloured lights, on the other hand, is an **additive process** and this is the method used in *colour television. *See also* PRIMARY COLOUR.

colour blindness Any disorder of vision in which colours are confused. The most common type is red–green colour blindness. This is due to a recessive gene carried on the X chromosome (*see* SEX LINKAGE), and therefore men are more likely to show the defect although women may be *carriers. It results in absence or malfunctioning of one or more of the three types of cone cell responsible for *colour vision.

colour centre A defect in a crystal that changes the way in which it absorbs light or other electromagnetic radiation. Impurities in the crystal affect the bind structure and allow transitions in different regions of the spectrums. Impurity colour centres are responsible for the characteristic colours of many gemstones. A particular type of colour centre is an **F-centre**. This is a missing nega-

tive ion in an ionic crystal, where the overall charge neutrality occurs by trapping an electron in the vacancy. The electron has energy levels similar to those of a particle in a box. F-centres can be produced by chemical activity or by irradiation.

colour charge *See* ELEMENTARY PARTICLES.

colour photography Any of various methods of forming coloured images on film or paper by photographic means. One common process is a subtractive reversal system that utilizes a film with three layers of light-sensitive emulsion, one responding to each of the three *primary colours. On development a black image is formed where the scene is blue. The white areas are dyed yellow, the *complementary colour of blue, and the blackened areas are bleached clean. A yellow filter between this emulsion layer and the next keeps blue light from the second emulsion, which is green-sensitive. This is dyed magenta where no green light has fallen. The final emulsion is red-sensitive and is given a cyan (blue-green) image on the negative after dying. When white light shines through the three dye layers the cyan dye subtracts red where it does not occur in the scene, the magenta subtracts green, and the yellow subtracts blue. The light projected by the negative therefore reconstructs the original scene either as a transparency or for use with printing paper.

colour television A television system in which the camera filters the light from the scene into the three component *primary colours, red, blue, and green, which are detected by separate camera tubes. The separate information so obtained relating to the colour of the image is combined with the sound and synchronization signals and transmitted using one of three systems, the American, British, or French. At the receiver, the signal is split again into red, blue, and green components, each being fed to a separate *electron gun in the cathode-ray tube of the receiver. By an additive process (*see* COLOUR) the picture is reconstituted by the beam from each gun activating a set of phosphor dots of that colour on the screen.

colour temperature The temperature of a non-black body as indicated by the temperature of a black body having approximately the same spectral distribution.

colour vision The ability of the eye to detect different wavelengths of light and to distinguish between these different wavelengths and their corresponding colours. In the mammalian eye this is achieved by the *cone cells, which are located in and around the *fovea near to the centre of the retina. The cone cells contain the light-sensitive pigment **iodopsin**, which – according to the **trichromatic theory** – exists in three forms, each form occurring in a different cone cell. Each form of iodopsin is sensitive to a different range of wavelengths of light. The relative stimulation of each type of cone will determine the colour that is interpreted by the brain. *See also* COLOUR BLINDNESS.

The *compound eye of certain insects is also capable of colour vision.

columbium A former name for the element *niobium.

column chromatography *See* CHROMATOGRAPHY.

coma **1.** A nebulous cloud of gas and dust that surrounds the nucleus of a *comet. **2.** An *aberration of a lens or mirror in which the image of a point lying off the axis has a comet-shaped appearance.

combinations *See* PERMUTATIONS AND COMBINATIONS.

combined cycle *See* FLUIDIZATION.

combustion A chemical reaction in which a substance reacts rapidly with oxygen with the production of heat and light. Such reactions are often free-radical chain reactions, which can usually be summarized as the oxidation of carbon to form its oxides and the oxidation of hydrogen to form water. *See also* FLAME.

comet A type of *small solar system body that travels around the sun in an eccentric orbit and typically has a **nucleus** consisting of ice and dust, surrounded by a *coma of dust and frozen gases that become volatile near the sun and are blown off by the *solar wind to form a **comet tail**. **Short-period comets** have orbital periods of less than 150 years. The others have very long periods, some exceeding 100 000 years, or visit the inner solar system only once before being ejected into interstellar space. The nuclei of most comets are thought to be 'dirty snowballs' about one kilometre in diameter, although the solar system has a few comets with nuclei exceeding 10 km in diameter. The coma may be 10^4–10^5 km in diameter, and the tail can be 10^7 km in length. Debris

from comets produces annual meteor showers as the earth passes through it on its annual solar orbit. *See also* HALLEY'S COMET.

C

commensalism An interaction between two animal or plant species that habitually live together in which one species (the **commensal**) benefits from the association while the other is not significantly affected. For example, the burrows of many marine worms contain commensals that take advantage of the shelter provided but do not affect the worm.

common-collector connection A technique used in the operation of some *transistors, in which the collector is common to both the input and output circuits, the input terminal is the *base, and the output terminal is the collector.

common logarithm *See* LOGARITHM.

common salt *See* SODIUM CHLORIDE.

communication An interaction between two organisms in which information is conveyed from one to the other. Communication can occur between individuals of the same species (**intraspecific communication**) or between members of different species (**interspecific communication**). It generally involves the transmission of a signal from one organism to another; signals can be visual, chemical, or tactile or they can take the form of sounds. Visual signals between members of the same species are widely used by animals in such activities as defining and protecting *territories and finding suitable mates (*see* COURTSHIP; DISPLAY BEHAVIOUR; BIOLUMINESCENCE). Chemical and tactile signals also play an important role in these activities (*see* PHEROMONE). Social species rely heavily on all three types of signalling, the classic example being provided by the *dance of the bees, in which information about the distance and direction of a food source is conveyed to other members of the colony. Visual signals, in the form of body coloration, are the principal means of communication between animals of different species (*see* MIMICRY; WARNING COLORATION). Sounds are more effective than visual signals for intraspecific communication over long distances and at night. Certain insects produce sounds by *stridulation, while birdsong and language are sophisticated examples of sound signals in birds and humans, respectively. Among plants, visual and chemical signals are important in communication. Flowering plants whose flowers are pollinated by insects or other animals depend on the colour, shape, and scent of their flowers to attract suitable pollinating agents. Some plants produce chemical signals to deter competitors and predators (*see* ALLELOPATHY).

communication satellite An unmanned artificial satellite sent by rocket into a geostationary orbit (*see* SYNCHRONOUS ORBIT) around the earth to enable television broadcasts and telephone communications to be made between points on the earth's surface that could not otherwise communicate by radio owing to the earth's curvature. Modulated *microwaves are transmitted to the satellite, which amplifies them and retransmits them at a different frequency to the receiving station. The satellites are powered by *solar cells. Three or more satellites in equatorial orbits can provide a world-wide communications linkage. The satellites are placed well above the ionosphere and therefore the carrier waves used have to be in the microwave region of the spectrum in order to pass through the ionosphere.

community A naturally occurring assemblage of plant and animal species living within a defined area or habitat. Communities are named after one of their *dominant species (e.g. a pine community) or the major physical characteristics of the area (e.g. a freshwater pond community). Members of a community interact in various ways (e.g. through *food chains and *competition). Large communities may be divided into smaller component communities. *See* ASSOCIATION.

commutative law The mathematical law stating that the value of an expression is independent of the order of combination of the numbers, symbols, or terms in the expression. The **commutative law for addition** applies if $x + y = y + x$. The **commutative law of multiplication** applies if $x \times y = y \times x$. Subtraction and division are not commutative. *Compare* ASSOCIATIVE LAW; DISTRIBUTIVE LAW.

commutator The part of the armature of an electrical motor or generator through which connections are made to external circuits. It consists of a cylindrical assembly of insulated copper conductors, each of which is connected to one point in the armature winding. Spring-loaded carbon brushes are positioned around the commutator to carry the current to or from it.

compact disk (CD) A 120 mm metal disk on which there is a *digital recording of audio information, providing high-quality recording and reproduction of music, speech, etc. The recording is protected by a layer of clear plastic. The information is permanently encoded in the form of a spiral track of minute pits impressed on one surface of the disk during manufacture; these impressions correspond to a changing sequence of *bits. The CD is rotated at constant linear velocity (CLV) in a CD player; the rotation rate is varied according to the radius of the track accessed. Information is retrieved from the rotating disk by means of a low-power laser focused on the track and modulated by the binary code impressed on the track.

companion cell A type of cell found within the *phloem of flowering plants. Each companion cell is usually closely associated with a *sieve element. It regulates the activity of the adjacent sieve element and takes part in loading and unloading sugar into the sieve element. In gymnosperms a similar function is attributed to **albuminous cells**, which are found closely associated with gymnosperm sieve elements.

compass A small magnet pivoted at its central point to revolve in a horizontal plane. In the earth's magnetic field the magnet (called the compass needle) aligns itself so that its north-seeking end points to the earth's magnetic north pole. A scale (called a compass card) is placed below the needle for use in navigation. In some navigation compasses the entire card is pivoted, indicating direction by a fixed mark on the casing. Such compasses are often filled with alcohol to provide damping. Magnetic compasses suffer from being affected by magnetic metals in their vicinity and to a large extent they have been replaced by *gyrocompasses.

compass plant A plant that has its leaves permanently orientated in a north–south direction. Such an arrangement enables the plant to take full advantage of morning and evening sun, while avoiding the stronger midday sunlight. An example is the compass plant of the prairies (*Silphium laciniatum*).

competent Describing embryonic tissue that is capable of developing into a specialized tissue when suitably stimulated. *See* INDUCTION; EVOCATION.

competition The interaction that occurs between two or more organisms, populations, or species that share some environmental resource when this is in short supply. Competition is an important force in evolution: plants, for example, become tall to compete for light, and animals evolve various foraging methods to compete for food. There may be a direct confrontation between competitors, as occurs between barnacles competing for space on a rock, or the numbers or fecundity of the competitors are indirectly reduced through joint dependence on limited resources. Competition occurs both between members of a species (**intraspecific competition**) and between different species (**interspecific competition**). Interspecific competition often results in the dominance of one species over another (*see* DOMINANT). Since competition ultimately results in the displacement by one competitor of the others, it is to the advantage of the competitors to avoid one another wherever possible. Thus in time the competitors become separated from each other geographically or ecologically, which promotes evolutionary change. Competition for mates may lead to *sexual selection.

competitive inhibition *See* INHIBITION.

complement A group of proteins present in blood plasma and tissue fluid that aids the body's defences following an *immune response; the genes encoding it form part of the *major histocompatibility complex. Following an antibody–antigen reaction, complement is activated chemically and becomes bound to the antibody–antigen complex (**complement fixation**); it can cause *lysis of certain types of bacteria, or it can render the target cell more susceptible to *phagocytosis.

complemental males The small males of certain animals that live in or on the females and are usually more or less degenerate apart from the reproductive organs. They occur in certain crustaceans (e.g. some barnacles), in which the normal individuals are hermaphrodite but the complemental males have suppressed ovaries, lose their alimentary canal, and lead a semiparasitic existence in the mantle cavity of the larger partner. This may ensure that cross fertilization occurs.

complementarity The concept that a single model may not be adequate to explain all the observations made of atomic or subatomic systems in different experiments. For

example, *electron diffraction is best explained by assuming that the electron is a wave (*see* DE BROGLIE WAVELENGTH), whereas the *photoelectric effect is described by assuming that it is a particle. The idea of two different but complementary concepts to treat quantum phenomena was first put forward by the Danish physicist Niels Bohr (1855–1962) in 1927. *See also* LIGHT.

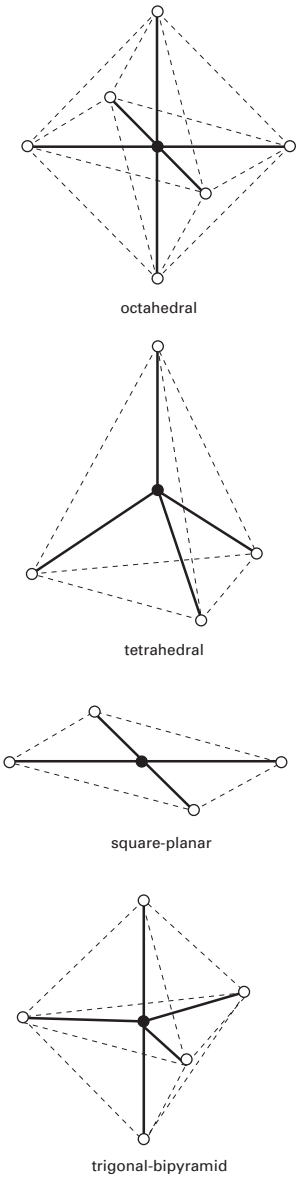
complementary colours A pair of coloured lights of specific hue (*see* COLOUR) that produce the sensation of white when mixed in appropriate intensities. There is an infinite number of such pairs, an example (with wavelengths) is orange (608 nm) and blue (490 nm).

complementary DNA (cDNA) A form of DNA prepared in the laboratory using messenger *RNA (mRNA) as template, i.e. the reverse of the usual process of *transcription in cells; the synthesis is catalysed by *reverse transcriptase. cDNA thus has a base sequence that is complementary to that of the mRNA template; unlike genomic DNA, it contains no noncoding sequences (*introns). cDNA is used in *gene cloning for the expression of eukaryote genes in prokaryote host cells or as a *gene probe.

complementary genes Two (or more) genes that are interdependent, such that the dominant *allele from either gene can only produce an effect on the *phenotype of an organism if the dominant allele from the other gene is also present.

complex A compound in which molecules or ions form coordinate bonds to a metal atom or ion (see illustration overleaf). Often complexes occur as positive or negative **complex ions**, such as $[Cu(H_2O)_6]^{2+}$ and $Fe[(CN)_6]^{3-}$. A complex may also be a neutral molecule (e.g. $PtCl_2(NH_3)_2$). The formation of such coordination complexes is typical behaviour of transition metals. The complexes formed are often coloured and have unpaired electrons (i.e. are paramagnetic). *See also* LIGAND; CHELATE.

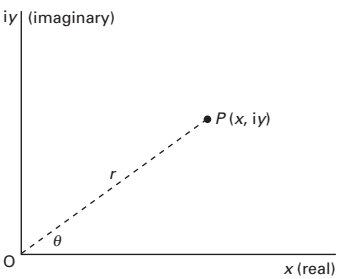
complexity The levels of *self-organization of a system. In physical systems, complexity is associated with *broken symmetry and the ability of a system to have different states between which it can make *phase transitions. It is also associated with having coherence in space over a long range. Examples of complexity include *superconductivity, *superfluidity, *lasers, and ordered



Complex. Some common shapes of coordination complexes.

phases that arise when a system is driven far from thermal equilibrium (*see* BÉNARD CELL). It is not necessary for a system to have a large number of degrees of freedom in order for complexity to occur. The study of complexity is greatly aided by computers in systems that cannot be described analytically. Complexity is also very important in a number of other fields, including theoretical biology.

complex number A number that has a real part, x, and an imaginary part, iy, where $i = \sqrt{-1}$ and x and y are real (x can also equal 0). The complex number therefore has the form $x + iy$, which can also be written in the polar form $r\cos\theta + ir\sin\theta$, where r is the **modulus** and θ is the **argument** (or **amplitude**). A complex number can be represented on an **Argand diagram**, devised by Jean-Robert Argand (1768–1822), in which the horizontal axis represents the real part of the number and the vertical axis the imaginary part (see illustration). In the polar form the modulus is the line joining the origin to the point representing the complex number and the argument is the angle between the modulus and the x-axis.



Complex number. Argand diagram.

complexometric analysis A type of volumetric analysis in which the reaction involves the formation of an inorganic *complex.

component A distinct chemical species in a mixture. If there are no reactions taking place, the number of components is the number of separate chemical species. A mixture of water and ethanol, for instance, has two components (but is a single phase). A mixture of ice and water has two phases but one component (H_2O). If an equilibrium reaction occurs, the number of components is taken to be the number of chemical species minus the number of reactions. Thus, in

$$H_2 + I_2 \rightleftharpoons 2HI$$

there are two components. *See also* PHASE RULE.

component vectors Two or more vectors that produce the same effect as a given vector; the vectors that combine to produce the effect of a resultant vector. A component vector in a given direction is the projection of the given vector ($\boldsymbol{V}$) along that direction, i.e. $\boldsymbol{V}\cos\theta$, where θ is the angle between the given vector and the direction.

composite fruit A type of fruit that develops from an inflorescence rather than from a single flower. *See* PSEUDOCARP; SOROSIS; STROBILUS; SYCONUS.

compost A mixture of decaying organic matter, such as vegetation and manure, that is used as a *fertilizer. The organic material is decomposed by aerobic saprotrophic organisms, mostly fungi and bacteria. Some decomposition is also carried out by *detritivores. Compost is used mainly on a domestic scale.

compound A substance formed by the combination of elements in fixed proportions. The formation of a compound involves a chemical reaction; i.e. there is a change in the configuration of the valence electrons of the atoms. Compounds, unlike mixtures, cannot be separated by physical means. *See also* MOLECULE.

compound eye The eye of insects and crustaceans, which consists of numerous visual units, the **ommatidia**. Each ommatidium consists of an outer cuticle covering a lens, beneath which are 6–8 retinal cells surrounding a light-sensitive **rhabdom**. Adjacent ommatidia are separated by pigment cells. The eye is convex, with nerve fibres from the retinal cells converging onto the optic nerve. There are two types of compound eye. In **apposition eyes**, typical of diurnal insects, each ommatidium focuses rays parallel to its long axis so that each gives an image of a minute part of the visual field, producing a detailed mosaic image. In **superposition eyes**, typical of nocturnal insects, the pigment separating ommatidia migrates to the ends of the cells, so that each ommatidium receives light from a larger part of the visual field and the image may overlap with those received by many neighbouring

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ommatidia. This produces an image that is bright but lacks sharpness of detail.

compound microscope *See* MICROSCOPE.

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compressibility The reciprocal of bulk modulus (*see* ELASTIC MODULUS). The compressibility (k) is given by $-V^{-1}\mathrm{d}V/\mathrm{d}p$, where $\mathrm{d}V/\mathrm{d}p$ is the rate of change of volume (V) with pressure.

compression ratio The ratio of the total volume enclosed in the cylinder of an *internal-combustion engine at the beginning of the compression stroke to the volume enclosed at the end of the compression stroke. For petrol engines the compression ratio is 8.5–9:1, with a recent tendency to the lower end of the range in order to make use of unleaded petrols. For Diesel engines the compression ratio is in the range 12–25:1.

comproportionation A reaction in which an element in a higher oxidation state reacts with the same element in a lower oxidation state to give the element in an intermediate oxidation state. An example is

$$Ag^{2+}(aq) + Ag(s) \rightarrow 2Ag^{+}(aq).$$

It is the reverse of *disproportionation.

Compton, Arthur Holly (1892–1962) US physicist, who became professor of physics at the University of Chicago in 1923. He is best known for his discovery (1923) of the *Compton effect, for which he shared the 1927 Nobel Prize for physics with C. T. R. *Wilson. In 1938 he demonstrated that *cosmic radiation consists of charged particles.

Compton effect The reduction in the energy of high-energy (X-ray or gamma-ray) photons when they are scattered by free electrons, which thereby gain energy. The phenomenon, first observed in 1923 by Arthur Compton, occurs when the photon collides with an electron; some of the photon's energy is transferred to the electron and consequently the photon loses energy $h(\nu_1 - \nu_2)$, where h is the *Planck constant and ν_1 and ν_2 are the frequencies before and after collision. As $\nu_1 > \nu_2$, the wavelength of the radiation increases after the collision. This type of inelastic scattering is known as **Compton scattering** and is similar to the *Raman effect. *See also* INVERSE COMPTON EFFECT.

SEE WEB LINKS

- Compton's original 1923 paper in *The Physical Review*

Compton wavelength The length below which a particle's quantum-mechanical properties become relevant in relativistic *quantum mechanics. For a particle of rest mass m the Compton wavelength is $\hbar/mc$, where $\hbar$ is the rationalized Planck constant and c is the speed of light. The Compton wavelength is so named because of its occurrence in the theory of the *Compton effect, where its value for the electron is 3.8616×10^{-13} m. The Compton wavelength is sometimes defined as h/mc, with h being the Planck constant, in which case the electron value is 2.4263×10^{-12} m.

computable structure A mathematical structure for which a systematic algorithm exists for solving all problems with that structure. It has been postulated that fundamental physics should involve computable structures, although some approaches to *quantum gravity involve mathematical structures that are not computable.

computer An electronic device that processes information according to a set of instructions, called the **program**. The most versatile type of computer is the **digital computer**, in which the input is in the form of characters, represented within the machine in *binary notation. Central to the operation of a computer is the **central processing unit** (**CPU**), which contains circuits for manipulating the information (*see* LOGIC CIRCUITS). The CPU contains the arithmetic/logic unit (ALU), which performs operations, and a control unit. It is supported by a short-term **memory**, in which data is stored in electronic circuits (*see* RAM). Associated storage usually involves *magnetic disks or *CD-ROM. There are also various peripheral input and output devices, such as a keyboard, visual-display unit (VDU), magnetic tape unit, and *printer. Computers range in size from the **microprocessor** with a few thousand logic elements, to the large **mainframe computer** with millions of logic circuits.

The **analog computer** is used in scientific experiments, industrial control, etc. In this type of device the input and output are continuously varying quantities, such as a voltage, rather than the discrete digits of the more commercially useful digital device. **Hybrid computers** combine the properties of both digital and analog devices. Input is usually in analog form, but processing is carried out digitally in a CPU.

Computer **hardware** consists of the actual

electronic or mechanical devices used in the system; the **software** consists of the programs and data. *See also* ROM.

concave Curving inwards. A **concave mirror** is one in which the reflecting surface is formed from the interior surface of a sphere or paraboloid. A **concave lens** has at least one face formed from the interior surface of a sphere. A **biconcave lens** has both faces concave and is therefore thinnest at its centre. The **plano-concave lens** has one plane face and one concave face. The **concavo-convex lens** (also called a **meniscus**) has one concave face and one *convex face. *See* LENS.

concavo-convex *See* CONCAVE.

concentrated Describing a solution that has a relatively high concentration of solute.

concentration The quantity of dissolved substance per unit quantity of solvent in a solution. Concentration is measured in various ways. The amount of substance dissolved per unit volume (symbol c) has units of mol dm^{-3} or mol l^{-1}. It is now called **amount concentration** (formerly **molarity**). The **mass concentration** (symbol ρ) is the mass of solute per unit volume of solvent. It has units of kg dm^{-3}, g cm^{-3}, etc. The **molal concentration** (or **molality**; symbol m) is the amount of substance per unit mass of solvent, commonly given in units of mol kg^{-1}. *See also* MOLE FRACTION.

concentration cell *See* CELL.

concentration gradient (diffusion gradient) The difference in concentration between a region of a solution or gas that has a high density of particles and a region that has a relatively lower density of particles. By random motion, particles will move from the area of high concentration towards the area of low concentration, by the process of *diffusion, until the particles are evenly distributed in the solution or gas.

conceptacle A flask-shaped cavity with a small opening (the **ostiole**) that is found in the swollen tip of certain brown algae, such as *Fucus*. It contains the sex organs.

conception The fertilization of a mammalian egg cell by a sperm cell, which occurs in the fallopian tube. Conception is followed by *implantation.

concerted reaction A type of reaction in which there is only one stage rather than a series of steps. The S_N2 mechanism in *nucleophilic substitutions is an example.

conchoidal fracture Fracture of a solid in which the surface of the material is curved and marked by concentric rings. It occurs particularly in amorphous materials.

condensation The change of a vapour or gas into a liquid. The change of phase is accompanied by the evolution of heat (*see* LATENT HEAT).

condensation polymerization *See* POLYMER.

condensation pump *See* DIFFUSION PUMP.

condensation reaction A chemical reaction in which two molecules combine to form a larger molecule with elimination of a small molecule (e.g. H_2O). *See* ALDEHYDES; KETONES.

condensed-matter physics *See* SOLID-STATE PHYSICS.

condenser **1.** A mirror or set of lenses used in optical instruments, such as a microscope or film projector, to concentrate the light diverging from a compact source. A common form consists of two plano-convex lenses with the plane faces pointing outwards. **2.** A device used to cool a vapour to cause it to condense to a liquid. In a steam engine the condenser acts as a reservoir that collects the part of the steam's internal energy that has not been used in doing work on the piston. The cooling water passed through the condenser is warmed and is used as fresh feedwater for the boiler. *See also* LIEBIG CONDENSER. **3.** *See* CAPACITOR.

condenser microphone *See* CAPACITOR MICROPHONE.

conditional response (conditioned reflex) A learned response that develops to an initially ineffective stimulus in classical *conditioning.

conditioning A process by which animals learn about a relation between two events. In **classical** (or **Pavlovian**) **conditioning**, repeated presentations of a neutral stimulus (e.g. the sound of a bell or buzzer) are followed each time by a biologically important stimulus (such as food or electric shock), which elicits a response (e.g. salivation). Eventually the neutral stimulus presented by itself produces a response (the **conditional response**, or **conditioned reflex**) similar to

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that originally evoked by the biologically important stimulus. In **instrumental** (or **operant**) **conditioning** the animal is rewarded (or punished) each time it makes a particular response; this eventually causes the frequency of the response to increase (or decrease). *See* LEARNING (Feature); REINFORCEMENT.

conductance The reciprocal of electrical resistance in a direct-current circuit. The ratio of the resistance to the square of the *impedance in an alternating-current circuit. The SI unit is the siemens, formerly called the mho or reciprocal ohm.

conducting polymer An organic polymer that conducts electricity. Conducting polymers have a crystalline structure in which chains of conjugated unsaturated carbon–carbon bonds are aligned. Examples are polyacetylene and polypyrrole. There has been considerable interest in the development of such materials because they would be cheaper and lighter than metallic conductors. They do, however, tend to be chemically unstable and, so far, no commercial conducting polymers have been developed.

conductiometric titration A type of titration in which the electrical conductivity of the reaction mixture is continuously monitored as one reactant is added. The equivalence point is the point at which this undergoes a sudden change. The method is used for titrating coloured solutions, which cannot be used with normal indicators.

conduction **1. (thermal conduction)** The transmission of heat through a substance from a region of high temperature to a region of lower temperature. In gases and most liquids, the energy is transmitted mainly by collisions between atoms and molecules with those possessing lower kinetic energy. In solid and liquid metals, heat conduction is predominantly by migration of fast-moving electrons, followed by collisions between these electrons and ions. In solid insulators the absence of free *electrons restricts heat transfer to the vibrations of atoms and molecules within crystal lattices. *See* CONDUCTIVITY. **2. (electrical conduction)** The passage of electric charge through a substance under the influence of an electric field. *See also* CHARGE CARRIER; ENERGY BANDS.

conduction band *See* ENERGY BANDS.

conductivity **1. (thermal conductivity)** A measure of the ability of a substance to conduct heat. For a block of material of cross section A, the energy transferred per unit time E/t, between faces a distance, l, apart is given by $E/t = \lambda A(T_2 - T_1)/l$, where λ is the conductivity and T_2 and T_1 are the temperatures of the faces. This equation assumes that the opposite faces are parallel and that there is no heat loss through the sides of the block. The SI unit is therefore J s^{-1} m^{-1} K^{-1}. **2. (electrical conductivity)** The reciprocal of the *resistivity of a material. It is measured in siemens per metre in SI units. When a fluid is involved the electrolytic conductivity is given by the ratio of the current density to the electric field strength.

SEE WEB LINKS

- Values of thermal conductivity for a range of materials at the NPL

conductivity water *See* DISTILLED WATER.

conductometric titration A type of *titration in which the end point is determined by detecting a sudden change in the conductivity of the solution. It is particularly useful in titrating weak acids against weak bases or for coloured solutions, for which indicators cannot be used.

conductor **1.** A substance that has a high thermal *conductivity. Metals are good conductors on account of the high concentration of free *electrons they contain. Energy is transmitted through a metal predominantly by means of collisions between electrons and ions. Most nonmetals are poor conductors (good **thermal insulators**) because there are relatively few free electrons. **2.** A substance that has a high electrical conductivity. Again conduction results from the movement of free electrons. *See* ENERGY BANDS.

condyle A smooth round knob of bone that fits into a socket on an adjoining bone, forming a *joint. Such a joint permits up-and-down or side-to-side movement but does not allow rotation. There are condyles where the lower jawbone (mandible) is attached to the skull, which permits chewing movements. *See also* OCCIPITAL CONDYLE.

Condy's fluid A mixture of calcium and potassium permanganates (manganate(VII)) used as an antiseptic.

cone **1.** (in botany) A reproductive structure occurring in gymnosperms, known technically as a **strobilus**. It consists of *sporophylls bearing the spore-producing

sporangia. Gymnosperms produce different male and female cones. The large woody female cones of pines, firs, and other conifers are made up of structures called **ovuliferous scales**, which bear the ovules. Cones are also produced by clubmosses and horsetails. **2.** (in animal anatomy) A type of light-sensitive receptor cell, found in the *retinas of all diurnal vertebrates. Cones are specialized to transmit information about colour (*see* COLOUR VISION) and are responsible for the *visual acuity of the eye. They function best in bright light. They are not evenly distributed on the retina, being concentrated in the *fovea and absent on the margin of the retina. *Compare* ROD. **3.** (in mathematics) A solid figure generated by a line (the **generator**) joining a point on the perimeter of a closed plane curve (the **directrix**) to a point (the **vertex**) outside this plane, as the line moves round the directrix. If the directrix is a circle, the figure is a **circular cone** standing on a circular **base**. If the line joining the vertex to the centre of the base (the **axis**) is perpendicular to the base the figure is a **right circular cone**, which has a volume $\pi r^2 h/3$, where r is the radius of the base and h is the height of the vertex above the base. If the axis of the cone is not perpendicular to the base, the figure is an **oblique cone**. In general, the volume of any cone is one third of its base area multiplied by the perpendicular distance of the vertex from the base.

configuration **1.** The arrangement of atoms or groups in a molecule. **2.** The arrangement of electrons in atomic *orbitals in an atom.

configuration space The n-dimensional space with coordinates $(q_1,q_2,\ldots,q_n)$ associated with a system that has n *degrees of freedom, where the values q describe the degrees of freedom. For example, in a gas of N atoms each atom has three positional coordinates, so the configuration space is $3N$-dimensional. If the particles also have internal degrees of freedom, such as those caused by vibration and rotation in a molecule, then these must be included in the configuration space, which is consequently of a higher dimension. *See also* PHASE SPACE.

confinement *See* QUANTUM CHROMODYNAMICS; QUARK CONFINEMENT.

confocal fluorescence microscopy A light microscopic technique that produces high-resolution images of fluorescently stained specimens without requiring elaborate preparation of the sample. The fluorescent markers, generally fluorescently labelled antibodies, are excited by light from a laser focused by the objective lens of the microscope so that it scans a single plane in the specimen, creating an optical section, under computer control. The emitted fluorescent light is captured by a photomultiplier and assembled into digital images by a computer. Serial scanning of, say, an entire cell can thus visualize successive sections through the cell or create three-dimensional, or even time-lapse, images. Moreover, numerous fluorescent probes are available for labelling different components of cells or other material.

conformal field theory A field theory that has *conformal invariance. There are important applications of conformal field theory in *string theory and *statistical mechanics.

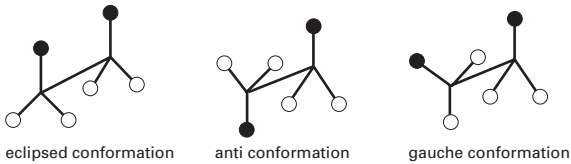
conformal invariance Invariance under *conformal transformations and under transformations of scale. Conformal invariance is important in theories with massless particles and in the theory of phase transitions.

conformal transformation A transformation that preserves the angles between curves. A well-known example is Mercator's projection in cartography, in which any angle between a line on the spherical surface and a line of latitude or longitude will be the same on the map. Conformal transformations are used in a number of areas in physics, particularly in dealing with electromagnetic and gravitational fields and in fluid mechanics. Problems can often be simplified by applying conformal transformations to change a complicated geometrical arrangement to a simpler one.

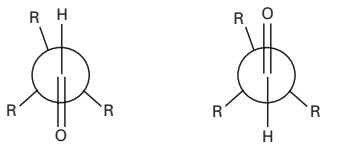
conformation Any of the large number of possible shapes of a molecule resulting from rotation of one part of the molecule about a single bond. See illustration overleaf.

congeners Elements that belong to the same group in the periodic table.

congenital Present at birth. Congenital disorders of the body may be due to genetic factors, e.g. *Down's syndrome, or caused by injury or environmental factors, e.g. drugs (such as thalidomide), chemicals (such as dioxin), and infections (such as those caused by **Listeria* and *cytomegalovirus).



Conformations of butane (sawhorse projection)



Conformations of R_3CHO (Newman projection)

Conformation.

conic A figure formed by the intersection of a plane and a *cone. If the intersecting plane is perpendicular to the axis of a right circular cone, the figure formed is a *circle. If the intersecting plane is inclined to the axis at an angle in excess of half the apex angle of the cone it is an *ellipse. If the plane is parallel to the sloping side of the cone, the figure is a *parabola. If the plane cuts both halves of the cone a *hyperbola is formed.

A conic can be defined as a plane curve in which for all points on the curve the ratio of the distance from a fixed point (the **focus**) to the perpendicular distance from a straight line (the **directrix**) is a constant called the **eccentricity** *e*. For a parabola $e = 1$, for an ellipse $e < 1$, and for a hyperbola $e > 1$.

conidiospore *See* CONIDIUM.

conidium (conidiospore) A spore of certain fungi, such as moulds, that is produced by the constriction of the tip of a specialized hypha, the **conidiophore**. Chains of conidia may be formed in this way; they are cut off, one at a time, from the tip of the hypha.

Coniferophyta A phylum of seed-bearing plants comprising the conifers, including the pines, firs, and spruces. Conifers have an extensive fossil record going back to the late Devonian. The gametes are carried in male and female *cones, fertilization usually being achieved by wind-borne pollen. The ovules and the seeds into which they develop are borne unprotected (rather than enclosed in a carpel, as are those of the *Anthophyta). Internal tissue and cell structure of these species is not as advanced as in the angiosperms. Conifers are typically evergreen trees inhabiting cool temperate regions and have leaves reduced to needles or scales. The wood of conifers, which is called **softwood** in contrast to the **hardwood** of angiosperm trees, is widely used for timber and pulp. *See also* GYMNOSPERM.

SEE WEB LINKS

- Well-illustrated survey of conifer biology, hosted by University of Hawaii

conjugate acid (conjugate base) *See* ACID.

conjugated Describing double or triple bonds in a molecule that are separated by one single bond. For example, the organic compound buta-1,3-diene, $H_2C{=}CH{-}CH{=}CH_2$, has conjugated double bonds. In such molecules, there is some delocalization of electrons in the pi orbitals between the carbon atoms linked by the single bond.

conjugate points Two points in the

vicinity of a *lens or *mirror such that a bright object placed at one will form an image at the other.

conjugation **1.** The fusion of two reproductive cells, particularly when these are both the same size (*see* ISOGAMY). **2.** A form of sexual reproduction seen in some algae (e.g. *Spirogyra*), some bacteria (e.g. *Escherichia coli*), and ciliate protozoans. Two individuals are united by a tube formed by outgrowths from one or both of the cells. Genetic material from one cell (designated the male) then passes through the tube to unite with that in the other (female) cell.

conjunction The alignment of two celestial bodies within the solar system so that they have the same celestial longitude as seen from the earth. A planet that orbits between the sun and the earth (Venus and Mercury) is in **superior conjunction** when it is in line with the sun and the earth but on the opposite side of the sun to the earth. It is in **inferior conjunction** when it lies between the earth and the sun. Conjunction may also occur between two planets or a moon and a planet.

conjunctiva The delicate membrane that covers the cornea and lines the inside of the eyelid of a vertebrate eye. It is kept clean by secretions of the *lacrimal (tear) gland and the reflex blink mechanism.

connection table A way of representing a molecule as a table showing the atoms, their coordinates, and the links between them. The widely used MDL molfile format uses a connection table in its representation of structure. Connection tables are a useful way of storing molecular data, both from the point of view of graphics programs and also for database searches, in which it is possible to use the table to look for substructures.

connective tissue An animal tissue consisting of a small number of cells (e.g. *fibroblasts and *mast cells) and fibres and a large amount of *extracellular matrix (ground substance). It is widely distributed and has many functions, including support, packing, defence, and repair. The individual constituents vary, depending on the function of the tissue. Different types of connective tissue include **mesenchyme** in the embryo, *adipose tissue, loose **areolar connective tissue** for packing and support, *blood, lymph, cartilage, and bone.

consensus sequence A sequence of nucleotides found in comparable regions of DNA or RNA, e.g. in the promoter regions (*see* OPERON) of different genes, in which certain bases occur with a frequency significantly greater than that expected by chance. Although such sequences may vary from case to case, it is possible to derive the most likely sequence overall. An example is the *Pribnow box of prokaryote promoters. The term is also applied to sequences of amino acids in polypeptides.

conservation The sensible use of the earth's natural resources in order to avoid excessive degradation and impoverishment of the environment (*see* DESERTIFICATION). It should include the search for alternative food and fuel supplies when these are endangered (as by *deforestation and overfishing); an awareness of the dangers of *pollution; and the maintenance and preservation of natural habitats and the creation of new ones (e.g. nature reserves, national parks, and *SSSIs).

conservation law A law stating that the total magnitude of a certain physical property of a system, such as its mass, energy, or charge, remains unchanged even though there may be exchanges of that property between components of the system. For example, imagine a table with a bottle of salt solution (NaCl), a bottle of silver nitrate solution ($AgNO_3$), and a beaker standing on it. The mass of this table and its contents will not change even when some of the contents of the bottles are poured into the beaker. As a result of the reaction between the chemicals two new substances (silver chloride and sodium nitrate) will appear in the beaker:

$$NaCl + AgNO_3 \rightarrow AgCl + NaNO_3,$$

but the total mass of the table and its contents will not change. This **conservation of mass** is a law of wide and general applicability, which is true for the universe as a whole, provided that the universe can be considered a closed system (nothing escaping from it, nothing being added to it). According to Einstein's mass–energy relationship, every quantity of energy (E) has a mass (m), which is given by E/c^2, where c is the speed of light. Therefore if mass is conserved, the law of **conservation of energy** must be of equally wide application. The laws of **conservation of linear momentum** and **angular momentum** also are believed to be universally true.

Because no way is known of either creating or destroying electric charge, the law of

conservation of charge is also a law of universal application. Other quantities are also conserved in reactions between elementary particles.

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conservative field A field of force in which the work done in moving a body from one point to another is independent of the path taken. The force required to move the body between these points in a conservative field is called a **conservative force**.

conserved sequence Any sequence of bases (or amino acids) in comparable segments of different nucleotides (or proteins) that tends to show similarity greater than that due to chance alone. The degree to which sequences are conserved can indicate the extent of structural and functional similarities between different genes or between different proteins and provides clues to their possible evolutionary relations.

consistent histories An interpretation of quantum mechanics that makes use of the concept of *decoherence to explain how the classical world emerges from quantum mechanics. The consistent-histories interpretation avoids the problem of observers and has greatly clarified our understanding of the problem of measurement in quantum mechanics.

consociation A climax plant *community that is dominated by one particular species, e.g. a pine forest. *See* DOMINANT. *Compare* ASSOCIATION.

consolute temperature The temperature at which two partially miscible liquids become fully miscible as the temperature is increased.

constant **1.** A component of a relationship between variables that does not change its value, e.g. in $y = ax + b$, b is a constant. **2.** A fixed value that has to be added to an indefinite integral. Known as the **constant of integration**, it depends on the limits between which the integration has been performed. **3.** *See* FUNDAMENTAL CONSTANTS.

constantan An alloy having an electrical resistance that varies only very slightly with temperature (over a limited range around normal room temperatures). It consists of copper (50–60%) and nickel (40–50%) and is used in resistance wire, thermocouples, etc.

constant-boiling mixture *See* AZEOTROPE.

constant proportions *See* CHEMICAL COMBINATION.

constellation A collection of stars arbitrarily grouped into a recognizable pattern, more than half of which were named by the ancients after animals and mythological characters; the rest, discovered when mariners explored the southern hemisphere, received names derived from navigational and scientific instruments. There are 88 constellations, which divide up the celestial sphere into regions named after them. The smallest is Crux (the [Southern] Cross) and the largest Hydra (the Sea Monster). Stars within a constellation are named according to a number of conventional systems. The brightest stars have individual names from Greek or Latin (Sirius, Arcturus) or Arabic (Aldebaran, Rigel), But for scientific and cataloguing purposes, most stars are named according to a system invented by a German lawyer and astronomer Johann Bayer (1572–1625), published in 1603. It uses a Greek letter and the genitive form of the constellation's Latin name (e.g. Alpha Crucis, Delta Cephei). Generally, α (alpha) signifies the brightest star, β (beta) the second brightest, etc. When the 24 letters of the Greek alphabet are exhausted, the Bayer system uses lower- and then upper-case Roman letters. Variable stars have their own designations, as in RR Lyrae or T Tauri.

SEE WEB LINKS

- Information about constellations, including clear star charts, from the International Astronomical Union
- A discussion of how the present constellation boundaries were established by the IAU in 1930

constitutive equations The equations $\boldsymbol{D} = \varepsilon \boldsymbol{E}$ and $\boldsymbol{B} = \mu \boldsymbol{H}$, where $\boldsymbol{D}$ is the electric displacement, ε is the *permittivity of the medium, $\boldsymbol{E}$ is the electric field intensity, $\boldsymbol{B}$ is the magnetic flux density, μ is the *permeability of the medium, and $\boldsymbol{H}$ is the *magnetic field strength.

consumer An organism that feeds upon those below it in a *food chain (i.e. at the preceding *trophic level). Herbivores, which feed upon green plants, are **primary consumers**; a carnivore that feeds only upon herbivores is a **secondary consumer**; a **tertiary consumer** is a carnivore that feeds on other carnivores. The consumer at the end of a food chain is known as the **top carnivore**. *Compare* PRODUCER.

contact potential difference The potential difference that occurs between two electrically connected metals or between the base regions of two semiconductors. If two metals with work functions ϕ_1 and ϕ_2 are brought into contact, their Fermi levels will coincide. If $\phi_1 > \phi_2$ the first metal will acquire a positive surface charge with respect to the other at the area of contact. As a result, a contact potential difference occurs between the two metals or semiconductors.

contact process A process for making sulphuric acid from sulphur dioxide (SO_2), which is made by burning sulphur or by roasting sulphide ores. A mixture of sulphur dioxide and air is passed over a hot catalyst

$$2SO_2 + O_2 \rightarrow 2SO_3$$

The reaction is exothermic and the conditions are controlled to keep the temperature at an optimum 450°C. Formerly, platinum catalysts were used but vanadium–vanadium oxide catalysts are now mainly employed (although less efficient, they are less susceptible to poisoning). The sulphur trioxide is dissolved in sulphuric acid

$$H_2SO_4 + SO_3 \rightarrow H_2S_2O_7$$

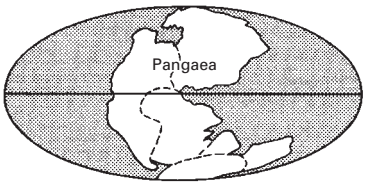
and the oleum is then diluted.

containment **1.** The prevention of the escape of radioactive materials from a *nuclear reactor. **2.** The process of preventing the plasma in a *thermonuclear reactor from touching the walls of the vessel by means of magnetic fields.

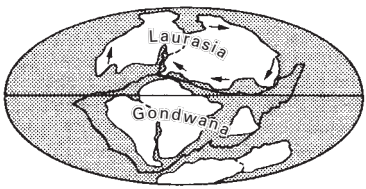
contig map *See* PHYSICAL MAP.

continent A large landmass that rises above the deep ocean floor. Geologically, the boundary of a continent lies offshore at the edge of the gentle slope of the continental shelf. The British Isles and other offshore islands consequently are parts of the nearby continents. It is generally accepted that there are seven continents – Asia, Africa, North America, South America, Europe, Australia, and Antarctica – occupying about 29% of the earth's surface.

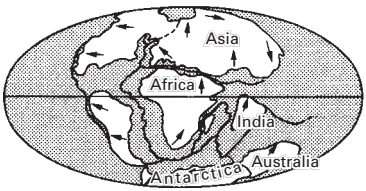
continental drift The theory that the earth's continents once formed a single mass and have since moved relative to each other. It was first postulated by A. Snider in 1858 and greatly developed by Alfred Wegener in 1915. He used evidence, such as the fit of South America into Africa and the distribution of rock types, flora, fauna, and geological structures, to suggest that the present



(a) 200 million years ago



(b) 135 million years ago



(c) 65 million years ago

Continental drift.

distribution of the continents results from the breaking up of one or two greater land masses. The original land mass was named Pangaea and it was suggested that this broke up into the northerly **Laurasia** and the southerly **Gondwanaland** (see illustration). The theory was not accepted for about 50 years by the majority of geologists but during the early 1960s, the seafloor-spreading hypothesis of Harry Hess (1906–69) and the subsequent development of *plate tectonics produced a mechanism to explain the drift of the continents.

SEE WEB LINKS

- Animation of continental drift during the earth's history

continuous culture A technique used to grow microorganisms or cells continually in a particular phase of growth. For example, if a constant supply of cells is required, a cell culture maintained in the log phase is best; the conditions must therefore be continually monitored and adjusted accordingly so that

the cells do not enter the stationary phase (*see* BACTERIAL GROWTH CURVE). Growth may also have to be maintained in a particular growth phase if an enzyme or chemical product is produced only during that phase.

C

continuous function A function f(x) is continuous at $x = a$ if the limit of f(x) as x approaches a is f(a). A function that does not satisfy this condition is said to be a **discontinuous function**.

continuous phase *See* COLLOIDS.

continuous spectrum *See* SPECTRUM.

continuous variation (quantitative variation) The range of differences that can be observed in many characteristics in a population. Characteristics resulting from polygenic inheritance (*see* QUANTITATIVE INHERITANCE) show continuous variation, e.g. the wide range of foot sizes in an adult human population. *Compare* DISCONTINUOUS VARIATION.

continuous wave A wave that is transmitted continuously rather than in pulses.

continuum A system of axes that form a *frame of reference. The three dimensions of space and the dimension of time together can be taken to form a four-dimensional continuum; this was suggested by Minkowski in connection with special *relativity.

contour A line drawn on a map or chart that joins points with equal elevation above (or below) a level (usually mean sea level). Contours thus show the relief of the land surface or sea bed (below sea level the line is called a **submarine contour**). The difference in height between two consecutive contours is the **contour interval**.

contour feathers *Feathers that are arranged in regular rows on a bird's body, giving the body its streamlined shape. Each has a central horny shaft (the **rachis**) with a flattened **vane** on each side. Each vane is composed of two rows of filament-like *barbs, which are connected to each other by means of hooked *barbules to form a smooth surface. There is often a small second vane, the **aftershaft**, near the base of the feather.

contraception *See* BIRTH CONTROL.

contractile root Any of the modified adventitious roots that develop from the base of the stem of a bulb or corm. The new bulb or corm develops at a higher level in the soil than the old one. The contractile roots shorten and pull it down to a suitable level.

contractile vacuole A membrane-surrounded cavity in a cell that periodically expands, filling with water, and then suddenly contracts, expelling its contents to the cell's exterior. It is thus an organ of *osmoregulation and excretion. Contractile vacuoles are common in freshwater sponges and typical of freshwater protists, such as *Amoeba* (which has one spherical vacuole) and *Paramecium* (in which a number of accessory vacuoles are attached to a main vacuole).

contraction (in animal physiology) The shortening of muscle fibres in order to exert a force on a tissue or organ of the body. In striated muscle contraction is brought about by interaction of actin and myosin filaments (*see* SARCOMERE; VOLUNTARY MUSCLE): it provides a force for *locomotion and plays a role in maintaining the balance and posture of the animal. *See also* INVOLUNTARY MUSCLE.

control **1.** The part of an experiment that acts as a standard by which to compare experimental observations. **2.** The natural regulation of biological processes. *See* CONTROL MECHANISM. **3.** *See* BIOLOGICAL CONTROL; CHEMICAL CONTROL.

control grid A wire-mesh electrode placed between the cathode and anode in a *thermionic valve or a *cathode-ray tube to control the flow of electrons from one to the other. A fluctuating potential signal fed to the control grid produces a current signal at the anode with similar but amplified fluctuations. It thus forms the basis of the electronic valve amplifier. In a cathode-ray tube the grid controls the intensity of the electron beam and hence the brightness of the image on the screen.

control mechanism (in biology) Any mechanism that regulates a biological process, such as a metabolic pathway or enzyme-controlled reaction, or that helps to maintain the *internal environment (*see* HOMEOSTASIS). *See also* FEEDBACK.

control rod One of a number of rods of a material, such as boron or cadmium, that absorbs neutrons. Control rods can be moved into or out of the core of a *nuclear reactor to control the rate of the reaction taking place within it.

control unit (CU) The part of the central

processor of a *computer that supervises the execution of a computer program.

convection A process by which heat is transferred from one part of a fluid to another by movement of the fluid itself. In **natural convection** the movement occurs as a result of gravity; the hot part of the fluid expands, becomes less dense, and is displaced by the colder denser part of the fluid as this drops below it. This is the process that occurs in most domestic hot-water systems between the boiler and the hot-water cylinder. A natural convection current is set up transferring the hot water from the boiler up to the cylinder (always placed above the boiler) so that the cold water from the cylinder can move down into the boiler to be heated. In some modern systems, where small-bore pipes are used or it is inconvenient to place the cylinder above the boiler, the circulation between boiler and hot-water cylinder relies upon a pump. This is an example of **forced convection**, where hot fluid is transferred from one region to another by a pump or fan.

conventional current A 19th-century convention, still in use, that treats any electrical current as a flow of positive charge from a region of positive potential to one of negative potential. The real motion, however, in the case of electrons flowing through a metal conductor, is in the opposite direction, from negative to positive. In semiconductors *hole conduction is in the direction of the conventional current; electron conduction is in the opposite direction.

convergent evolution The development of superficially similar structures in unrelated organisms, usually because the organisms live in the same kind of environment. Examples are the wings of insects and birds and the streamlined bodies of whales and fish. *Compare* ADAPTIVE RADIATION.

convergent series A series $a_1 + a_2 + \ldots + a_i + \ldots$, for which a partial sum $S_n = a_1 + a_2 + \ldots + a_n$ tends to a finite (or zero) limit as n tends to infinity. This limit is the **sum** of the series. For example, the series $1 + 1/2 + 1/4 + 1/8 + \ldots$ (with the general term a_i equal to $(1/2)^{i-1}$) tends to the limit 2. A series that is not convergent is said to be a **divergent series**. In such a series the partial sum tends to plus or minus infinity or may oscillate. For example, the series $1 + 1/2 + 1/3 + 1/4 + \ldots$ (with a_i equal to $1/i$) is divergent. As can be seen from this latter example, a series may be divergent even if the individual terms a_i tend to zero as i tends to infinity.

converging lens or mirror A lens or mirror that can refract or reflect a parallel beam of light so that it converges at a point (the principal focus). Such a mirror is concave; a converging lens is thicker at its centre than at its edges (i.e. it is biconvex, plano-convex, or convexo-concave). *Compare* DIVERGING LENS OR MIRROR.

conversion electron *See* INTERNAL CONVERSION.

converter **1.** An electrical machine for converting alternating current into direct current, or less frequently, vice versa. **2.** The reaction vessel in the *Bessemer process or some similar steel-making process. **3.** A computer device for converting information coded in one form into some other form.

converter reactor A *nuclear reactor that converts fertile material (e.g. thorium–232) into *fissile material (e.g. uranium–233). A converter reactor can also be used to produce electrical power.

convex Curving outwards. A **convex mirror** is one in which the reflecting surface is formed from the exterior surface of a sphere or paraboloid. A **convex lens** has at least one face formed from the exterior surface of a sphere. A **biconvex lens** has both faces convex and is therefore thickest at its centre. The **plano-convex lens** has one plane face and one convex face. The **convexo-concave lens** (also called a **meniscus**) has one convex face and one *concave face. *See* LENS.

convoluted tubule *See* DISTAL CONVOLUTED TUBULE; PROXIMAL CONVOLUTED TUBULE; NEPHRON.

coolant A fluid used to remove heat from a system by *convection (usually forced), either to control the temperature or to extract energy. In a water-cooled car engine the coolant is water (or water and antifreeze), which is pumped around the engine and cooled in the radiator. In a *nuclear reactor the coolant is used to transfer the heat of the reaction from the core to a heat exchanger or to the steam-raising plant. In gas-cooled reactors the coolant is usually carbon dioxide. Pressurized water or boiling water is used as both coolant and *moderator in several types of reactor. In fast reactors, liquid sodium is used as the coolant.

Cooper, Leon *See* BARDEEN, JOHN.

C

cooperative phenomenon A phenomenon in which the constituents of a system cannot be regarded as acting independently from each other. Cooperative phenomena result from interactions between the constituents. Phenomena that can be described by the *liquid-drop model of nuclei, such as nuclear fission, are examples of cooperative phenomena because they involve the *nucleus as a whole rather than individual nucleons. Other examples of cooperative phenomena occur when a substance undergoes a *phase transition, as in the phenomena of ferromagnetism (*see* MAGNETISM) or *superconductivity.

Cooper pairs *See* SUPERCONDUCTIVITY.

coordinate *See* CARTESIAN COORDINATES; POLAR COORDINATES.

coordinate bond *See* CHEMICAL BOND.

coordinate geometry *See* ANALYTICAL GEOMETRY.

coordinate system A system that uniquely specifies points in a plane or in three-dimensional space. The simplest coordinate system is the *Cartesian coordinate system. In a plane two coordinates are necessary to specify a point. In three-dimensional space three coordinates are required. Many coordinate systems can be used to specify a point; however, sometimes one particular coordinate system is more convenient than others; indeed, certain problems can be solved in one coordinate system but not in others. For example, the Schrödinger equation for the hydrogen atom can be solved using spherical *polar coordinates but not using Cartesian coordinates.

coordination (in animal physiology) The processes involved in the reception of sensory information, the integration of that information, and the subsequent response of the organism. Coordination is controlled by regions of the brain that deal with specific functions, such as locomotion and breathing, and is carried out by the nervous system.

coordination compound A compound in which coordinate bonds are formed (*see* CHEMICAL BOND). The term is used especially for inorganic *complexes.

SEE WEB LINKS

- Information about IUPAC nomenclature

coordination number The number of groups, molecules, atoms, or ions surrounding a given atom or ion in a complex or crystal. For instance, in a square-planar complex the central ion has a coordination number of four. In a close-packed crystal (*see* CLOSE PACKING) the coordination number is twelve.

Copepoda A class of crustaceans occurring in marine and freshwater habitats. Copepods are usually 0.5–2 mm long and lack both a carapace and compound eyes. Copepods are important members of plankton: some are free-living, feeding on microscopic organisms; others are parasitic. A familiar freshwater genus is *Cyclops*, so named because the members have a single median eye.

Copernican astronomy The system of astronomy that was proposed by the Polish astronomer Nicolaus Copernicus in his book *De revolutionibus orbium coelestium*, which was published in the month of his death (in 1543) and first seen by him on his deathbed. It used some elements of *Ptolemaic astronomy, but rejected the notion, then current, that the earth was a stationary body at the centre of the universe. Instead, Copernicus proposed the apparently unlikely concept that the sun was at the centre of the universe and that the earth travelled in a circular orbit about it. In addition Copernicus revived the idea that the movement of the sun and the fixed stars was due to the daily axial rotation of the earth. Galileo's attempts, some 70 years later, to convince the Catholic church that in spite of scriptural authority to the contrary, the Copernican system was correct, met with such stern resistance that *De revolutionibus* was placed on the church's list of forbidden books, where it remained until 1835.

Copernicus, Nicolaus (Mikolaj Kopernik; 1473–1543) Polish astronomer, who studied mathematics and optics. By 1514 he had formulated his proposal that the planets, including the earth, orbit the sun in circular paths, although it was not formally published until the year he died. This refutation of an earth-centred universe raised hostile opposition from the church as well as from other astronomers.

copolymer *See* POLYMER.

copper Symbol Cu. A red-brown *transition element; a.n. 29; r.a.m. 63.546; r.d. 8.92; m.p. 1083.4°C; b.p. 2567°C. Copper has been extracted for thousands of years; it was known to the Romans as cuprum, a name

linked with the island of Cyprus. The metal is malleable and ductile and an excellent conductor of heat and electricity. Copper-containing minerals include cuprite (Cu_2O) as well as azurite ($2CuCO_3.Cu(OH)_2$), chalcopyrite ($CuFeS_2$), and malachite ($CuCO_3.Cu(OH)_2$). Native copper appears in isolated pockets in some parts of the world. The large mines in the USA, Chile, Canada, Zambia, Democratic Republic of Congo, and Peru extract ores containing sulphides, oxides, and carbonates. They are usually worked by smelting, leaching, and electrolysis. Copper metal is used to make electric cables and wires. Its alloys, brass (copper–zinc) and bronze (copper–tin), are used extensively.

Water does not attack copper but in moist atmospheres it slowly forms a characteristic green surface layer (patina). The metal will not react with dilute sulphuric or hydrochloric acids, but with nitric acid oxides of nitrogen are formed. Copper compounds contain the element in the +1 and +2 oxidation states. Copper(I) compounds are mostly white (the oxide is red). Copper(II) salts are blue in solution. The metal also forms a large number of coordination complexes.

SEE WEB LINKS

- Information from the WebElements site

copperas *See* IRON(II) SULPHATE.

copper(I) chloride A white solid compound, CuCl; cubic; r.d. 4.14; m.p. 430°C; b.p. 1490°C. It is obtained by boiling a solution containing copper(II) chloride, excess copper turnings, and hydrochloric acid. Copper(I) is present as the $[CuCl_2]^-$ complex ion. On pouring the solution into air-free distilled water copper(I) chloride precipitates. It must be kept free of air and moisture as it oxidizes to copper(II) chloride under those conditions.

Copper(I) chloride is essentially covalent and its structure is similar to that of diamond; i.e. each copper atom is surrounded tetrahedrally by four chlorine atoms and vice versa. In the vapour phase, dimeric and trimeric species are present. Copper(I) chloride is used in conjunction with ammonium chloride as a catalyst in the dimerization of ethyne to but-1-ene-3-yne (vinyl acetylene), which is used in the production of synthetic rubber. In the laboratory a mixture of copper(I) chloride and hydrochloric acid is used for converting benzene diazonium chloride to chlorobenzene – the Sandmeyer reaction.

copper(II) chloride A brown-yellow powder, $CuCl_2$; r.d. 3.386; m.p. 620°C. It exists as a blue-green dihydrate (rhombic; r.d. 2.54; loses H_2O at 100°C). The anhydrous solid is obtained by passing chlorine over heated copper. It is predominantly covalent and adopts a layer structure in which each copper atom is surrounded by four chlorine atoms at a distance of 0.23 nm and two more at a distance of 0.295 nm. A concentrated aqueous solution is dark brown in colour due to the presence of complex ions such as $[CuCl_4]^{2-}$. On dilution the colour changes to green and then blue because of successive replacement of chloride ions by water molecules, the final colour being that of the $[Cu(H_2O)_6]^{2+}$ ion. The dihydrate can be obtained by crystallizing the solution.

copper glance A mineral form of copper(I) sulphide, Cu_2S.

copper(II) nitrate A blue deliquescent solid, $Cu(NO_3)_2.3H_2O$; r.d. 2.32; m.p. 114.5°C. It may be obtained by reacting either copper(II) oxide or copper(II) carbonate with dilute nitric acid and crystallizing the resulting solution. Other hydrates containing 6 or 9 molecules of water are known. On heating it readily decomposes to give copper(II) oxide, nitrogen dioxide, and oxygen. The anhydrous form can be obtained by reacting copper with a solution of nitrogen dioxide in ethyl ethanoate. It sublimes on heating suggesting that it is appreciably covalent.

copper(I) oxide A red insoluble solid, Cu_2O; r.d. 6.0; m.p. 1235°C. It is obtained by reduction of an alkaline solution of copper(II) sulphate. Since the addition of alkalis to a solution of copper(II) salt results in the precipitation of copper(II) hydroxide the copper(II) ions are complexed with tartrate ions; under such conditions the concentration of copper(II) ions is so low that the solubility product of copper(II) hydroxide is not exceeded.

When copper(I) oxide reacts with dilute sulphuric acid a solution of copper(II) sulphate and a deposit of copper results, i.e. disproportionation occurs.

$$Cu_2O + 2H^+ \rightarrow Cu^{2+} + Cu + H_2O$$

When dissolved in concentrated hydrochloric acid the $[CuCl_2]^-$ complex ion is formed. Copper(I) oxide is used in the manufacture of rectifiers and the production of red glass.

C

copper(II) oxide A black insoluble solid, CuO; monoclinic; r.d. 6.3; m.p. 1326°C. It is obtained by heating either copper(II) carbonate or copper(II) nitrate. It decomposes on heating above 800°C to copper(I) oxide and oxygen. Copper(II) oxide reacts readily with mineral acids on warming, with the formation of copper(II) salts; it is also readily reduced to copper on heating in a stream of hydrogen. Copper(II) oxide is soluble in dilute acids forming blue solutions of cupric salts.

copper pyrites *See* CHALCOPYRITE.

copper(II) sulphate A blue crystalline solid, $CuSO_4.5H_2O$; triclinic; r.d. 2.284. The pentahydrate loses $4H_2O$ at 110°C and the fifth H_2O at 150°C to form the white anhydrous compound (rhombic; r.d. 3.6; decomposes above 200°C). The pentahydrate is prepared either by reacting copper(II) oxide or copper(II) carbonate with dilute sulphuric acid; the solution is heated to saturation and the blue pentahydrate crystallizes out on cooling (a few drops of dilute sulphuric acid are generally added to prevent hydrolysis). It is obtained on an industrial scale by forcing air through a hot mixture of copper and dilute sulphuric acid. In the pentahydrate each copper(II) ion is surrounded by four water molecules at the corner of a square, the fifth and sixth octahedral positions are occupied by oxygen atoms from the sulphate anions, and the fifth water molecule is held in place by hydrogen bonding. Copper(II) sulphate has many industrial uses, including the preparation of the Bordeaux mixture (a fungicide) and the preparation of other copper compounds. It is also used in electroplating and textile dying and as a timber preservative. The anhydrous form is used in the detection of traces of moisture.

Copper(II) sulphate pentahydrate is also known as **blue vitriol**.

coprecipitation The removal of a substance from solution by its association with a precipitate of some other substance. For example, if A and B are present in solution and a reagent is added such that A forms an insoluble precipitate, then B may be carried down with the precipitate of A, even though it is soluble under the conditions. This can occur by occlusion or absorption.

copulation *See* SEXUAL INTERCOURSE.

coral Any of a group of sedentary colonial marine invertebrates belonging to the class Anthozoa of the phylum *Cnidaria. A coral colony consists of individual *polyps within a protective skeleton that they secrete: this skeleton may be soft and jelly-like, horny, or stony. The horny skeleton secreted by corals of the genus *Corallium*, especially *C. rubrum*, constitutes the red, or precious, coral used as a gemstone. The skeleton of stony, or true, corals consists of almost pure calcium carbonate and forms the coral reefs common in tropical seas.

cordite An explosive mixture of cellulose nitrate and nitroglycerin, with added plasticizers and stabilizers, used as a propellant for guns.

core **1.** A rod or frame of magnetic material that increases the inductance of a coil through which it passes. Cores are used in transformers, electromagnets, and the rotors and stators of electrical machines. It may consist of laminated metal, ferrite, or compressed ferromagnetic particles in a matrix of an insulating binder (**dust core**). **2.** The inner part of a *nuclear reactor in which the nuclear reaction takes place. **3.** The devices that make up the memory in certain types of computer. **4.** The central region of a star or planet.

Coriolis force A fictitious force sometimes used to simplify calculations involving rotating systems, such as the movement of air, water, and projectiles over the surface of the rotating earth. The concept was first used in 1835 by Gaspard de Coriolis (1792–1843), a French physicist. The daily rotation of the earth means that in 24 hours a point on its equator moves a distance of some 40 000 kilometres, giving it a tangential velocity of about 1670 kilometres per hour. A point at the latitude of, say, Rome, travels a shorter distance in the same time and therefore has a lower tangential velocity – about 1340 km/hr. Air over the equator has the full tangential velocity of 1670 km/hr and as it travels north, say, it will retain this velocity; to an observer outside the earth this would be clear. However, to an observer in Rome it appears to be moving eastwards, because the earth at that point is moving eastwards more slowly than the air. The Coriolis force (which is quite fictitious) is the force that a naive observer thinks is needed to push the air eastwards.

cork (phellem) A protective waterproof plant tissue produced by the *cork cambium. It develops in plants undergoing *secondary

growth and replaces the epidermis. Its cells, whose walls are impregnated with *suberin, are arranged in radial rows and fit closely together except where the cork is interrupted by *lenticels. Some cork cells become air-filled while others contain deposits of lignin, tannins, and fatty acids, which give the cork a particular colour. The cork oak (*Quercus suber*) produces cork that can be used commercially.

cork cambium (phellogen) A type of *cambium arising within the outer layers of the stems of woody plants, usually as a complete ring surrounding the inner tissues. The cells of the cork cambium divide to produce an outer corky tissue (*cork or **phellem**) and an inner secondary cortex (**phelloderm**). Cork, cork cambium, and phelloderm together make up the **periderm**, an impermeable outer layer that protects the inner stem tissues if the outer tissues split as the stem girth increases with age. It thus takes over the functions of the epidermis.

corm An underground organ formed by certain plants, e.g. crocus and gladiolus, that enables them to survive from one growing season to the next (see illustration). It consists of a short swollen food-storing stem surrounded by protective scale leaves. One or more buds in the axils of scale leaves produce new foliage leaves and flowers in the subsequent season, using up the food stored in the stem. *Compare* BULB.

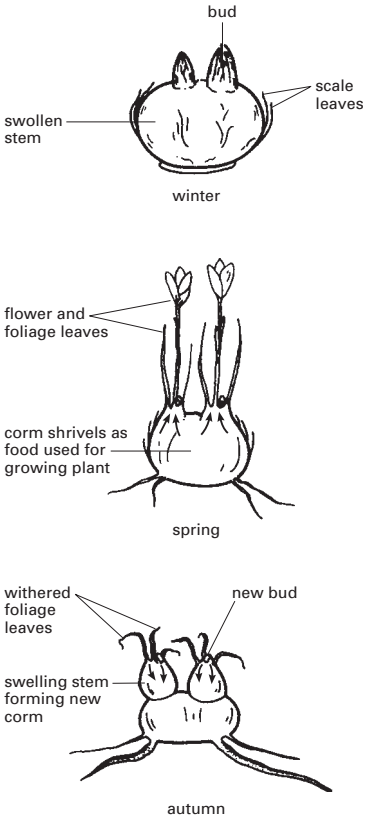
cornea A transparent layer of tissue, continuous with the *sclerotic, that forms the front part of the vertebrate eye, over the iris and lens. The cornea refracts light entering the eye onto the lens, thus assisting in the focusing of images onto the *retina. *See also* ASTIGMATISM.

cornification *See* KERATINIZATION.

CORN rule *See* ABSOLUTE CONFIGURATION.

corolla The *petals of a flower, collectively, forming the inner whorl of the *perianth. It encircles the stamens and carpels. The form of the corolla is very variable. The petals may either be free (**polypetalous**) or united to form a tube (**gamopetalous** or **sympetalous**).

corona **1.** The outer part of the sun's atmosphere. Its two main components are the K-corona (or inner corona), with a temperature of about 2×10^6 K at a height of some 75 000 km, and the F-corona (or outer corona), which is considerably cooler and extends for several million kilometres into space. **2.** A glowing region of the air surrounding a conductor when the potential gradient near it exceeds a critical value. It is caused by ionization of the air and may be accompanied by hissing sounds. **Corona discharge** (or **point discharge**) occurs at sharp points where the surface charge density is high by the attraction, charging, and consequent repulsion of air molecules.



Corm development.

coronal mass ejection (CME; coronal transient) A huge bubble of energetic gas interlaced with magnetic field lines that is hurled out of the sun's corona into interplanetary space, reaching speeds of between

200 and 1000 km s^{-1} as it expands over several hours. CMEs are often connected with *solar flares or solar *prominences but may occur alone. The frequency of these events reaches its peak at *sunspot maximum (*see* SOLAR CYCLE). On earth CMEs can produce magnetic storms and spectacular aurorae, disrupt radio communications and electricity supplies, and damage power transmission lines and satellites.

coronary vessels Two pairs of blood vessels (the coronary arteries and coronary veins) that supply the muscles of the heart itself. The coronary arteries arise from the aorta and divide into branches that encircle the heart. A blood clot in a coronary artery (**coronary thrombosis**) is one of the causes of a 'heart attack'.

corpus callosum The sweeping band (commissure) of *white matter that provides a connection between the two halves of the cerebrum in the brain. It enables the transfer of information and learning from one cerebral hemisphere to the other.

corpuscular theory *See* LIGHT.

corpus luteum (yellow body) The yellowish mass of tissue that forms in the cavity of a *Graafian follicle in the ovary of a mammal after the release of the egg cell. It secretes the hormone *progesterone. Some species of sharks, reptiles, and birds have similar structures in their ovaries but the function of these is less well understood.

corrosion Chemical or electrochemical attack on the surface of a metal. *See also* ELECTROLYTIC CORROSION; RUSTING.

cortex **1.** (in botany) The tissue between the epidermis and the vascular system in plant stems and roots. It is composed of *parenchyma cells and shows little or no structural differentiation. Cortex is produced by activity of the *apical meristem. *See also* ENDODERMIS. **2.** (in zoology) The outermost layer of tissue of various organs, including the adrenal glands (**adrenal cortex**), kidneys (**renal cortex**), and cerebral hemispheres (*see* CEREBRAL CORTEX).

corticosteroid Any of several hormones produced by the cortex of the *adrenal glands. **Glucocorticoids** regulate the use of carbohydrates, proteins, and fats in the body and include *cortisol and *cortisone. **Mineralocorticoids** regulate salt and water balance (*see* ALDOSTERONE).

corticotrophin *See* ACTH.

cortisol (hydrocortisone) A hormone (*see* CORTICOSTEROID), produced by the adrenal glands, that promotes the synthesis and storage of glucose and is therefore important in the normal response to stress, suppresses or prevents inflammation, and regulates deposition of fat in the body. It is used as treatment for various allergies and for rheumatic fever, certain skin conditions, and adrenal failure (Addison's disease).

cortisone A biologically inactive *corticosteroid produced in the adrenal glands from the active hormone *cortisol, which is structurally very similar to it. Cortisone is reconverted to cortisol in the liver and other organs. Cortisone may be administered therapeutically as an inactive precursor (prodrug) of cortisol.

corundum A mineral form of aluminium oxide, Al_2O_3. It crystallizes in the trigonal system and occurs as well-developed hexagonal crystals. It is colourless and transparent when pure but the presence of other elements gives rise to a variety of colours. *Ruby is a red variety containing chromium; *sapphire is a blue variety containing iron and titanium. Corundum occurs as a rock-forming mineral in both metamorphic and igneous rocks. It is chemically resistant to weathering processes and so also occurs in alluvial (placer) deposits. The second hardest mineral after diamond (it has a hardness of 9 on the Mohs' scale), it is used as an abrasive.

corymb A type of flowering shoot (*see* RACEMOSE INFLORESCENCE) in which the lower flower stalks are longer than the higher ones, resulting in a flat-topped cluster of flowers. Examples are candytuft and wallflower.

cos *See* TRIGONOMETRIC FUNCTIONS.

cosecant *See* TRIGONOMETRIC FUNCTIONS.

cosech *See* HYPERBOLIC FUNCTIONS.

cosh *See* HYPERBOLIC FUNCTIONS.

cosine *See* TRIGONOMETRIC FUNCTIONS.

cosine rule In any triangle, with sides of length a, b, and c, $c^2 = a^2 + b^2 - 2ab\cos\theta$, where θ is the angle between sides a and b.

cosmic censorship A hypothesis concerning singularities and *black holes in the general theory of *relativity. It was suggested

in 1969 by the British physicist Roger Penrose (1931–). The **cosmic censorship conjecture** asserts that all singularities in general relativity are hidden behind an event horizon. The conjecture has never been proved mathematically, although there is some evidence for it in many situations. Even if cosmic censorship is not correct, singularities would not be seen experimentally if the singularities are removed by *quantum gravity. It may be that in classical general relativity the cosmic censorship hypothesis is true for 'reasonable' physical situations but that it is possible to construct counter-examples to it for various special situations.

cosmic neutrino background (CNB) The neutrino analogue of the cosmic *microwave background radiation, i.e. a background radiation consisting of neutrinos. The CNB has not yet been detected; it is thought that it would have a temperature of about 1.9 kelvin.

cosmic radiation High-energy particles that fall on the earth from space. **Primary cosmic rays** consist of nuclei of the most abundant elements, with *protons (hydrogen nuclei) forming by far the highest proportion; electrons, positrons, neutrinos, and gamma-ray photons are also present. The particle energies range from 10^{-11} J to 10 J (10^8 to 10^{20} eV) and as they enter the earth's atmosphere they collide with oxygen and nitrogen nuclei producing **secondary cosmic rays**. The secondary rays consist of elementary particles and gamma-ray photons. A single high-energy primary particle can produce a large **shower** of secondary particles. The sources of the primary radiation are not all known, although the sun is believed to be the principal source of particles with energies up to about 10^{10} eV. It is believed that all particles with energies of less than 10^{18} eV originate within the Galaxy.

cosmic string *See* STRING.

cosmid A hybrid *vector, used in *gene cloning, that includes the *cos* gene (from the lambda bacteriophage). It also contains drug resistance *marker genes and other plasmid genes. Cosmids can incorporate larger DNA fragments than either phage or plasmid vectors alone and are especially suitable for cloning large mammalian genes or multigene fragments.

cosmoid scale *See* SCALES.

cosmological constant A term that can be added to Einstein's field equation for general *relativity theory. The cosmological constant is independent of space and time. It was put forward by Einstein in 1917 to allow for the possibility of a static universe. Although the discovery of the *expansion of the universe removed the original motivation for the cosmological constant, the discovery that the expansion of the universe is accelerating suggests that the constant has a non-zero value, albeit by a factor of 10^{120} smaller than expected theoretically. Explaining this small non-zero value is one of the main challenges for theoretical physics at the present time.

cosmological principle The claim that on extremely large scales, i.e. much greater scales than those associated with *large-scale structure, the universe is homogeneous and isotropic. There is some evidence that the cosmological principle is valid, notably from the cosmic microwave background radiation, but it cannot be said to have been demonstrated conclusively.

cosmology The study of the nature, origin, and evolution of the universe. Various theories concerning the origin and evolution of the universe exist. See Chronology. *See also* BIG-BANG THEORY; STEADY-STATE THEORY; EARLY UNIVERSE.

SEE WEB LINKS

- The home page of the Caltech Observational Cosmology Group
- A cosmology website run by the University of Cambridge

cotangent *See* TRIGONOMETRIC FUNCTIONS.

coth *See* HYPERBOLIC FUNCTIONS.

Cottrell precipitator An electrostatic precipitator used to remove dust particles from industrial waste gases, by attracting them to charged grids or wires.

cotyledon (seed leaf) A part of the embryo in a seed plant. The number of cotyledons is an important feature in classifying plants. Among the flowering plants, the class known as *Monocotyledoneae have a single cotyledon and *Dicotyledoneae have two. Conifers have either two cotyledons, as in *Taxus* (yews), or five to ten, as in *Pinus* (pines). In seeds without an *endosperm, e.g. garden pea and broad bean, the cotyledons store food, which is used in germination. In seeds showing *epigeal germination,

COSMOLOGY

260 BC	Greek astronomer Aristarchus of Samos (*c.* 320–230 BC) proposes a sun-centred universe.
c.150 AD	Greek-Egyptian astronomer Ptolemy (2nd century AD) proposes an earth-centred universe.
1543	Copernicus publishes his sun-centred theory of the universe (solar system).
1576	English mathematician Thomas Digges (*c.* 1546–95) proposes that the universe is infinite (because stars are at varying distances).
1584	Italian philosopher Giordano Bruno (1548–1600) states that the universe is infinite.
1633	Galileo champions Copernicus's sun-centred universe, but is forced by the Roman Catholic Inquisition to recant.
1854	Helmholtz predicts the heat death of the universe, based on thermodynamics.
1917	Einstein proposes a static universe theory.
1922	Russian astronomer Alexander Friedmann proposes the expanding universe theory.
1927	George Lemaître proposes the big-bang theory of the universe.
1929	Edwin Hubble demonstrates the expansion of the universe.
1948	US physicists George Gamow (1904–68), Ralph Alpher (1921–2007), and Hans Bethe (1906–2005) develop the big-bang theory, and the α-β-γ theory of the origin of the elements; Alpher also predicts that the big bang would have produced a microwave background. British astronomers Herman Bondi (1919–2005), Thomas Gold (1920–2004), and Fred Hoyle (1915–2001) propose a steady-state theory of the universe in which matter is continuously being formed.
1965	US astrophysicists Arno Penzias (1933–) and Robert Wilson (1936–) discover the microwave background radiation.
1980	US physicist Allan Guth (1947–) proposes the inflationary theory of the universe.
1992	US COBE (Cosmic Background Explorer) astronomical satellite detects ripples in residual cosmic radiation (cited as evidence of the big bang).
2001	US WMAP (Wilkinson Microwave Anisotropy Probe) launched. The ekpyrotic universe model is proposed as an alternative to the inflationary model.
2003	WMAP results give a detailed map of the cosmic microwave background and support the inflationary theory.

e.g. runner bean, they emerge above the soil surface and become the first photosynthetic leaves.

coudé system *See* TELESCOPE.

coulomb Symbol C. The *SI unit of electric charge. It is equal to the charge transferred by a current of one ampere in one second. The unit is named after Charles de Coulomb.

Coulomb, Charles Augustin de (1736–1806) French physicist, who served as an army engineer in Martinique before return-

ing to France. He is best known for his 1785 proposal of *inverse-square laws to describe the interaction between electrical charges and between magnets (*see* COULOMB'S LAW), which he proved experimentally using a *torsion balance.

Coulomb explosion The sudden disruption of a molecule from which the electrons have been stripped to leave only the nuclei, which repel each other because of their electric charge. The technique of **coulomb explosion imaging** uses this effect to investigate the shape of molecules. A beam of high-energy neutral molecules is produced by first adding electrons, accelerating the ions in an electric field, and then removing the electrons. The beam collides with a thin metal foil having a thickness of about 30 atoms. As the molecules pass through this foil their electrons are scattered and only the nuclei of the molecules emerge. The process occurs within a very short period of time, shorter than the time required for a complete molecular vibration, and consequently the nuclei retain the molecular shape until they are suddenly repulsed by the like charges. The nuclei then impinge on a detector that records their velocity and direction, thus enabling the spatial arrangement of the original molecule to be derived.

Coulomb field *See* COULOMB'S LAW.

Coulomb force *See* COULOMB'S LAW.

Coulomb's law The force (sometimes called the **Coulomb force**) between two charged particles, regarded as point charges Q_1 and Q_2 a distance d apart, is proportional to the product of the charges and inversely proportional to the square of the distance between them. The law is now usually stated in the form $F = Q_1Q_2/4\pi\varepsilon d^2$, where ε is the absolute *permittivity of the intervening medium. $\varepsilon = \varepsilon_r\varepsilon_0$, where ε_r is the relative permittivity (the dielectric constant) and ε_0 is the electric constant. The electric field surrounding a point charge is called the **Coulomb field** and the scattering of charged particles by the Coulomb field surrounding an atomic nucleus is called **Coulomb scattering**. The law was first published by Charles de Coulomb in 1785.

counter Any device for detecting and counting objects or events, often incident charged particles or photons. The latter devices usually work by allowing the particle to cause ionization, which creates a current or voltage pulse. The pulses are then counted electronically. *See* CERENKOV COUNTER; CRYSTAL COUNTER; GEIGER COUNTER; PROPORTIONAL COUNTER; SCINTILLATION COUNTER; SPARK COUNTER. These names are often applied merely to the actual detectors; the ancillary counting mechanism is then called a *scaler.

countercurrent flow Flow of two fluids in opposite directions with transfer of heat or matter between them. *Compare* COCURRENT FLOW.

countercurrent heat exchange A *counterflow mechanism that enables fluids at different temperatures flowing in channels in opposite directions to exchange their heat content without mixing. An example of countercurrent heat exchange occurs in the feet of penguins, in which heat from blood in the arteries supplying the feet is transferred to blood returning to the body's core in veins that lie close to these arteries. This helps to maintain the core temperature in freezing conditions.

counterflow The flow of two fluids in apposed vessels in opposite directions. In biological systems such an arrangement enables the efficient transfer of heat, ions, molecules, etc., from fluids that are rich in these resources to fluids that are deficient in them.

counter ion An ion of opposite charge to a given ion. For example, in a crystal of sodium chloride, the chloride ions can be regarded as counter ions to the sodium ions. In certain colloids, the charge on the surface of colloidal particles is neutralized by oppositely charged counter ions in the surrounding solution.

country rock (host rock) Older rock that surrounds veins of minerals or an igneous magma *intrusion, such as a *batholith. The extreme heat of the intrusion may cause changes (contact metamorphism) in the composition of the adjacent country rock.

couple Two equal and opposite parallel forces applied to the same body that do not act in the same line. The forces create a torque, the *moment of which is equal to the product of the force and the perpendicular distance between them.

coupling **1.** (in physics) An interaction between two different parts of a system or between two or more systems. Examples of coupling in the *spectra of atoms and nuclei

C

are *Russell–Saunders coupling, *j-j coupling, and spin–orbit coupling. In the spectra of molecules there are five idealized ways (called the **Hund coupling cases**) in which the different types of angular momentum in a molecule (the electron orbital angular momentum *L*, the electron spin angular momentum *S*, and the angular momentum of nuclear rotation *N*) couple to form a resultant angular momentum *J*. (In practice, the coupling for many molecules is intermediate between Hund's cases due to interactions, which are ignored in the idealized cases.) In *solid-state physics an example of coupling is electron–phonon coupling, the analysis of which gives the theories of electrical *conductivity and *superconductivity. *See also* COUPLING CONSTANT. **2.** (in chemistry) A type of chemical reaction in which two molecules join together; for example, the formation of an *azo compound by coupling of a diazonium ion with a benzene ring.

coupling constant A physical constant that is a measure of the strength of interaction between two parts of a system or two or more systems. In the case of a *field theory, the coupling constant is a measure of the magnitude of the force exerted on a particle by a field. In the case of a *quantum field theory, a coupling constant is not constant but is a function of energy, the dependence on energy being described by the *renormalization group. *See also* COUPLING; ASYMPTOTIC FREEDOM.

courtship Behaviour in animals that plays a part in the initial attraction of a mate or as a prelude to copulation. Courtship often takes the form of *displays that have evolved through *ritualization; some are derived from other contexts (e.g. food begging in some birds). Chemical stimuli (*see* PHEROMONE) are also important in many mammals and insects.

As well as ensuring that the prospective mate is of the same species, the male's courtship performance allows females to choose between different males. The later stages of courtship may involve both partners in an alternating series of displays that inhibit *aggression and fear responses and ensure synchrony of sexual arousal.

COV *See* CROSSOVER VALUE.

covalent bond *See* CHEMICAL BOND.

covalent crystal A crystal in which the atoms are held together by covalent bonds. Covalent crystals are sometimes called **macromolecular** or **giant-molecular crystals**. They are hard high-melting substances. Examples are diamond and boron nitride.

covalent radius An effective radius assigned to an atom in a covalent compound. In the case of a simple diatomic molecule, the covalent radius is half the distance between the nuclei. Thus, in Cl_2 the internuclear distance is 0.198 nm so the covalent radius is taken to be 0.099 nm. Covalent radii can also be calculated for multiple bonds; for instance, in the case of carbon the values are 0.077 nm for single bonds, 0.0665 nm for double bonds, and 0.0605 nm for triple bonds. The values of different covalent radii can sometimes be added to give internuclear distances. For example, the length of the bond in interhalogens (e.g. ClBr) is nearly equal to the sum of the covalent radii of the halogens involved. This, however, is not always true because of other effects (e.g. ionic contributions to the bonding).

covariance In *statistics, a measure of the association between a pair of random variables. It equals the expected value of the product of their deviations (from the mean value). For two sets of observations $(x_1,y_1),\ldots,(x_n,y_n)$, where $\bar{x}$ is the mean of x_i and $\bar{y}$ is the mean of y_i, it is given by

$$(1/n)\ \sum_{i=1}^{n}(x_i-\bar{x})\ (y_i-\bar{y})$$

See also VARIANCE.

Cowan, Clyde *See* PAULI, WOLFGANG ERNST.

Cowper's glands (bulbourethral glands) A pair of pea-sized glands that lie beneath the prostate gland. Cowper's glands secrete an alkaline fluid that forms part of the *semen. This fluid neutralizes the acidic environment of the urethra, thereby protecting the sperm. The glands are named after William Cowper (1666–1709). *See also* SEMINAL VESICLE.

coxa The first segment, attached to the thorax, of an insect's leg. *See also* FEMUR; TROCHANTER.

CP invariance The symmetry generated by the combined operation of changing *charge conjugation (*C*) and *parity (*P*). **CP violation** occurs in weak interactions in kaon decay and in *B-mesons. *See also* CPT THEOREM; TIME REVERSAL.

CPT theorem The theorem that the com-

bined operation of changing *charge conjugation *C*, *parity *P*, and *time reversal *T*, denoted **CPT**, is a fundamental *symmetry of relativistic *quantum field theory. No violation of the CPT theorem is known experimentally. When *C*, *P*, and *T* (or any two of them) are violated, the principles of relativistic quantum field theory are not affected; however, violation of **CPT invariance** would drastically alter the fundamentals of relativistic quantum field theory. It is not known whether *superstrings obey versions of the CPT theorem.

CPU (central processing unit) The main operating part of a *computer; it includes the **control unit** (CU) and the arithmetic/logic unit (*see* ALU). Its function is to fetch instructions from memory, decode them, and execute the program. It also provides timing signals. An *integrated circuit that has a complete CPU on a single silicon chip is called a microprocessor.

crack cocaine *See* COCAINE.

cracking The process of breaking down chemical compounds by heat. The term is applied particularly to the cracking of hydrocarbons in the kerosine fraction obtained from *petroleum refining to give smaller hydrocarbon molecules and alkenes. It is an important process, both as a source of branched-chain hydrocarbons suitable for gasoline (for motor fuel) and as a source of ethene and other alkenes. **Catalytic cracking** is a similar process in which a catalyst is used to lower the temperature required and to modify the products obtained.

cranial nerves Ten to twelve pairs of nerves in vertebrates that emerge directly from the brain. They supply the sense organs and muscles of the head, neck, and viscera. Examples of cranial nerves include the *optic nerve (II) and the *vagus nerve (X). With the *spinal nerves, the cranial nerves form an important part of the *peripheral nervous system.

cranial reflex *See* REFLEX.

Craniata A clade or subphylum of chordate animals characterized by a cartilaginous or bony skull protecting the brain and major sense organs. Craniates comprise two major clades: the Myxini (hagfishes) and the Vertebrata (lampreys and jawed vertebrates). Hagfishes have long eel-like bodies lacking fins, vertebrae, and a lower jaw; the notochord is retained into adulthood. Hagfishes scavenge for food on the seabed, often feeding on dead fish and whales. In vertebrates the notochord is present only in the embryo or larva and becomes replaced by the *vertebral column (backbone) before birth or metamorphosis. This has permitted the vertebrates a greater degree of movement and subsequent improvement in the sense organs and enlargement of the brain. Lampreys (clade Hyperoartia; order Petromyzontiformes) are slender wormlike animals that lack jaws but possess rudimentary vertebrae in adult life. They chiefly feed as parasites on fish using their toothed circular mouth as a sucker to bore into their host and suck its blood. The jawed vertebrates comprise the *Gnathostomata.

cranium (brain case) The part of the vertebrate *skull that encloses and protects the brain. It is formed by the fusion of several flattened bones, which have immovable joints (sutures) between them.

C-reactive protein (CRP) A protein secreted into blood plasma by the liver in response to inflammation and infection. It binds to the cell walls of certain bacteria and fungi, thereby increasing susceptibility of the target cell to ingestion by phagocytes; it can also activate the *complement cascade, hence triggering destruction of pathogens by this means.

cream of tartar *See* POTASSIUM HYDROGENTARTRATE.

creatine A compound, synthesized from the amino acids arginine, glycine, and methionine, that occurs in muscle. In the form of **creatine phosphate** (or **phosphocreatine**), it is an important reserve of energy for muscle contraction, which is released when creatine phosphate loses its phosphate and is converted to **creatinine**, which is excreted in the urine (at a rate of 1.2–1.5 g/day in humans). *See also* PHOSPHAGEN.

creatinine *See* CREATINE.

creationist A proponent of the theory of *special creation.

creep The continuous deformation of a solid material, usually a metal, under a constant stress that is well below its yield point. It usually only occurs at high temperatures and the creep characteristics of any material destined to be used under conditions of high stress at high temperatures must be investigated.

C

cremocarp A dry fruit that is a type of *schizocarp formed from two one-seeded carpels. The carpels remain separate and form indehiscent **mericarps** that are attached to a central supporting strand (**carpophore**) for some time before dispersal. It is characteristic of the Umbelliferae (Apiaceae; carrot family).

crenation The shrinkage of cells that occurs when the surrounding solution is *hypertonic to the cellular cytoplasm. Water leaves the cells by *osmosis, which causes the plasma membrane to wrinkle and the cellular contents to condense.

creosote **1. (wood creosote)** An almost colourless liquid mixture of phenols obtained by distilling tar obtained by the destructive distillation of wood. It is used medically as an antiseptic and expectorant. **2. (coal-tar creosote)** A dark liquid mixture of phenols and cresols obtained by distilling coal tar. It is used for preserving timber.

cresols *See* METHYLPHENOLS.

Cretaceous The final geological period of the Mesozoic era. It extended from about 144 million years ago, following the Jurassic, to about 65 million years ago, when it was succeeded by the Palaeogene period. The name of the period is derived from *creta* (Latin: chalk) and the Cretaceous was characterized by the deposition of large amounts of *chalk in western Europe. The Cretaceous was the time of greatest flooding in the Mesozoic. Angiosperm plants made their first appearance on land and in the early Cretaceous Mesozoic reptiles reached their peak. At the end of the period there was a *mass extinction of the dinosaurs, flying reptiles, and ammonites, the cause of which may be related to environmental changes resulting from collisions of the earth with large meteorites (*see* ALVAREZ EVENT; IRIDIUM ANOMALY).

Creutzfeldt–Jakob disease (CJD) A disease of humans characterized by dementia and destruction of brain tissue, first described by the German psychiatrists H. G. Creutzfeldt (1885–1964) and A. M. Jakob (1884–1931). It is now known to be caused by an abnormal *prion protein and is transmissible, although there is also an inherited familial form. This rare disease typically affects middle-aged and elderly people and leads to rapid mental deterioration and death. The abnormal prion interferes with the structure of normal prion protein in brain tissue, resulting in accumulations of the protein and consequent tissue damage. In most cases the source of infection is unknown. However, it is well established that infection can result, for example, via injections of growth hormone derived from infected human cadavers. During the 1990s a novel form of the disease emerged, called variant CJD, which typically affects young healthy individuals. This is thought to be caused by consumption of beef products derived from cattle infected with *bovine spongiform encephalopathy.

CRG process (catalytic rich gas process) An industrial process for producing fuel gas from naphtha and other hydrocarbon sources. It involves a nickel-based catalyst, pressures of up to 70 bar, and temperatures between 250°C and 650°C depending on the feedstock. The reactions are:

$$C_nH_{2n+2} + nH_2O \rightarrow nCO + (2n+1)H_2$$

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

$$CO + H_2O \rightarrow CO_2 + H_2$$

The result is a mixture of methane, carbon monoxide, carbon dioxide, and trace amounts of ethane and other hydrocarbons. With partial carbon dioxide removal it is possible to produce town gas with medium calorific value containing about 30% CH_4, 30% H_2, and 2% CO. The process can be used to produce SNG. In this case there are multiple methanation stages and complete removal of CO_2 to give a product containing about 98.5% CH_4, 0.9% H_2, and 0.1% CO.

Crick, Francis Harry Compton (1916–2004) British molecular biologist, who in 1951 teamed up with James *Watson at Cambridge University to try to find the structure of *DNA. This they achieved in 1953, using the X-ray diffraction data of Rosalind Franklin (1920–58) and Maurice Wilkins (1916–2004). Crick went on to investigate *codons and the role of transfer *RNA. Crick, Watson, and Wilkins shared a Nobel Prize in 1962.

crista **1.** *See* SEMICIRCULAR CANALS. **2.** *See* MITOCHONDRION.

cristobalite A mineral form of *silicon(IV) oxide, SiO_2.

critical angle *See* TOTAL INTERNAL REFLECTION.

critical damping *See* DAMPING.

critical density In astronomy, the mean

density of the universe below which value it is an expanding and continuously open system. The luminous material in the universe (galaxies, etc.) is estimated to account for about 10% of this figure. The remainder is thought to consist mainly of dark matter (*see* MISSING MASS).

critical group A large group of related organisms that, although variations exist between them, cannot be divided into smaller groups of equivalent taxonomic rank to the parent group. Critical groups are found among plants that reproduce by *apomixis; for example, the 400 or so species of *Rubus* (brambles, etc.) are regarded as a critical group.

critical mass The minimum mass of fissile material that will sustain a nuclear *chain reaction. For example, when a nucleus of uranium–235 disintegrates two or three neutrons are released in the process, each of which is capable of causing another nucleus to disintegrate, so creating a chain reaction. However, in a mass of U–235 less than the critical mass, too many neutrons escape from the surface of the material for the chain reaction to proceed. In the atom bomb, therefore, two or more subcritical masses have to be brought together to make a mass in excess of the critical mass before the bomb will explode.

critical pressure The pressure of a fluid in its *critical state; i.e. when it is at its critical temperature and critical volume.

critical reaction A nuclear *chain reaction in which, on average, one transformation causes exactly one other transformation so that the chain reaction is self-sustaining. If the average number of transformations caused by one transformation falls below one, the reaction is **subcritical** and the chain reaction ceases; if it exceeds one the reaction is **supercritical** and proceeds explosively.

critical state The state of a fluid in which the liquid and gas phases both have the same density. The fluid is then at its *critical temperature, *critical pressure, and *critical volume.

critical temperature **1.** The temperature above which a gas cannot be liquefied by an increase of pressure. *See also* CRITICAL STATE. **2.** *See* TRANSITION POINT.

critical volume The volume of a fixed mass of a fluid in its *critical state; i.e. when it is at its critical temperature and critical pressure. The **critical specific volume** is its volume per unit mass in this state: in the past this has often been called the critical volume.

CRO *See* CATHODE-RAY OSCILLOSCOPE.

Cromagnon man The earliest form of modern humans (*Homo sapiens*), which is believed to have appeared in Europe about 35 000 years ago and possibly at least 70 000 years ago in Africa and Asia. Fossils indicate that these hominids were taller and more delicate than *Neanderthal man, which they replaced. They used intricately worked tools of stone and bone and left the famous cave drawings at Lascaux in the Dordogne. The name is derived from the site at Cromagnon, France, where the first fossils were found in 1868.

Crookes, Sir William (1832–1919) British chemist and physicist, who in 1861 used *spectroscopy to discover *thallium and in 1875 invented the radiometer. He also developed an improved vacuum tube (**Crookes' tube**) for studying gas discharges.

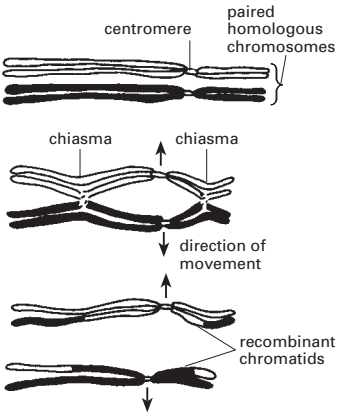
crop **1.** A plant that is cultivated for the purpose of harvesting its seeds, roots, leaves, or other parts that are useful to humans. *See* AGRICULTURE. **2.** An enlarged portion of the anterior section of the alimentary canal in some animals, in which food may be stored and/or undergo preliminary digestion. The term is most commonly applied to the thin-walled sac in birds between the oesophagus and the *proventriculus. In female pigeons the crop contains glands that secrete **crop milk**, used to feed nestlings.

crop rotation An agricultural practice in which different crops are cultivated in succession on the same area of land over a period of time so as to maintain soil fertility and reduce the adverse effects of pests. Legumes are important in the rotation as they are a source of nitrogen for the soil (*see* NITROGEN FIXATION; ROOT NODULE). In the UK, other crops that may be included in a typical four-stage rotation are wheat, barley, and root crops. However, the use of pesticides enables the monoculture of crops in modern farming systems (*see* AGRICULTURE).

cross **1.** A mating between two selected individuals. Controlled crosses are made for many reasons, e.g. to investigate the inheritance of a particular characteristic or to improve a livestock or crop variety. *See also*

BACK CROSS; RECIPROCAL CROSS; TEST CROSS. **2.** An organism resulting from such a mating.

cross-fertilization *See* FERTILIZATION.



Crossing over. At two chiasmata in a pair of homologous chromosomes.

crossing over An exchange of portions of chromatids between *homologous chromosomes. As the chromosomes begin to move apart at the end of the first prophase of *meiosis, they remain in contact at a number of points (*see* CHIASMA). At these points the chromatids break and rejoin in such a way that sections are exchanged (see illustration). Crossing over thus alters the pattern of genes in the chromosomes. *See* RECOMBINATION.

cross linkage A short side chain of atoms linking two longer chains in a polymeric material.

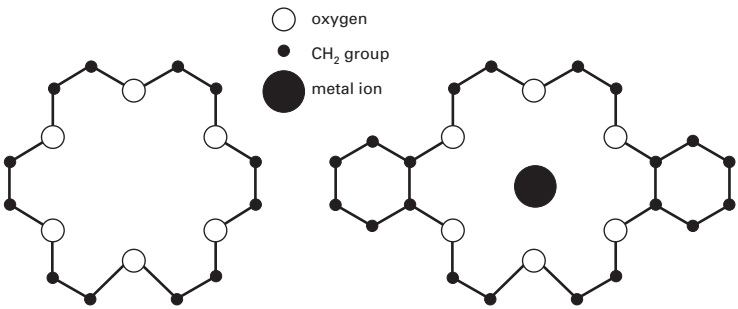
crossover value (COV) The percentage of linked genes (*see* LINKAGE) that are exchanged during the process of *crossing over during the first prophase of *meiosis. The COV can be calculated by the percentage of offspring that show *recombination and is used to map the genes on a chromosome (*see* CHROMOSOME MAP). A small COV for a given pair of genes indicates that the genes are situated close together on the chromosome.

cross-pollination *See* POLLINATION.

cross product *See* VECTOR PRODUCT.

cross section **1.** A plane surface formed by cutting a solid, especially by cutting at right angles to its longest axis. **2.** The area of such a surface. **3.** A measure of the probability that a collision will occur between a beam of radiation and a particular particle, expressed as the effective area presented by the particle in that particular process. It is measured in square metres or *barns. The **elastic cross section** amounts for all elastic scattering in which the radiation loses no energy to the particle. The **inelastic cross section** accounts for all other collisions. It is further subdivided to account for specific interactions, such as the **absorption cross section**, **fission cross section**, **ionization cross section**, etc.

crown ethers Organic compounds with molecules containing large rings of carbon and oxygen atoms. The crown ethers are



Crown ethers.

macrocyclic polyethers. The first to be synthesized was the compound 18-crown-6, which consists of a ring of six $–CH_2–CH_2–O–$ units (i.e. $C_{12}H_{24}O_6$). The general method of naming crown ethers is to use the form *n*-crown-*m*, where *n* is the number of atoms in the ring and *m* is the number of oxygen atoms. Substituted crown ethers can also be made. The crown ethers are able to form strongly bound complexes with metal ions by coordination through the oxygen atoms. The stability of these complexes depends on the size of the ion relative to the cavity available in the ring of the particular crown ether. Crown ethers also form complexes with ammonium ions (NH_4^+) and alkyl ammonium ions (RNH_3^+). They can be used for increasing the solubility of ionic salts in nonpolar solvents. For example, dicyclohexyl-18-crown-6 complexes with the potassium ion of potassium permanganate and allows it to dissolve in benzene, giving a purple neutral solution that can oxidize many organic compounds. They also act as catalysts in certain reactions involving organic salts by complexing with the positive metal cation and thereby increasing its separation from the organic anion, which shows a consequent increase in activity. Some of the uses of crown ethers depend on their selectivity for specific sizes of anions. Thus they can be used to extract specific ions from mixtures and enrich isotope mixtures. Their selectivity also makes them useful analytical reagents. *See also* CRYPTANDS.

crucible A dish or other vessel in which substances can be heated to a high temperature.

crude oil *See* PETROLEUM.

Crustacea A subphylum of *arthropods containing over 35 000 species distributed worldwide, mainly in freshwater and marine habitats, where they constitute a major component of plankton. Crustaceans include shrimps, crabs, lobsters, etc. (*see* DECAPODA) and the terrestrial woodlice, all of which belong to the class Malacostraca; the barnacles (class Cirripedia); the water fleas (*see* DAPHNIA), fairy shrimps, and tadpole shrimps (class Branchiopoda); and the copepods (*see* COPEPODA). The segmented body usually has a distinct head (bearing *compound eyes, two pairs of *antennae, and various mouthparts), thorax, and abdomen, and is protected by a shell-like carapace. Each body segment may bear a pair of branched (**biramous**) appendages used for locomotion, as gills, and for filtering food particles from the water. Appendages in the head region are modified to form jaws and in the abdominal region are often reduced or absent. Typically, the eggs hatch to produce a free-swimming **nauplius** larva. This develops either by a series of moults or undergoes metamorphosis to the adult form.

SEE WEB LINKS

- Overview of crustacean phylogeny at the Tree of Life web project

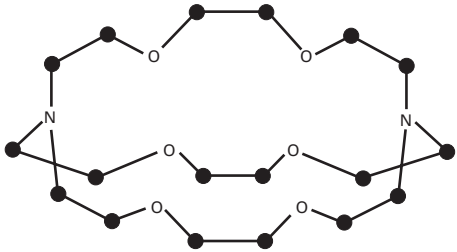
cryobiology The study of the effects of very low temperatures on organisms, tissues, and cells. The ability of some animal tissues to remain viable in a frozen state (**cryopreservation**) enables them to be preserved by freezing for future use as *grafts.

cryogenic pump A *vacuum pump in which pressure is reduced by condensing gases on surfaces maintained at about 20 K by means of liquid hydrogen or at 4 K by means of liquid helium. Pressures down to 10^{-8} mmHg (10^{-6} Pa) can be maintained; if they are used in conjunction with a *diffusion pump, pressures as low as 10^{-15} mmHg (10^{-13} Pa) can be reached.

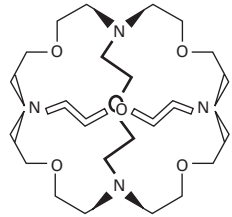
cryogenics The study of very low temperatures and the techniques for producing them. Objects are most simply cooled by placing them in a bath containing liquefied gas maintained at a constant pressure. In general, a liquefied gas can provide a constant bath temperature from its triple point to its critical temperature and the bath temperature can be varied by changing the pressure above the liquid. The lowest practical temperature for a liquid bath is 0.3 K. Refrigerators (*see* REFRIGERATION) consist essentially of devices operating on a repeated cycle, in which a low-temperature reservoir is a continuously replenished liquid bath. Above 1 K they work by compressing and expanding suitable gases. Below this temperature liquids or solids are used and by *adiabatic demagnetization it is possible to reach 10^{-6} K.

cryohydrate A eutectic mixture of ice and some other substance (e.g. an ionic salt) obtained by freezing a solution.

cryolite A rare mineral form of sodium aluminofluoride, Na_3AlF_6, which crystallizes in the monoclinic system. It is usually white but may also be colourless. The only important occurrence of the mineral is in Green-



(2,2,2) cryptand



spherical cryptand

Cryptands.

land. It is used chiefly to lower the melting point of alumina in the production of aluminium.

cryometer A thermometer designed to measure low temperatures. *Thermocouples can be used down to about 1 K and *resistance thermometers can be used at 0.01 K. Below this magnetic thermometers (0.001 K) and nuclear-resonance thermometers (3×10^{-7} K) are required.

cryophyte An organism that can live in ice and snow. Most cryophytes are algae, including the green alga *Chlamydomonas nivalis* and some diatoms, but they also include certain dinoflagellates, mosses, bacteria, and fungi.

cryoscopic constant *See* DEPRESSION OF FREEZING POINT.

cryoscopy The use of *depression of freezing point to determine relative molecular masses.

cryostat A vessel enabling a sample to be maintained at a very low temperature. The *Dewar flask is the most satisfactory vessel for controlling heat leaking in by radiation, conduction, or convection. Cryostats usually consist of two or more Dewar flasks nesting in each other. For example, a liquid nitrogen bath is often used to cool a Dewar flask containing a liquid helium bath.

cryotron A switch that relies on *superconductivity. It consists of a coil of wire of one superconducting material surrounding a straight wire of another superconducting material; both are immersed in a liquid-helium bath. A current passed through the coil creates a magnetic field, which alters the superconducting properties of the central wire, switching its resistance from zero to a finite value. Cryotron switches can be made very small and take very little current.

cryptands Compounds with large three-dimensional molecular structures containing ether chains linked by three-coordinate nitrogen atoms. Thus cryptands are macropolycyclic polyaza-polyethers. For example, the compound (2,2,2)-cryptand has three chains of the form

$$-CH_2CH_2OCH_2CH_2OCH_2CH_2-.$$

These chains are linked at each end by a nitrogen atom. Cryptands, like the *crown ethers, can form coordination complexes with ions that can fit into the cavity formed by the open three-dimensional structure, i.e. they can 'cryptate' the ion. Various types of cryptand have been produced having both spherical and cylindrical cavities. The cryptands have the same kind of properties as the crown ethers and the same uses. In general, they form much more strongly bound complexes and can be used to stabilize unusual ionic species. For example, it is possible to produce the negative Na^- ion in the compound $[(2,2,2)\text{-cryptand-Na}]^+Na^-$, which is a gold-coloured crystalline substance stable at room temperature. Cluster ions, such as Pb_5^{2-}, can be similarly stabilized.

cryptic coloration The type of colouring or marking of an animal that helps to camouflage it in its natural environment. It may enable the animal to blend with its background or, like the stripes of zebras and tigers, help to break up the outline of its body.

crypts of Lieberkühn (intestinal glands) Tubular glands that lie between the finger-

like projections (*see* VILLUS) of the inner surface of the small intestine. The cells of these glands (called **Paneth cells**) secrete *intestinal juice as they gradually migrate along the side of the crypt and the villus; they are eventually shed into the lumen of the intestine.

crystal A solid with a regular polyhedral shape. All crystals of the same substance grow so that they have the same angles between their faces. However, they may not have the same external appearance because different faces can grow at different rates, depending on the conditions. The external form of the crystal is referred to as the **crystal habit**. The atoms, ions, or molecules forming the crystal have a regular arrangement and this is the **crystal structure**.

crystal counter A type of solid-state *counter in which a potential difference is applied across a crystal; when the crystal is struck by an elementary particle or photon, the electron–ion pairs created cause a transient increase in conductivity. The resulting current pulses are counted electronically.

crystal defect An imperfection in the regular lattice pattern of a crystal. See Feature (pp 210–211).

crystal-field theory A theory of the electronic structures of inorganic *complexes, in which the complex is assumed to consist of a central metal atom or ion surrounded by ligands that are ions. For example, the complex $[PtCl_4]^{2-}$ is thought of as a Pt^{2+} ion surrounded by four Cl^- ions at the corners of a square. The presence of these ions affects the energies of the *d*-orbitals, causing a splitting of energy levels. The theory can be used to explain the spectra of complexes and their magnetic properties. Ligand-field theory is a development of crystal-field theory in which the overlap of orbitals is taken into account. Crystal-field theory was initiated in 1929 by the German-born US physicist Hans Albrecht Bethe (1906–2005) and extensively developed in the 1930s.

crystal habit *See* CRYSTAL.

crystal lattice The regular pattern of atoms, ions, or molecules in a crystalline substance. A crystal lattice can be regarded as produced by repeated translations of a **unit cell** of the lattice. *See also* CRYSTAL SYSTEM.

SEE WEB LINKS

- An interactive version of the structures of a range of crystals from a US Navy website
- Crystal models from the University of Calgary

crystalline Having the regular internal arrangement of atoms, ions, or molecules characteristic of crystals. Crystalline materials need not necessarily exist as crystals; all metals, for example, are crystalline although they are not usually seen as regular geometric crystals.

crystallite A small crystal, e.g. one of the small crystals forming part of a microcrystalline substance.

crystallization The process of forming crystals from a liquid or gas.

crystallography The study of crystal form and structure. *See also* X-RAY CRYSTALLOGRAPHY.

crystalloids *See* COLLOIDS.

crystal meth *See* AMPHETAMINE.

crystal microphone A microphone in which the sound waves fall on a plate of Rochelle salt or similar material with piezoelectric properties, the variation in pressure being converted into a varying electric field by the *piezoelectric effect. Crystal microphones have a good high-frequency response and are nondirectional; they are now rarely used except when their cheapness is important.

crystal oscillator (piezoelectric oscillator) An oscillator in which a piezoelectric crystal is used to determine the frequency. An alternating electric field applied to two metallic films sputtered onto the parallel faces of a crystal, usually of quartz, causes it to vibrate at its natural frequency; this frequency can be in the kilohertz or megahertz range, depending on how the crystal is cut. The mechanical vibrations in turn create an alternating electric field across the crystal that does not suffer from frequency drift. The device can be used to replace the tuned circuit in an oscillator by providing the resonant frequency or it can be coupled to the oscillator circuit, which is tuned approximately to the crystal frequency. In this type, the crystal prevents frequency drift. The device is widely used in *quartz clocks and watches.

crystal pick-up A pick-up in a record player in which the mechanical vibrations

CRYSTAL DEFECTS

A crystal *lattice is formed by a repeated arrangement of atoms, ions, or molecules. Within one cubic centimetre of material one can expect to find up to 10^{22} atoms and it is extremely unlikely that all of these will be arranged in perfect order. Some atoms will not be exactly in the right place with the result that the lattice will contain *defects. The presence of defects within the crystal structure has profound consequences for certain bulk properties of the solid, such as the electrical resistance and the mechanical strength.

Point defects

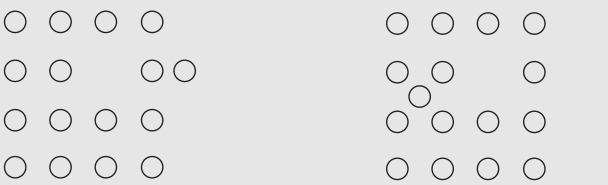
Local crystal defects called **point defects**, appear as either impurity atoms or gaps in the lattice. Impurity atoms can occur in the lattice either at **interstitial sites** (between atoms in a non-lattice site) or at **substitutional sites** (replacing an atom in the host lattice). Lattice gaps are called **vacancies** and arise when an atom is missing from its site in the lattice. Vacancies are sometimes called **Schottky defects**. A vacancy in which the missing atom has moved to an interstitial position is known as a **Frenkel defect**.

Colour centres

In ionic crystals, the ions and vacancies always arrange themselves so that there is no build-up of one type of charge in any small volume of the crystal. If ions or charges are introduced into or removed from the lattice, there will, in general, be an accompanying rearrangement of the ions and their outer valence electrons. This rearrangement is called **charge compensation** and is most dramatically observed in **colour centres**. If certain crystals are irradiated with X-rays, gamma rays, neutrons, or electrons a colour change is observed. For example, diamond may be coloured blue by electron bombardment and quartz may be coloured brown by irradiation with neutrons. The high-energy radiation produces defects in the lattice and, in an attempt to maintain charge neutrality, the crystal undergoes some measure of charge compensation. Just as electrons around an atom have a series of discrete permitted energy levels, so charges residing at point defects exhibit sets of discrete levels, which are separated from one another by energies corresponding to wavelengths in the visible region of the spectrum. Thus light of certain wavelengths can be absorbed at the defect sites, and the material appears to be coloured. Heating the irradiated crystal can, in many cases, repair the irradiation damage and the crystal loses its coloration.

Dislocations

Non-local defects may involve entire planes of atoms. The most important of these is called a **dislocation.** Dislocations are essentially **line-defects**; that is,



Formation of a Schottky defect

Formation of a Frenkel defect

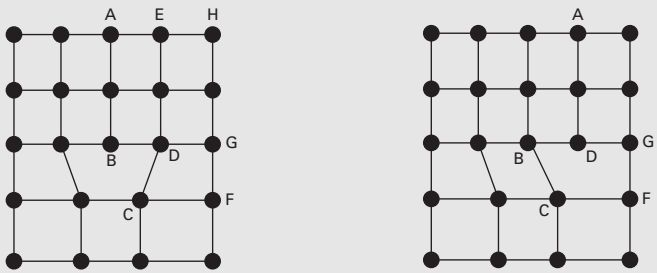
Point defects in a two-dimensional crystal

there is an incomplete plane of atoms in the crystal lattice. In 1934, Taylor, Orowan, and Polanyi independently proposed the concept of the dislocation to account for the mechanical strength of metal crystals. Their microscopic studies revealed that when a metal crystal is plastically deformed, the deformation does not occur by a separation of individual atoms but rather by a slip of one plane of atoms over another plane. Dislocations provide a mechanism for this slipping of planes that does not require the bulk movement of crystal material. The passage of a dislocation in a crystal is similar to the movement of a ruck in a carpet. A relatively large force is required to slide the carpet as a whole. However, moving a ruck over the carpet can inch it forward without needing such large forces. This movement of dislocations is called **plastic flow**.

Strength of materials

In practice most metal samples are **polycrystalline;** that is they consist of many small crystals or grains at different angles to each other. The boundary between two such grains is called a **grain boundary**. The plastic flow of dislocations may be hindered by the presence of grain boundaries, impurity atoms, and other dislocations. Pure metals produced commercially are generally too weak to be of much mechanical use. The weakness of these samples can be attributed to the ease with which the dislocations are able to move within the sample. Slip, and therefore deformation, can then occur under relatively low stresses. Impurity atoms, other dislocations, and grain boundaries can all act as obstructions to the slip of atomic planes. Traditionally, methods of making metals stronger involved introducing defects that provide regions of disorder in the material. For example, in an alloy, such as steel, impurity atoms (e.g. carbon) are introduced into the lattice during the forging process. The perfection of the iron lattice structure is disturbed and the impurities oppose the dislocation motion. This makes for greater strength and stiffness.

The complete elimination of dislocations may seem an obvious way to strengthen materials. However, this has only proved possible for hair-like single crystal specimens called **whiskers.** These whiskers are only a few micrometers thick and are seldom more than a few millimetres long; nevertheless their strength approaches the theoretical value.



Dislocation in a two-dimensional crystal. The extra plane of atoms AB causes strain at bond CD. On breaking, the bond flips across to form CB. This incremental movement shifts the dislocation across so that the overall effect is to slide the two planes BDG and CF over each other.

produced by undulations in the record groove are transmitted to a piezoelectric crystal, which produces a varying electric field of the same frequency as the sound. This signal is amplified and fed to loudspeakers in order to recreate the sound.

C

crystal structure *See* CRYSTAL.

crystal system A method of classifying crystalline substances on the basis of their unit cell. There are seven crystal systems. If the cell is a parallelopiped with sides *a*, *b*, and *c* and if α is the angle between *b* and *c*, β the angle between *a* and *c*, and γ the angle between *a* and *b*, the systems are:
(1) **cubic** $a=b=c$ and $\alpha=\beta=\gamma=90°$
(2) **tetragonal** $a=b\neq c$ and $\alpha=\beta=\gamma=90°$
(3) **rhombic** (or **orthorhombic**) $a\neq b\neq c$ and $\alpha=\beta=\gamma=90°$
(4) **hexagonal** $a=b\neq c$ and $\alpha=\beta=\gamma=90°$
(5) **trigonal** $a=b\neq c$ and $\alpha=\beta=\gamma\neq90°$
(6) **monoclinic** $a\neq b\neq c$ and $\alpha=\gamma=90°\neq\beta$
(7) **triclinic** $a=b=c$ and $\alpha\neq\beta\neq\gamma$

crystal test A type of *presumptive test in which a substance is identified by the formation of characteristic crystals when a certain reagent is added. Usually, such tests are conducted using a microscope (**microcrystal test**). An example is the *acetone–chlor–haemin test for blood.

CSF **1.** *See* CEREBROSPINAL FLUID. **2.** *See* COLONY-STIMULATING FACTOR.

CS gas The vapour from a white solid, $C_6H_4(Cl)CH{:}C(CN)_2$, causing tears and choking, used in 'crowd control'.

CT scanner (computerized tomography scanner) *See* TOMOGRAPHY.

CU *See* CONTROL UNIT.

cubane A crystalline hydrocarbon, C_8H_8; r.d. 1.29; m.p. 131°C. It has a novel structure with eight carbon atoms at the corners of a cube, each attached to a hydrogen. Cubane was first synthesized in 1964 by Philip Eaton. The C–C–C bond angle of 90° is highly strained and cubane and its derivatives have been investigated as high-energy fuels and explosives. In particular, **octanitrocubane**, in which the hydrogen atoms are replaced by $–NO_2$ groups, is possibly the most powerful chemical explosive known, although, so far, only small amounts have been synthesized. It decomposes to carbon dioxide and nitrogen:

$$C_8(NO_2)_8 \rightarrow 8CO_2 + 4N_2$$

cubewano A *Kuiper belt object (KBO) that is in direct orbit around the sun but is not held in orbital resonance with Neptune or any other planet. Cubewanos take their name from QB_1 – now (15760) QB_1 – the first known KBO, which was discovered in 1992. Cubewanos orbit the sun at mean distances of between 42 and 48 astronomical units. The dwarf planet (136472) Makemake (at an estimated 1500 km in diameter) is the largest cubewano so far known.

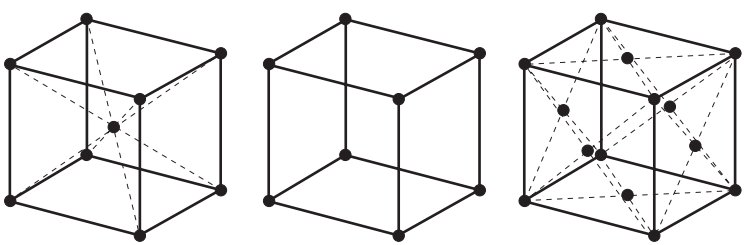
cubic close packing *See* CLOSE PACKING.

cubic crystal A crystal in which the unit cell is a cube (*see* CRYSTAL SYSTEM). There are three possible packings for cubic crystals: **simple cubic**, **face-centred cubic**, and **body-centred cubic**. See illustration.

SEE WEB LINKS

- An interactive version of a simple cubic crystal
- An interactive version of a body-centred cubic crystal
- An interactive version of a face-centred cubic crystal

cubic equation An equation in which the



Cubic crystal structures.

highest power of the variable is three. It has the general form $ax^3 + bx^2 + cx + d = 0$ and, in general, is satisfied by three values of x.

cubic expansivity *See* EXPANSIVITY.

cubic zirconia (CZ) A crystal form of zircon(IV) oxide (zircon dioxide, ZrO_2) made by fusing ZrO_2 and allowing it to cool under controlled conditions. It is used as an inexpensive diamond substitute in jewellery. Often it is erroneously called *zircon.

cultivar A plant that has been developed and maintained by cultivation as a result of agricultural or horticultural practices. The term is derived from *culti*vated *var*iety.

cultivation The planting and breeding of crop plants in *agriculture and horticulture. It involves the investigation of new means of increasing crop yield and quality.

culture A batch of cells, which can be microorganisms or of animal or plant origin, that are grown under specific conditions of nutrient levels, temperature, pH, oxygen levels, osmotic factors, light, pressure, and water content. Cultures of cells are prepared in the laboratory for a wide spectrum of scientific research. A *culture medium provides the appropriate conditions for growth. *See also* CONTINUOUS CULTURE; TISSUE CULTURE.

culture medium A nutrient material, either solid or liquid, used to support the growth and reproduction of microorganisms or to maintain tissue or organ cultures. *See also* AGAR.

cumene process An industrial process for making phenol from benzene. A mixture of benzene vapour and propene is passed over a phosphoric acid catalyst at 250°C and high pressure

$$C_6H_6 + CH_3CH{:}CH_2 \rightarrow C_6H_5CH(CH_3)_2$$

The product is called **cumene**, and it can be oxidized in air to a peroxide, $C_6H_5C(CH_3)_2O_2H$. This reacts with dilute acid to give phenol (C_6H_5OH) and propanone (acetone, CH_3OCH_3), which is a valuable by-product.

cupellation A method of separating noble metals (e.g. gold or silver) from base metals (e.g. lead) by melting the mixture with a blast of hot air in a shallow porous dish (the **cupel**). The base metals are oxidized, the oxide being carried away by the blast of air or absorbed by the porous container.

cuprammonium ion The tetraamminecopper(II) ion $[Cu(NH_3)_4]^{2+}$. *See* AMMINE.

cupric compounds Compounds containing copper in its higher (+2) oxidation state; e.g. cupric chloride is copper(II) chloride ($CuCl_2$).

cuprite A red mineral cubic form of copper(I) oxide, Cu_2O; an important ore of copper. It occurs where deposits of copper have been subjected to oxidation. The mineral has been mined as a copper ore in Chile, Democratic Republic of Congo, Bolivia, Australia, Russia, and the USA.

cupronickel A type of corrosion-resistant alloy of copper and nickel containing up to 45% nickel.

cuprous compounds Compounds containing copper in its lower (+1) oxidation state; e.g. cuprous chloride is copper(I) chloride (CuCl).

cupule **1.** A hard or membranous cup-shaped structure formed from bracts and enclosing various fruits, such as the hazelnut and acorn. **2.** A structure in club mosses (*Lycopodium* species) that protects the gemma (resting bud) during its development. It is composed of six leaflike structures. **3.** The bright red tissue around the seed of yew (*Taxus*), forming the yew 'berry'.

curare A resin obtained from the bark of South American trees of the genera *Strychnos* and *Chondrodendron* that causes paralysis of voluntary muscle. It acts by blocking the action of the neurotransmitter *acetylcholine at *neuromuscular junctions. Curare is used as an arrow poison by South American Indians and was formerly used as a muscle relaxant in surgery.

curd The solid component produced by the coagulation of milk during the manufacture of cheese. After being pasteurized, milk is cooled down and a culture of lactic acid bacteria is added to ferment the milk sugar, lactose, to lactic acid. The resulting decrease in pH causes casein, a milk protein, to coagulate, a process known as **curdling**. The solid curds are then separated from the liquid component, known as **whey**, and inoculated with different types of microbes to produce different cheeses.

curie The former unit of *activity (*see* RADIATION UNITS). It is named after Pierre Curie.

Curie, Marie (Marya Sklodowska;

1867–1934) Polish-born French chemist, who went to Paris in 1891. She married the physicist **Pierre Curie** (1859–1906) in 1895 and soon began work on seeking radioactive elements other than uranium in pitchblende (to account for its unexpectedly high radioactivity). By 1898 she had discovered *radium and *polonium, although it took her four years to purify them. In 1903 the Curies shared the Nobel Prize for physics with Henri *Becquerel, who had discovered radioactivity. In 1911 Marie Curie was awarded the Nobel Prize for chemistry.

SEE WEB LINKS

- A comprehensive website about her life and work run by The American Institute of Physics Center for History of Physics

Curie point (Curie temperature) The temperature at which a ferromagnetic substance loses its ferromagnetism and becomes only paramagnetic. For iron the Curie point is 760°C and for nickel 356°C.

Curie's law The susceptibility (χ) of a paramagnetic substance is proportional to the thermodynamic temperature (T), i.e. $\chi = C/T$, where C is the Curie constant. A modification of this law, the **Curie–Weiss law**, is more generally applicable. It states that $\chi = C/(T-\theta)$, where θ is the Weiss constant, a characteristic of the material. The law was first proposed by Pierre Curie and modified by another French physicist, Pierre-Ernest Weiss (1865–1940).

curium Symbol Cm. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 96; mass number of the most stable isotope 247 (half-life 1.64×10^7 years); r.d. (calculated) 13.51; m.p. 1340±40°C. There are nine known isotopes. The element was first identified by Glenn Seaborg (1912–99) and associates in 1944 and first produced by L. B. Werner and I. Perlman in 1947 by bombarding americium–241 with neutrons.

SEE WEB LINKS

- Information from the WebElements site

curl (rot) The *vector product of the *gradient operator with a vector. For a vector $\boldsymbol{u}$ that has components u_1, u_2, and u_3 in the x, y, and z directions (with respective unit vectors $\boldsymbol{i}$, $\boldsymbol{j}$, and $\boldsymbol{k}$), and is a function of x, y, and z, the curl is given by:

$$\text{curl } \boldsymbol{u} = \nabla \times \boldsymbol{u}$$

$$= (\partial u_3/\partial y - \partial u_2/\partial z)\boldsymbol{i} +$$

$$(\partial u_1/\partial z - \partial u_3/\partial x)\boldsymbol{j} +$$

$$(\partial u_2/\partial x - \partial u_1/\partial y)\boldsymbol{k}.$$

See also DIVERGENCE.

current Symbol I. A flow of electric charge through a conductor. The current at a particular cross section is the rate of flow of charge. The charge may be carried by electrons, ions, or positive holes (*see* CHARGE CARRIER). The unit of current is the ampere. *See also* CONVENTIONAL CURRENT.

current balance An instrument used to measure a current absolutely, on the basis of the definition of the ampere. An accurate form consists of a beam balance with similar coils attached to the ends of the balance arms. Fixed coils are situated above and below these two coils. The six coils are then connected in series so that a current passing through them creates a torque on the beam, which is restored to the horizontal by means of a rider. From the position and weight of the rider, and the geometry of the system, the current can be calculated.

current density **1.** The current flowing through a conductor per unit cross-sectional area, measured in amperes per square metre. **2.** The current flowing through an electrolyte per unit area of electrode.

cusp **1.** (in dentistry) A sharp raised protuberance on the surface of a *molar tooth. The cusps of opposing molars (i.e. on opposite jaws) are complementary to each other, which increases the efficiency of grinding food during chewing. **2.** (in anatomy) A flap forming part of a *valve. **3.** (in mathematics) A point at which two arcs of a curve intersect.

cuticle **1.** (in botany) The continuous waxy layer that covers the aerial parts of a plant. Composed of *cutin, it is secreted by the *epidermis and its primary function is to prevent water loss. **2.** (in zoology) A layer of horny noncellular material covering, and secreted by, the epidermis of many invertebrates. It is usually made of a collagen-like protein or of *chitin and its main function is protection. In arthropods it is also strong enough to act as a skeleton (*see* EXOSKELETON) and in insects it reduces water loss. Growth is allowed by moulting of the cuticle (*see* ECDYSIS).

cuticularization The secretion by the outer (epidermal) layer of cells of plants and

many invertebrates of substances that then harden to form a *cuticle.

cutin A polymer of long-chain fatty acids that forms the main constituent of the *cuticle of mature epidermal plant cells. Cutin polymers are cross-linked to form a network, which is embedded in a matrix of waxes. The deposition of cutin (**cutinization**) reduces water loss by the plant and helps prevent the entry of pathogens. *See also* SUBERIN.

cutinization The deposition of *cutin in plant cell walls, principally in the outermost layers of leaves and young stems.

cutis *See* DERMIS.

cutting A part of a plant, such as a bud, leaf, or a portion of a root or shoot, that, when detached from the plant and inserted in soil, can take root and give rise to a new daughter plant. Taking or striking cuttings is a horticultural method for propagating plants. *See also* VEGETATIVE PROPAGATION.

cutting agent (adulterant) A substance used to dilute illegal drugs such as heroin and cocaine. Examples include flour, starch, sugar, and caffeine.

Cuvier, George Léopold Chrétien Frédéric Dagobert (1769–1832) French anatomist, who became professor at the Collège de France in 1799, moving in 1802 to the Jardin de Plantes. Cuvier extended the classification system of *Linnaeus, adding the category *phylum and concentrating on the taxonomy of fishes. He also initiated the classification of fossils and established the science of palaeontology.

cyanamide **1.** An inorganic salt containing the ion CN_2^{2-}. *See* CALCIUM CYANAMIDE. **2.** A colourless crystalline solid, H_2NCN, made by the action of carbon dioxide on hot sodamide. It is a weakly acidic compound (the parent acid of cyanamide salts) that is soluble in water and ethanol. It is hydrolysed to urea in acidic solutions.

cyanamide process *See* CALCIUM CYANAMIDE.

cyanate *See* CYANIC ACID.

cyanic acid An unstable explosive acid, HOCN. The compound has the structure H–O–C≡N, and is also called **fulminic acid**. Its salts and esters are **cyanates** (or **fulminates**). The compound is a volatile liquid, which readily polymerizes. In water it hydrolyses to ammonia and carbon dioxide. It is isomeric with another acid, H–N=C=O, which is known as **isocyanic acid**. Its salts and esters are **isocyanates**.

cyanide **1.** An inorganic salt containing the cyanide ion CN^-. Cyanides are extremely poisonous because of the ability of the CN^- ion to coordinate with the iron in haemoglobin, thereby blocking the uptake of oxygen by the blood. **2.** A metal coordination complex formed with cyanide ions.

cyanide process A method of extracting gold by dissolving it in potassium cyanide (to form the complex ion $[Au(CN)_2]^-$). The ion can be reduced back to gold with zinc.

cyanine dyes A class of dyes that contain a –CH= group linking two nitrogen-containing heterocyclic rings. They are used as sensitizers in photography.

Cyanobacteria A phylum consisting of two groups of photosynthetic eubacteria. The **blue-green bacteria** (formerly known as blue-green algae, or Cyanophyta), which comprise the vast majority of members, contain the photosynthetic pigment chlorophyll *a* plus accessory pigments: phycocyanins, responsible for their blue colour, and (in some) red pigments (phycoerythrins). Blue-green bacteria are unicellular but sometimes become joined in colonies or filaments by a sheath of mucilage. They occur in all aquatic habitats. A few species fix atmospheric nitrogen and thus contribute to soil fertility (*see* NITROGEN FIXATION). Others exhibit symbiosis (*see* LICHENS). The **chloroxybacteria** (grass-green bacteria or prochlorophytes) have been found in marine and freshwater habitats. They differ from the blue-green bacteria in containing chlorophyll *a* and chlorophyll *b* but no blue or red pigments – a combination like that found in plant chloroplasts, which they resemble.

cyanocobalamin *See* VITAMIN B COMPLEX.

cyanogen A colourless gas, $(CN)_2$, with a pungent odour; soluble in water, ethanol, and ether; d. 2.335 g dm^{-3}; m.p. –27.9°C; b.p. –20.7°C. The compound is very toxic. It may be prepared in the laboratory by heating mercury(II) cyanide; industrially it is made by gas-phase oxidation of hydrogen cyanide using air over a silver catalyst, chlorine over activated silicon(IV) oxide, or nitrogen dioxide over a copper(II) salt. Cyanogen is an important intermediate in the preparation of various fertilizers and is also used as a stabi-

lizer in making nitrocellulose. It is an example of a *pseudohalogen.

cyano group The group –CN in a chemical compound. *See* NITRILES.

C

cyanohydrins Organic compounds formed by the addition of hydrogen cyanide to aldehydes or ketones (in the presence of a base). The first step is attack by a CN^- ion on the carbonyl carbon atom. The final product is a compound in which a –CN and –OH group are attached to the same carbon atom. For example, ethanal reacts as follows

$$CH_3CHO + HCN \rightarrow CH_3CH(OH)(CN)$$

The product is 2-hydroxypropanonitrile. Cyanohydrins of this type can be oxidized to α-hydroxy carboxylic acids.

cyanuric acid A white crystalline water-soluble trimer of cyanic acid, $(HNCO)_3$. It is a cyclic compound having a six-membered ring made of alternating imide (NH) and carbonyl (CO) groups (i.e. three –NH–C(O)– units). It can also exist in a phenolic form (three –N=C(OH)– units).

Cycadofilicales (Pteridospermales; seed ferns) An extinct order of gymnosperms that flourished in the Carboniferous period. They possessed characteristics of both the ferns and the seed plants in reproducing by means of seeds and yet retaining fernlike leaves. Their internal anatomy combined both fern and seed-plant characteristics.

Cycadophyta A phylum of seed plants (*see* GYMNOSPERM) that contains many extinct species; the few modern representatives of the group include *Cycas* and *Zamia*. Cycads inhabit tropical and subtropical regions, sometimes growing to a height of 20 m. The stem bears a crown of fernlike leaves. These species are among the most primitive of living seed plants.

cyclamates Salts of the acid, $C_6H_{11}.NH.SO_3H$, where C_6H_{11}– is a cyclohexyl group. Sodium and calcium cyclamates were formerly used as sweetening agents in soft drinks, etc., until their use was banned when they were suspected of causing cancer.

cycle A regularly repeated set of changes to a system that brings back all its parameters to their original values once in every set of changes. The duration of one cycle is called its *period and the rate of repetition of cycle, called the *frequency, is measured in *hertz. *See* SIMPLE HARMONIC MOTION.

cyclic Describing a compound that has a ring of atoms in its molecules. In **homocyclic** compounds all the atoms in the ring are the same type, e.g. benzene (C_6H_6) and cyclohexane (C_6H_{12}). These two examples are also examples of **carbocyclic** compounds; i.e. the rings are of carbon atoms. If different atoms occur in the ring, as in pyridine (C_5H_5N), the compound is said to be **heterocyclic**.

cyclic AMP (cAMP; cyclic adenosine monophosphate) A derivative of *ATP that is widespread in cells as a *second messenger in many biochemical reactions induced by hormones. Binding of the hormone to its receptor on the cell surface activates *G proteins, which in turn activate *adenylate cyclase, the enzyme that catalyses cyclic AMP production. Cyclic AMP controls activity of protein kinase A, enabling it to activate intracellular proteins that mediate the ultimate effects of the hormone on the cell. Cyclic AMP is also involved in controlling gene expression and cell division, in immune responses, and in nervous transmission.

cyclic model (of the universe) *See* EKPYROTIC UNIVERSE.

cyclic phosphorylation (cyclic photophosphorylation) *See* PHOTOPHOSPHORYLATION.

cyclization The formation of a cyclic compound from an open-chain compound. *See* RING.

cyclo- Prefix designating a cyclic compound, e.g. a cycloalkane or a cyclosilicate.

cycloalkanes Cyclic saturated hydrocarbons containing a ring of carbon atoms joined by single bonds. They have the general formula C_nH_{2n}, for example cyclohexane, C_6H_{12}, etc. In general they behave like the *alkanes but are rather less reactive.

SEE WEB LINKS

- Information about IUPAC nomenclature

cyclohexadiene-1,4-dione (benzoquinone; quinone) A yellow solid, $C_6H_4O_2$; r.d. 1.3; m.p. 116°C. It has a six-membered ring of carbon atoms with two opposite carbon atoms linked to oxygen atoms (C=O) and the other two pairs of carbon atoms linked by double bonds (HC=CH). The compound is used in making dyes. *See also* QUINHYDRONE ELECTRODE.

cyclohexane A colourless liquid *cycloalkane, C_6H_{12}; r.d. 0.78; m.p. 6.5°C; b.p.

81°C. It occurs in petroleum and is made by passing benzene and hydrogen under pressure over a heated Raney nickel catalyst at 150°C, or by the reduction of cyclohexanone. It is used as a solvent and paint remover and can be oxidized using hot concentrated nitric acid to hexanedioic acid (adipic acid). The cyclohexane ring is not planar and can adopt boat and chair *conformations; in formulae it is represented by a single hexagon.

cycloid The curve traced by a point on the circumference of a circle as it rolls without slipping along a straight line. The length of the arc formed by one revolution of the circle is $8r$, where r is the radius of the circle. The horizontal distance between cusps is $2\pi r$.

cyclone An area of low pressure in the atmosphere. Winds rotate about the low-pressure centre in an anti-clockwise direction in the northern hemisphere and in a clockwise direction in the southern hemisphere. In the mid- and high-latitudes these low-pressure systems are now commonly referred to as *depressions, or lows, and the term cyclone is avoided. *See also* TROPICAL CYCLONE.

cyclonite A highly explosive nitro compound, $(CH_2N.NO_2)_3$. It has a cyclic structure with a six-membered ring of alternating CH_2 groups and nitrogen atoms, with each nitrogen being attached to a NO_2 group. It is made by nitrating hexamine, $C_6H_{12}N_4$, which is obtained from ammonia and methanal. Cyclonite is a very powerful explosive used mainly for military purposes. It is also called **RDX**. The abbreviation is for 'Research Department composition X', used at the Chemical Research and Development Department, Woolwich.

cyclopentadiene A colourless liquid cyclic *alkene, C_5H_6; r.d. 0.8021; m.p. –97.2°C; b.p. 40.0°C. It is prepared as a by-product during the fractional distillation of crude benzene from coal tar. It undergoes condensation reactions with ketones to give highly coloured compounds (fulvenes) and readily undergoes polymerization at room temperature to give the dimer, dicyclopentadiene. The compound itself is not aromatic because it does not have the required number of pi electrons. However, removal of a hydrogen atom produces the stable **cyclopentadienyl ion**, $C_5H_5^-$, which does have aromatic properties. In particular, the ring can coordinate to positive ions in such compounds as *ferrocene.

cyclopentadienyl ion *See* CYCLOPENTADIENE.

cyclophane A compound consisting of one or more aromatic rings forming part of a larger ring system in which aliphatic chains of the CH_2 groups link the aromatic rings. Compounds of this type have the suffix **phane** in their names. Depending on the sizes of the $(CH_2)_n$ chains, the aromatic rings may not be planar.

SEE WEB LINKS

- Information about IUPAC nomenclature

cyclopropane A colourless gas, C_3H_6, b.p. –34.5°C, whose molecules contain a triangular ring of carbon atoms. It is made by treating 1,3-dibromopropane with zinc metal, and is used as a general anaesthetic.

cyclosarin A highly toxic colourless liquid, $C_7H_{14}FO_2P$; r.d. 1.13; m.p. –30°C; b.p. 239°C. it is a fluorinated organophosphorus compound, (fluoromethylphosphoryl)oxycyclohexane. Cyclosarin was discovered in 1949 and belongs to the G-series of *nerve agents (GF).

cyclosis *See* CYTOPLASMIC STREAMING.

cyclotetramethylenetetranitramine *See* HMX.

cyclotron A cyclic particle *accelerator in which charged particles fed into the centre of the device are accelerated in an outward spiral path inside two hollow D-shaped conductors placed to form a split circle. A magnetic field is applied at right-angles to the plane of the dees and an alternating potential difference is applied between them. The frequency of the alternating p.d. is arranged so that the particles are accelerated each time they reach the evacuated gap between the dees. The magnetic field makes them follow curved paths. After several thousand revolutions inside the dees the particles reach the perimeter of the dees, where a deflecting field directs them onto the target. In this device protons can achieve an energy of 10^{-12} J (10 MeV). The first working cyclotron was produced in 1931 by the US physicist Ernest Lawrence (1901–58). *See also* SYNCHROCYCLOTRON.

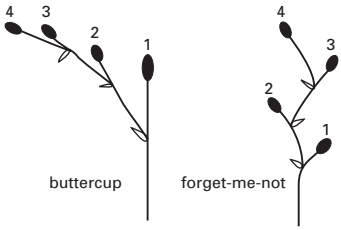
SEE WEB LINKS

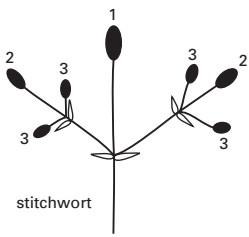
- The US National Superconducting Cyclotron Society's You Tube channel

cylinder gas *See* BOTTLED GAS.

cylindrical polar coordinates *See* POLAR COORDINATES.

cyme *See* CYMOSE INFLORESCENCE.





1 = oldest flower

Cymose inflorescence. Different types.

cymose inflorescence (cyme; definite inflorescence) A type of flowering shoot (*see* INFLORESCENCE) in which the first-formed flower develops from the growing region at the top of the flower stalk (see illustration). Thus no new flower buds can be produced at the tip and other flowers are produced from lateral buds beneath. In a **monochasial cyme** (or **monochasium**), the development of the flower at the tip is followed by a new flower axis growing from a single lateral bud. Subsequent new flowers may develop from the same side of the lateral shoots, as in the buttercup, or alternately on opposite sides, as in forget-me-not. In a **dichasial cyme** (or **dichasium**), the development of the flower at the apex is followed by two new flower axes developing from buds opposite one another, as in plants of the family Caryophyllaceae (such as stitchwort). *Compare* RACEMOSE INFLORESCENCE.

cypsela A dry single-seeded fruit that does not split open during seed dispersal and is formed from a double ovary in which only one ovule develops into a seed. It is similar to an *achene and characteristic of members of the family Compositae (Asteraceae), such as the dandelion. *See also* PAPPUS.

cysteine *See* AMINO ACID.

cystine A molecule resulting from the oxidation reaction between the sulphydryl (–SH) groups of two cysteine molecules (*see* AMINO ACID). This often occurs between adjacent cysteine residues in polypeptides. The resultant *disulphide bridges (–S–S–) are important in stabilizing the structure of protein molecules.

cytidine A nucleoside comprising one cytosine molecule linked to a D-ribose sugar molecule. The derived nucleotides, cytidine mono-, di-, and triphosphate (CMP, CDP, and CTP respectively), participate in various biochemical reactions, notably in phospholipid synthesis.

cytochrome Any of a group of proteins, each with an iron-containing *haem group, that form part of the *electron transport chain in mitochondria and chloroplasts. Electrons are transferred by reversible changes in the iron atom between the reduced Fe(II) and oxidized Fe(III) states. *See also* CYTOCHROME OXIDASE.

cytochrome oxidase An enzyme complex comprising the terminal two cytochromes of the respiratory chain in the mitochondria (*see* ELECTRON TRANSPORT CHAIN). It is responsible for the reduction of oxygen to form water.

cytogenetics The study of inheritance in relation to the structure and function of cells. For example, the results of breeding experiments can be explained in terms of the behaviour of chromosomes during the formation of the reproductive cells.

cytokine Any of numerous small proteins released from a variety of cell types that affect cell behaviour. Cytokines can influence the cells releasing them or nearby cells; in some cases they can enter the bloodstream to influence distant cells. Cytokines are crucial to many aspects of cell proliferation, differentiation, migration, and function, and play a central role in immune responses and inflammation. Cytokines produced by lymphocytes are termed **lymphokines**, and

those affecting cell migration, particularly of immune cells, form a large group of **chemokines**. Cytokines fall into two main families: the haemopoietins, which include some of the interleukins, erythropoietin, and the *colony-stimulating factors; and the tumour necrosis factor (TNF) family.

cytokinesis *See* CELL CYCLE; MITOSIS.

cytokinin (kinin) Any of a group of plant hormones chemically related to the purine adenine. Among other roles, cytokinins stimulate cell division in the presence of *auxin and have also been found to delay senescence, overcome *apical dominance, and promote cell expansion. Zeatin is a naturally occurring cytokinin.

cytology The study of the structure and function of cells. The development of the light and electron microscopes has enabled the detailed structure of the nucleus (including the chromosomes) and other organelles to be elucidated. Microscopic examination of cells, either live or as stained sections on a slide, is also used in the detection and diagnosis of various diseases, especially *cancer.

cytolysis The breakdown of cells, usually as a result of destruction or dissolution of their outer membranes. Certain drugs (**cytotoxic drugs**) have this effect and are used in the treatment of some forms of cancer.

cytomegalovirus A virus belonging to the herpes group (*see* HERPESVIRUS). In humans it normally causes symptoms that are milder than the common cold, but it can produce more serious symptoms in those whose *immune response is disturbed (e.g. cancer patients and people who are HIV-positive). Infection in pregnant women may cause congenital handicap in their children.

cytoplasm The material surrounding the nucleus of a *cell. It can be differentiated into dense outer **ectoplasm**, which is concerned primarily with cell movement, and less dense **endoplasm**, which contains most of the cell's structures.

cytoplasmic inheritance The inheritance of genes contained in the cytoplasm of a cell, rather than the nucleus. Only a very small number of genes are inherited in this way. The phenomenon occurs because certain organelles, the *mitochondria and (in plants) the *chloroplasts, contain their own genes and can reproduce independently. The female reproductive cell (the egg) has a large amount of cytoplasm containing many such organelles, which are consequently incorporated into the cytoplasm of all the cells of the embryo. The male reproductive cells (sperm or pollen), however, consist almost solely of a nucleus. Cytoplasmic organelles are thus not inherited from the male parent. In plants, male sterility can be inherited via the cytoplasm. The inheritance of any such factors does not follow Mendelian laws.

cytoplasmic streaming (cyclosis) The directional movement of cytoplasm in certain cells, which allows movement of substances through the cell, especially around the cell's periphery. It has been observed most clearly in large cells, such as plant sieve elements and unicellular algae, in which simple diffusion is ineffective as a means of local transport in the cell. The mechanism involves the interaction of *myosin proteins (attached to organelles) with *actin microfilaments parallel to the direction of flow and requires energy from ATP. A similar streaming of cytoplasm is responsible for *amoeboid movement.

cytosine A *pyrimidine derivative. It is one of the principal component bases of *nucleotides and the nucleic acids *DNA and *RNA.

cytoskeleton A network of fibres permeating the matrix of eukaryotic cells that provides a supporting framework for organelles, anchors the cell membrane, facilitates cellular movement, and provides a suitable surface for chemical reactions to take place. The fibres are composed of *microtubules and *actin microfilaments.

cytosol The semifluid soluble part of the cytoplasm of cells, which contains the components of the *cytoskeleton. The cell's organelles are suspended in the cytosol.

cytotaxonomy *See* TAXONOMY.

cytotoxic Destructive to living cells. The term is applied particularly to a class of drugs that inhibit cell division and are therefore used in chemotherapy to destroy cancer cells and to a group of *T cells that destroy virus-infected cells.

CZ *See* CUBIC ZIRCONA.

CZE Capillary zone electrophoresis. *See* CAPILLARY ELECTROPHORESIS.