B

Babbage, Charles (1792–1871) British mathematician who is best known for his early work on mechanical calculating machines. He began work on his first 'difference engine' in 1823, but abandoned it ten years later due to lack of funds. His second machine of 1834 was a programmable punched-card 'analytical engine', but this too was never completed.

Babbit metal Any of a group of related alloys used for making bearings. They consist of tin containing antimony (about 10%) and copper (1–2%), and often lead. The original alloy was invented in 1839 by the US inventor Isaac Babbit (1799–1862).

Babo's law The vapour pressure of a liquid is decreased when a solute is added, the amount of the decrease being proportional to the amount of solute dissolved. The law was discovered in 1847 by the German chemist Lambert Babo (1818–99). *See also* RAOULT'S LAW.

BAC *See* BACTERIAL ARTIFICIAL CHROMOSOME.

Bacillariophyta A phylum of *algae comprising the diatoms. These marine or freshwater unicellular organisms have cell walls composed of pectin impregnated with silica and consisting of two halves, one overlapping the other. Diatoms are found in huge numbers in plankton and are important in the food chains of seas and rivers. Past deposition has resulted in diatomaceous earths (kieselguhr) and the oil reserves of these species have contributed to oil deposits.

bacillus Any rod-shaped bacterium. Generally, bacilli are large, Gram-positive, spore-bearing, and have a tendency to form chains and produce a *capsule. Some are motile, bearing flagella. They are ubiquitous in soil and air and many are responsible for food spoilage. The group also includes *Bacillus anthracis*, which causes anthrax.

backbiting A rearrangement that can occur in some polymerization reactions involving free radicals. A radical that has an unpaired electron at the end of the chain changes into a radical with the unpaired electron elsewhere along the chain, the new radical being more stable than the one from which it originates. For example, the radical

$RCH_2CH_2CH_2CH_2CH_2CH_2\cdot$

may change into

$RCH_2CH\cdot CH_2CH_2CH_2CH_3$.

The rearrangement is equivalent to a hydrogen atom being transferred within the molecule. The new unpaired electron initiates further polymerization, with the production of polymers with butyl ($CH_3CH_2CH_2CH_2$–) side chains.

backbone *See* VERTEBRAL COLUMN.

back cross A mating between individuals of the parental generation (P) and the first generation of offspring (F_1) in order to identify hidden *recessive alleles. If an organism displays a *dominant characteristic, it may possess two dominant alleles (i.e. it is homozygous) or a dominant and a recessive allele for that characteristic (i.e. it is heterozygous). To find out which is the case, the organism is crossed with one displaying the recessive characteristic. If all the offspring show the dominant characteristic then the organism is homozygous, but if half show the recessive characteristic, then the organism is heterozygous. *See also* TEST CROSS.

back donation A form of chemical bonding in which a *ligand forms a sigma bond to an atom or ion by donating a pair of electrons, and the central atom donates electrons back by overlap of its *d*-orbitals with empty *p*- or *d*-orbitals on the ligand.

back e.m.f. An electromotive force that opposes the main current flow in a circuit. For example, when the coils of the armature in an electric motor are rotated a back e.m.f. is generated in these coils by their interaction with the field magnet (*see* INDUCTANCE). Also, in an electric cell, *polarization causes a back e.m.f. to be set up, in this case by chemical means.

background radiation Low intensity *ionizing radiation present on the surface of the earth and in the atmosphere as a result

of *cosmic radiation and the presence of radioisotopes in the earth's rocks, soil, and atmosphere. The radioisotopes are either natural or the result of nuclear fallout or waste gas from power stations. Background counts must be taken into account when measuring the radiation produced by a specified source. *See also* MICROWAVE BACKGROUND RADIATION.

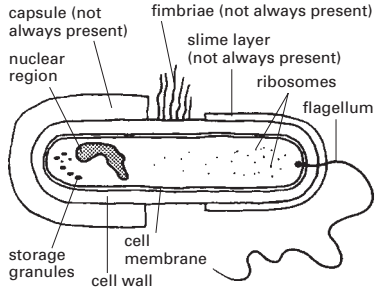
backing store Supplementary computer memory, usually in the form of magnetic disks, in which data and programs are held permanently for reference; small sections of this information can then be copied into the main memory (*RAM) of a computer when required for processing. Backing store is less costly and can hold more information than semiconductor RAM, but the speed of access of information in RAM is considerably faster. Use of a hierarchy of different memory devices, including backing store and RAM, greatly improves performance, efficiency, and economy in a computer.

back titration A technique in *volumetric analysis in which a known excess amount of a reagent is added to the solution to be estimated. The unreacted amount of the added reagent is then determined by titration, allowing the amount of substance in the original test solution to be calculated.

backup A resource that can be used as a substitute in the event of, say, a fault in a component or system or loss of data from a computer file. A backup file is a copy of a file taken in case the original is destroyed or unintentionally altered and the data lost.

bacteria A diverse group of ubiquitous microorganisms all of which consist of only a single *cell that lacks a distinct nuclear membrane and has a *cell wall of a unique composition (see illustration). Bacteria constitute the prokaryotic organisms of the living world. It is now recognized, on the basis of differences in ribosomal RNA structure and nucleotide sequences (*see* MOLECULAR SYSTEMATICS), that prokaryotes form two groups so evolutionarily distinct that they should each be raised to the status of *domain: *Archaea (the archaebacteria) and **Eubacteria**. Generally speaking, the term 'bacteria' includes both archaebacteria and eubacteria.

Bacteria can be characterized in a number of ways, for example by their reaction with *Gram's stain or on the basis of their metabolic requirements (e.g. whether or not they require oxygen: *see* AEROBIC RESPIRATION; ANAEROBIC RESPIRATION) and shape. A bacterial cell may be spherical (*see* COCCUS), rod-like (*see* BACILLUS), spiral (*see* SPIRILLUM), comma-shaped (*see* VIBRIO), corkscrew-shaped (*see* SPIROCHAETE), or filamentous, resembling a fungal cell. The majority of bacteria range in size from 0.5 to 5 μm. Many are motile, bearing *flagella, possess an outer slimy *capsule, and produce resistant spores (*see* ENDOSPORE). In general bacteria reproduce only asexually, by simple division of cells, but a few groups undergo a form of sexual reproduction (*see* CONJUGATION). Bacteria are largely responsible for decay and decomposition of organic matter, producing a cycling of such chemicals as carbon (*see* CARBON CYCLE), oxygen, nitrogen (*see* NITROGEN CYCLE), and sulphur (*see* SULPHUR CYCLE). A few bacteria obtain their food by means of *photosynthesis, including the *Cyanobacteria; some are saprotrophs; and others are parasites, causing disease. The symptoms of bacterial infections are produced by *toxins.



Bacteria. A generalized bacterial cell.

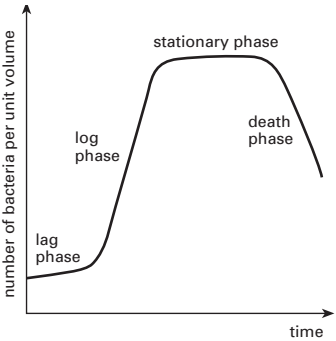
SEE WEB LINKS

- Online textbook of bacteriology devised by Kenneth Todar, University of Wisconsin-Madison

bacterial artificial chromosome *See* ARTIFICIAL CHROMOSOME.

bacterial growth curve A curve on a graph that shows the changes in size of a bacterial population over time in a culture. The bacteria are cultured in sterile nutrient medium and incubated at the optimum temperature for growth. Samples are removed at intervals and the number of viable bacteria is counted. A logarithmic growth curve is plotted, which shows various phases (see graph).

In the **lag** (or **latent**) **phase** there is only a small increase in numbers as the bacteria



Bacterial growth curve.

imbibe water, and synthesize ribosomal RNA and subsequently enzymes, in adjusting to the new conditions. The length of this phase depends on which medium was used to culture the bacteria before the investigation and which phase the cells are already in. As the life span (generation time) of the cells decreases, they enter the **log** (or **exponential**) **phase**, in which the cells reach a maximum rate of reproduction and the number of bacteria increases directly with time, giving a straight slope on a logarithmic scale (*see* EXPONENTIAL GROWTH). For example, the fastest generation time for *E. coli* is 21 minutes. Growth rate can be estimated in this phase. With time, as the population grows, it enters the **stationary phase**, when the nutrients and electron acceptors are depleted and the pH drops as carbon dioxide and other waste poisons accumulate. As the cell's energy stores are depleted the rate of cell division decreases. The **death** (or **final**) **phase** occurs when the rate at which the bacteria die exceeds the rate at which they are produced; the population declines as the levels of nutrients fall and toxin levels increase. *See also* POPULATION GROWTH.

bactericidal Capable of killing bacteria. Common bactericides are some *antibiotics, *antiseptics, and *disinfectants. *Compare* BACTERIOSTATIC.

bacteriochlorophyll A form of chlorophyll found in photosynthetic bacteria, notably the purple and green bacteria. There are several types, designated *a* to *g*. For example, bacteriochlorophyll *a* and bacteriochlorophyll *b* are structurally similar to the chlorophyll *a* and chlorophyll *b* found in plants. Bacteriochlorophyll is located in specialized membrane systems (**chromatophores**).

bacteriology The study of bacteria, including their identification, form, function, reproduction, and classification. Much attention is focused on the role of bacteria as agents of disease in animals, including humans, and in plants, and on methods of controlling pathogenic bacteria in the food chain and elsewhere in the environment. However, bacteriologists also investigate the many benefits of bacteria, e.g. in the production of antibiotics, enzymes, and amino acids, and in sewage treatment.

bacteriophage (phage) A virus that is parasitic within a bacterium. Each phage is specific for only one type of bacterium. Most phages (**virulent phages**) infect, quickly multiply within, and destroy (lyse) their host cells. However, some (**temperate phages**) remain dormant in their hosts after initial infection: their nucleic acid becomes integrated into that of the host and multiplies with it, producing infected daughter cells. Lysis may eventually be triggered by environmental factors. Phages are used experimentally to identify bacteria, to control manufacturing processes (such as cheese production) that depend on bacteria, and, because they can alter the genetic make-up of bacterial cells, they are important tools in genetic engineering as cloning *vectors.

bacteriostatic Capable of inhibiting or slowing down the growth and reproduction of bacteria. Some *antibiotics are bacteriostatic. *Compare* BACTERICIDAL.

Baer, Karl Ernst von (1792–1876) Estonian-born German biologist. He studied medicine and comparative anatomy before becoming professor of zoology at Königsberg University in 1817. Ten years later he discovered the mammalian ovum, and traced its development from the Graafian follicle to the embryo. He also noted the similarities between the young embryos of widely different species (the biogenetic law).

Baeyer test A test for unsaturated compounds in which potassium permanganate is used. Alkenes, for example, are oxidized to glycols, and the permanganate loses its colour:

$$3R_2C{=}CR_2 + 2KMnO_4 + 4H_2O \rightarrow 2MnO_2 + 2KOH + 3R_2COHR_2COH$$

b

Bakelite A trade name for certain *phenol–formaldehyde resins, first introduced in 1909 by the Belgian–US chemist Leo Hendrik Baekeland (1863–1944).

baker's yeast Strains of the yeast **Saccharomyces cerevisiae* that are used in bread-making to enable the dough to rise. Water is added to flour, which activates the *amylase enzymes that hydrolyse the starch in flour to glucose. Baker's yeast is then added, which uses the glucose as a substrate for *aerobic respiration. The carbon dioxide produced from yeast respiration causes bubbles to form in the dough; these become larger during heating in an oven, giving bread its typical texture.

baking soda *See* SODIUM HYDROGENCARBONATE.

balance **1.** An accurate weighing device. The simple **beam balance** consists of two pans suspended from a centrally pivoted beam. Known masses are placed on one pan and the substance or body to be weighed is placed in the other. When the beam is exactly horizontal the two masses are equal. An accurate laboratory balance weighs to the nearest hundredth of a milligram. Specially designed balances can be accurate to a millionth of a milligram. More modern **substitution balances** use the substitution principle. In this calibrated weights are removed from the single lever arm to bring the single pan suspended from it into equilibrium with a fixed counter weight. The substitution balance is more accurate than the two-pan device and enables weighing to be carried out more rapidly. In automatic electronic balances, mass is determined not by mechanical deflection but by electronically controlled compensation of an electric force. A scanner monitors the displacement of the pan support generating a current proportional to the displacement. This current flows through a coil forcing the pan support to return to its original position by means of a magnetic force. The signal generated enables the mass to be read from a digital display. The mass of the empty container can be stored in the balance's computer memory and automatically deducted from the mass of the container plus its contents. *See also* SPRING BALANCE. **2.** (in animal physiology) Equilibrium in the posture of the body. In vertebrates balance is sensed and maintained by the *vestibular apparatus of the inner ear. **3.** (in nutrition) *See* DIET.

baleen *See* WHALEBONE.

ballistic galvanometer A moving-coil *galvanometer designed for measuring charge by detecting a surge of current. It has a heavy coil with minimal damping. When a surge of current is passed through the coil, the initial maximum deflection (the 'throw') is proportional to the total charge that has passed.

ballistic pendulum A device used to measure the velocity of a projectile, such as a bullet. A large mass of relatively soft material is suspended from a horizontal bar and the angle through which this mass is displaced when it is struck by the projectile in flight enables the momentum and hence the velocity of the projectile to be calculated by successive application of the laws of conservation of linear momentum and of energy.

ballistics The study of the flight of projectiles, especially those that have a parabolic flight path from one point on the earth's surface to another.

ball lightning A luminous sphere that sometimes appears at ground level in a thunderstorm. Ball lightning is slow moving and usually disappears without detonation. The spheres vary in diameter up to a few metres. The phenomenon is still not fully understood. *See also* LIGHTNING.

Balmer series *See* HYDROGEN SPECTRUM.

banana bond Informal name for the type of electron-deficient three-centre bond holding the B–H–B bridges in *boranes and similar compounds.

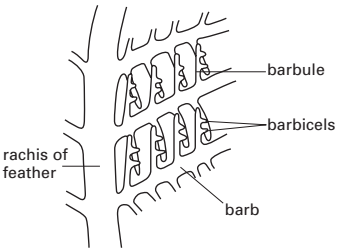
band spectrum *See* SPECTRUM.

band theory *See* ENERGY BANDS.

bandwidth The frequency range over which a radio signal of specified frequency spreads. For example, in a *modulation system it is the range of frequencies occupied by the modulating signal on either side of the carrier wave. In an amplifier, it is the range of frequencies over which the power amplification falls within a specified fraction of the maximum value. In an aerial it is the range of frequencies that an aerial system can handle without mismatch.

bar A c.g.s. unit of pressure equal to 10^6 dynes per square centimetre or 10^5 pascals (approximately 750 mmHg or 0.987 atmosphere). The **millibar** (100 Pa) is commonly used in meteorology.

barb **1.** (in zoology) Any one of the stiff filaments forming a row on each side of the longitudinal shaft of a feather (see illustration). Together the barbs form the expanded part (**vane**) of the feather. *See* BARBULE. **2.** (in botany) A hooked hair.



Barb. Interlocking barbs of a contour feather.

Barbier–Wieland degradation The stepwise degradation of a carboxylic acid to the next lower homologue. First the ester is converted into a tertiary alcohol using a Grignard reagent (PhMgX) and acid (HX):

$RCH_2COOCH_3 \rightarrow RCH_2C(OH)Ph_2$.

The secondary alcohol is then dehydrated using ethanoic anhydride ($CH_3COOCOCH_3$) to give an alkene:

$RCH_2C(OH)Ph_2 \rightarrow RCH{=}CPh_2$.

The alkene is oxidized with chromic acid:

$RCH{=}CPh_2 \rightarrow RCOOH + Ph_2CO$.

The result is conversion of an acid RCH_2COOH to the lower acid RCOOH.

barbiturate Any one of a group of drugs derived from barbituric acid, which have a depressant effect on the central nervous system. Barbiturates were originally used as sedatives and sleeping pills but their clinical use is now limited due to their toxic side-effects; prolonged use can lead to addiction. Specific barbiturates still in clinical use include butobarbital, used to treat insomnia, and thiopental, used to induce general anaesthesia.

barbule Any of the minute filaments forming a row on each side of the *barb of a feather. In a *contour feather adjacent barbules interlock by means of hooks (**barbicels**) and grooves, forming a firm vane. Down feathers have no barbicels.

barchan *See* DUNE.

Bardeen, John (1908–91) US physicist, who worked at Harvard, Minnesota University, and Bell Telephone Labs before becoming a professor at the University of Illinois in 1951. At Bell, with Walter Brattain (1902–87) and William Shockley (1910–89), he developed the point-contact transistor. The three scientists shared the 1956 Nobel Prize for physics for this work. In 1956, with Leon Cooper (1930–) and John Schrieffer (1931–), he formulated the BCS theory of *superconductivity, for which they shared the 1972 Nobel Prize.

Barfoed's test A biochemical test to detect monosaccharide (reducing) sugars in solution, devised by the Swedish physician Christen T. Barfoed (1815–99). **Barfoed's reagent**, a mixture of ethanoic (acetic) acid and copper(II) acetate, is added to the test solution and boiled. If any reducing sugars are present a red precipitate of copper(II) oxide is formed. The reaction will be negative in the presence of disaccharide sugars as they are weaker reducing agents.

barite *See* BARYTES.

barium Symbol Ba. A silvery-white reactive element belonging to *group 2 (formerly IIA) of the periodic table; a.n. 56; r.a.m. 137.34; r.d. 3.51; m.p. 725°C; b.p. 1640°C. It occurs as the minerals barytes ($BaSO_4$) and witherite ($BaCO_3$). Extraction is by high-temperature reduction of barium oxide with aluminium or silicon in a vacuum, or by electrolysis of fused barium chloride. The metal is used as a getter in vacuum systems. It oxidizes readily in air and reacts with ethanol and water. Soluble barium compounds are extremely poisonous. It was first identified in 1774 by Karl Scheele, and was extracted by Humphry Davy in 1808.

SEE WEB LINKS

- Information from the WebElements site

barium bicarbonate *See* BARIUM HYDROGENCARBONATE.

barium carbonate A white insoluble compound, $BaCO_3$; r.d. 4.43. It decomposes on heating to give barium oxide and carbon dioxide:

$BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$

The compound occurs naturally as the mineral **witherite** and can be prepared by adding an alkaline solution of a carbonate to a solution of a barium salt. It is used as a raw material for making other barium salts, as a flux for ceramics, and as a raw material in

the manufacture of certain types of optical glass.

b

barium chloride A white compound, $BaCl_2$. The anhydrous compound has two crystalline forms: an α form (monoclinic; r.d. 3.856), which transforms at 962°C to a β form (cubic; r.d. 3.917; m.p. 963°C; b.p. 1560°C). There is also a dihydrate, $BaCl_2.2H_2O$ (cubic; r.d. 3.1), which loses water at 113°C. It is prepared by dissolving barium carbonate (witherite) in hydrochloric acid and crystallizing out the dihydrate. The compound is used in the extraction of barium by electrolysis.

barium hydrogencarbonate (barium bicarbonate) A compound, $Ba(HCO_3)_2$, which is only stable in solution. It can be formed by the action of carbon dioxide on a suspension of barium carbonate in cold water:

$$BaCO_3(s) + CO_2(g) + H_2O(l) \rightarrow Ba(HCO_3)_2(aq)$$

On heating, this reaction is reversed.

barium hydroxide (baryta) A white solid, $Ba(OH)_2$, sparingly soluble in water. The common form is the octahydrate, $Ba(OH)_2.8H_2O$; monoclinic; r.d. 2.18; m.p. 78°C. It can be produced by adding water to barium monoxide or by the action of sodium hydroxide on soluble barium compounds and is used as a weak alkali in volumetric analysis.

barium oxide A white or yellowish solid, BaO, obtained by heating barium in oxygen or by the thermal decomposition of barium carbonate or nitrate; cubic; r.d. 5.72; m.p. 1923°C; b.p. 2000°C. When barium oxide is heated in oxygen the peroxide, BaO_2, is formed in a reversible reaction that was once used as a method for obtaining oxygen (the **Brin process**). Barium oxide is now used in the manufacture of lubricating-oil additives.

barium peroxide A dense off-white solid, BaO_2, prepared by carefully heating *barium oxide in oxygen; r.d. 4.96; m.p. 450°C. It is used as a bleaching agent. With acids, hydrogen peroxide is formed and the reaction is used in the laboratory preparation of hydrogen peroxide.

barium sulphate An insoluble white solid, $BaSO_4$, that occurs naturally as the mineral *barytes (or **heavy spar**) and can be prepared as a precipitate by adding sulphuric acid to barium chloride solution; r.d. 4.50; m.p. 1580°C. The rhombic form changes to a monoclinic form at 1149°C. It is used as a raw material for making other barium salts, as a pigment extender in surface coating materials (called **blanc fixe**), and in the glass and rubber industries. Barium compounds are opaque to X-rays, and a suspension of the sulphate in water is used in medicine to provide a contrast medium for X-rays of the stomach and intestine. Although barium compounds are extremely poisonous, the sulphate is safe to use because it is very insoluble.

bark The protective layer of mostly dead cells that covers the outside of woody stems and roots. It includes the living and dead tissues external to the xylem, including the phloem and periderm. The term can be used more specifically to describe the periderm together with other tissues isolated by the activity of the *cork cambium. In some species, such as birch, there is one persistent cork cambium but in the older stems of certain other species a second cork cambium becomes active beneath the periderm and further periderm layers are formed every few years. The result is a composite tissue called **rhytidome**, composed of cork, dead cortex, and dead phloem cells.

Barkhausen effect The magnetization of a ferromagnetic substance by an increasing magnetic field takes place in discontinuous steps rather than continuously. The effect results from the orientation of magnetic domains (*see* MAGNETISM). It was first observed by H. Barkhausen (1881–1956) in 1919.

Barlow wheel *See* HOMOPOLAR GENERATOR.

barn A unit of area sometimes used to measure *cross sections in nuclear interactions involving incident particles. It is equal to 10^{-28} square metre. The name comes from the phrase 'side of a barn' (something easy to hit).

barograph A meteorological instrument that records on paper variations in atmospheric pressure over a period. It often consists of an aneroid barometer operating a pen that rests lightly on a rotating drum to which the recording paper is attached.

barometer A device for measuring *atmospheric pressure. The **mercury barometer** in its simplest form consists of a glass tube about 80 cm long sealed at one end and filled with mercury. The tube is then in-

verted and the open end is submerged in a reservoir of mercury; the mercury column is held up by the pressure of the atmosphere acting on the surface of mercury in the reservoir. This type of device was invented by the Italian scientist Evangelista Torricelli (1608–47), who first noticed the variation in height from day to day, and constructed a barometer in 1644.

In such a device, the force exerted by the atmosphere balanced the weight of the mercury column. If the height of the column is h and the cross-sectional area of the tube is A, then the volume of the mercury in the column is hA and its weight is $hA\rho$, where ρ is the density of mercury. The force is thus $hA\rho g$, where g is the acceleration of free fall and the pressure exerted is this force divided by the area of the tube; i.e. $h\rho g$. Note that the height of the mercury is independent of the diameter of the tube. At standard atmospheric pressure the column is 760 mm high. The pressure is then expressed as 760 mmHg (101 325 pascals).

Mercury barometers of this type, with a reservoir of mercury, are known as **cistern barometers**. A common type is the **Fortin barometer**, in which the mercury is held in a leather bag so that the level in the reservoir can be adjusted. The height is read from a scale along the side of the tube in conjunction with a vernier scale that can be moved up and down. Corrections are made for temperature.

The second main type of barometer is the **aneroid barometer**, in which the cumbersome mercury column is replaced by a metal box with a thin corrugated lid. The air is removed from the box and the lid is supported by a spring. Variations in atmospheric pressure cause the lid to move against the spring. This movement is magnified by a system of delicate levers and made to move a needle around a scale. The aneroid barometer is less accurate than the mercury type but much more robust and convenient, hence its use in *altimeters.

baroreceptor A *receptor that responds to changes in pressure. The *carotid sinus in the carotid artery contains baroreceptors that respond to changes in arterial pressure and are therefore involved in the regulation of blood pressure and heart beat.

Barr body A structure consisting of a condensed X chromosome (*see* SEX CHROMOSOME) that is found in nondividing nuclei of female mammals. The presence of a Barr body is used to confirm the sex of athletes in sex determination tests. It is named after the Canadian anatomist M. L. Barr (1908–95), who identified it in 1949.

barrel A measurement of volume, widely used in the chemical industry, equal to 35 UK gallons (approximately 159 litres).

barycentre The *centre of mass of a system.

barye A c.g.s. unit of pressure equal to one dyne per square centimetre (0.1 pascal).

baryon A *hadron with half-integral spin. Nucleons comprise a subclass of baryons. According to currently accepted theory, baryons are made up of three quarks (**antibaryons** are made up of three antiquarks) held together by gluons (*see* ELEMENTARY PARTICLES). Baryons possess a quantum number, called the **baryon number**, which is +1 for baryons, –1 for antibaryons, 1/3 for quarks, –1/3 for antiquarks, and 0 for all other particles such as electrons, neutrinos, and photons. Baryon number has always appeared to have been conserved experimentally, but *grand unified theories postulate interactions at very high energies that allow it not to be conserved. It is thought that nonconservation of baryon number at the high energies characteristic of the early universe may provide an explanation for the asymmetry between matter and antimatter in the universe. *See* PROTON DECAY.

baryta *See* BARIUM HYDROXIDE.

barytes (barite) An orthorhombic mineral form of *barium sulphate, $BaSO_4$; the chief ore of barium. It is usually white but may also be yellow, grey, or brown. Large deposits occur in Andalusia, Spain, and in the USA.

basal body *See* UNDULIPODIUM.

basal ganglia Small masses of nervous tissue within the brain that connect the *cerebrum with other parts of the nervous system. They are involved with the subconscious regulation of voluntary movements.

basal metabolic rate (BMR) The rate of energy metabolism required to maintain an animal at rest. BMR is measured in terms of heat production per unit time and is usually expressed in kilojoules of heat released per square metre of body surface per hour ($kJ\ m^{-2}\ h^{-1}$). It indicates the energy con-

sumed in order to sustain such vital functions as heartbeat, breathing, nervous activity, active transport, and secretion. Different tissues have different metabolic rates (e.g. the BMR of brain tissue is much greater than that of bone tissue) and therefore the tissue composition of an animal determines its overall BMR. For organisms generally, BMR is proportional to body weight; small animals tend to have a higher metabolic rate per unit weight than large ones.

basalt A fine-grained basic igneous rock. It is composed chiefly of calcium-rich plagioclase feldspar and pyroxene; other minerals present may be olivine, magnetite, and apatite. Basalt is the commonest type of lava.

base **1.** (in chemistry) A compound that reacts with a protonic acid to give water (and a salt). The definition comes from the Arrhenius theory of acids and bases. Typically, bases are metal oxides, hydroxides, or compounds (such as ammonia) that give hydroxide ions in aqueous solution. Thus, a base may be either: (1) An insoluble oxide or hydroxide that reacts with an acid, e.g.

$$CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$$

Here the reaction involves hydrogen ions from the acid

$$CuO(s) + 2H^+(aq) \rightarrow H_2O(l) + Cu^{2+}(aq)$$

(2) A soluble hydroxide, in which case the solution contains hydroxide ions. The reaction with acids is a reaction between hydrogen ions and hydroxide ions:

$$H^+ + OH^- \rightarrow H_2O$$

(3) A compound that dissolves in water to produce hydroxide ions. For example, ammonia reacts as follows:

$$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + {}^-OH$$

Similar reactions occur with organic *amines (*see also* NITROGENOUS BASE; AMINE SALTS). A base that dissolves in water to give hydroxide ions is called an **alkali**. Ammonia and sodium hydroxide are common examples.

The original Arrhenius definition of a base has been extended by the Lowry–Brønsted theory and by the Lewis theory. *See* ACID. **2.** (in mathematics) **a.** The number of different symbols in a number system. In the decimal system the base is 10; in *binary notation it is 2. **b.** The number that when raised to a certain power has a *logarithm equal to that power. For example if 10 is raised to the power of 3 it is equal to 1000; 3 is then the (common) logarithm of 1000 to the base 10. In natural or Napierian logarithms the base is e. To change the base from common to natural logarithms the formula used is: $\log_{10} y = \log_e y \times \log_{10} e = 0.43429 \log_e y$. **3.** (in electronics) *See* TRANSISTOR.

base dissociation constant *See* DISSOCIATION.

basement membrane A thin sheet of fibrous proteins that supports the cells of an overlying epithelium or endothelium, separating this from underlying connective tissue. Such membranes also surround muscle cells, Schwann cells, and fat cells, and a thick basement membrane is found in the kidney glomerulus, where it acts as a filter (*see* ULTRAFILTRATION). Basement membranes are components of the *extracellular matrix and help to regulate passage of materials between epithelial cells and adjacent blood vessels. A basement membrane consists of two layers: a **reticular lamina**, containing a network of *collagen fibrils; and a **basal lamina**, consisting largely of laminin proteins, which bind the collagen to neighbouring cells and the underlying connective tissue.

base metal A common relatively inexpensive metal, such as iron or lead, that corrodes, oxidizes, or tarnishes on exposure to air, moisture, or heat, as distinguished from precious metals, such as gold and silver.

base pair Symbol bp. A unit used at the molecular level for measuring distances along a duplex polynucleotide and corresponding to the number of paired bases in a particular segment of DNA (or duplex RNA). *See also* BASE PAIRING; KILOBASE.

base pairing The chemical linking of two complementary nitrogenous bases in *DNA and in certain types of *RNA molecules. Of the four such bases in DNA, adenine pairs with thymine and cytosine with guanine. In RNA, thymine is replaced by uracil. Base pairing is responsible for holding together the two strands of a DNA molecule to form a double helix and for faithful reproduction and reading of the *genetic code. The links between bases take the form of *hydrogen bonds.

base unit A unit that is defined arbitrarily rather than being defined by simple combinations of other units. For example, the ampere is a base unit in the SI system defined in terms of the force produced between two current-carrying conductors, whereas the coulomb is a **derived unit**, defined as the

quantity of charge transferred by one ampere in one second.

basic **1.** Describing a compound that is a base. **2.** Describing a solution containing an excess of hydroxide ions; alkaline.

BASIC A high-level computer programming language. The name is short for *b*eginner's *a*ll-purpose *s*ymbolic *i*nstruction *c*ode. It dates from the 1960s, is easy to learn and use, and is mainly employed in teaching programming. There are several variants, including **Visual Basic**, which is used to program graphic user interfaces.

basic dye *See* DYES.

basicity constant *See* DISSOCIATION.

basic-oxygen process (BOP process) A high-speed method of making high-grade steel. It originated in the **Linz–Donawitz (L–D) process**. Molten pig iron and scrap are charged into a tilting furnace, similar to the Bessemer furnace except that it has no tuyeres. The charge is converted to steel by blowing high-pressure oxygen onto the surface of the metal through a water-cooled lance. The excess heat produced enables up to 30% of scrap to be incorporated into the charge. The process has largely replaced the Bessemer and open-hearth processes.

basic rock An igneous rock containing a comparatively low amount of silica (up to 45–52%) but rich in calcium or magnesium and iron. Examples include basalt, dolerite, and gabbro.

basic salt A compound that can be regarded as being formed by replacing some of the oxide or hydroxide ions in a base by other negative ions. Basic salts are thus mixed salt–oxides (e.g. bismuth(III) chloride oxide, BiOCl) or salt–hydroxides (e.g. lead(II) chloride hydroxide, Pb(OH)Cl).

basic slag *Slag formed from a basic flux (e.g. calcium oxide) in a blast furnace. The basic flux is used to remove acid impurities in the ore and contains calcium silicate, phosphate, and sulphide. If the phosphorus content is high the slag can be used as a fertilizer.

basic stains *See* STAINING.

Basidiomycota A phylum of fungi, formerly classified as a class (Basidiomycetes) or a subdivision (Basidiomycotina). Sexual reproduction is by means of **basidiospores** (spores produced externally on a club-shaped or cylindrical cell, the **basidium**). Basidia are often grouped together forming fruiting structures, such as mushrooms, puffballs, and bracket fungi. Exceptions are the *rusts and *smuts, which do not produce obvious fruiting bodies.

basophil A type of white blood cell (*leucocyte) that has a lobed nucleus surrounded by granular cytoplasm (*see* GRANULOCYTE). Basophils are produced continually by stem cells in the red bone marrow; they are *phagocytes and – like *mast cells – produce histamine and heparin as part of the body's defences at the site of an infection or injury (*see* INFLAMMATION).

Basov, Nikolai Gennediyevitch (1922–2001) Russian physicist best known for the development of the *maser, the precursor of the laser. In 1955, while working as a research student with Aleksandr Prokhorov (1916–2000) at the Soviet Academy of Sciences, he devised a microwave amplifier based on ammonia molecules. The two scientists shared the 1964 Nobel Prize with American Charles Townes (1915–), who independently developed a maser.

bast An old name for *phloem.

Bateson, William (1861–1926) British geneticist, who worked at Cambridge University. In 1900 he translated and championed the rediscovered work of *Mendel and went on to study inheritance in chickens. He found that some traits are controlled by more than one gene. He also coined the term 'genetics'.

batholith A large *intrusion of igneous rock, often surrounded by metamorphic rock, with a surface area in excess of 100 sq km. It is an irregular mass, which may penetrate to a great depth (up to 30 km), and is usually associated with a mountain belt (*see* OROGENESIS). Many batholiths are composed of granite and there are often veins of useful ores in the surrounding country rock.

bats *See* CHIROPTERA.

battery A number of electric cells joined together. The common car battery, or *accumulator, usually consists of six secondary cells connected in series to give a total e.m.f. of 12 volts. A torch battery is usually a *dry cell, two of which are often connected in series. Batteries may also have cells connected in parallel, in which case they have the same e.m.f. as a single cell, but their capacity is in-

creased, i.e. they will provide more total charge. The capacity of a battery is usually specified in ampere-hours, the ability to supply 1 A for 1 hr, or the equivalent.

baud A unit for measuring signal speed in a computer or communications system. When the signal is a sequence of *bits, the baud rate is given in bits per second (bps). The unit is named after Jean-Maurice-Emile Baudot (1845–1903).

bauxite The chief ore of aluminium, consisting of hydrous aluminium oxides and aluminous laterite. It is a claylike amorphous material formed by the weathering of silicate rocks under tropical conditions. The chief producers are Australia, Guinea, Jamaica, Russia, Brazil, and Surinam.

Bayesian inference A technique of statistical inference that estimates the probability of an event occurring in terms of the frequency at which the event occurred previously. It depends on *Bayes' theorem.

Bayesian statistics and probability A method of interpreting *probability in terms of a number indicating how much confidence is placed in a proposition, i.e. how true it is. The *entropy of a probability distribution is maximized to assign a probability. A hypothesis can be confirmed by an observation that is likely if the hypothesis is true and unlikely if it is false. *See also* BAYES' THEOREM.

Bayes' theorem A theorem that deals with conditional *probabilities of propositions or events. Given an event A the conditional probability of an event E is formulated as $P(A|E) = P(E)/P(A)$. Bayes' theorem enables prior estimates of probability to be updated when further information becomes available. It was named after the British mathematician Thomas Bayes (1702–61).

b.c.c. Body-centred cubic. *See* CUBIC CRYSTAL.

B cell (B lymphocyte) A *lymphocyte that is derived from stem cells in the bone marrow but does not mature in the thymus (*compare* T CELL); in birds it matures in the bursa of the cloaca (hence *B* cell). Each B cell has a unique set of receptor molecules on its surface, designed to recognize and bind to a specific antigen, which is taken into the cell. Here, the antigen is bound with MHC class II proteins (*see* HISTOCOMPATIBILITY); the antigen–MHC class II complex migrates to the cell surface and is recognized by helper T cells, which adhere to the B cell. This triggers the T cells to release lymphokines (*see* CYTOKINE), which cause the B cell to undergo repeated division to form a clone of cells. These mature into *plasma cells, capable of producing large amounts of specific antibody (*see* IMMUNOGLOBULIN), which circulates in the blood and lymph and binds to the corresponding antigen. After a few days of antibody production the plasma cells die. However, some cells from the clone remain in the form of **memory cells**, which initiate a more rapid immune response on subsequent exposure to the same antigen. *See also* CLONAL SELECTION THEORY.

BCS theory *See* SUPERCONDUCTIVITY.

Beadle, George Wells (1903–89) US geneticist who, after holding several professorships, went to Stanford University, where he worked with Edward Tatum (1909–75). Using moulds, they deduced that the function of genes is to control the production of enzymes, which in turn control metabolic processes. They found that mutant genes result in abnormal (and non-operative) enzymes. For this 'one gene–one enzyme' theory (*see* ONE GENE–ONE POLYPEPTIDE HYPOTHESIS), they were awarded the 1958 Nobel Prize in physiology or medicine.

beam A group of rays moving in an organized manner. It may consist of particles (e.g. an electron beam) or of electromagnetic radiation (e.g. a radar beam).

beam balance *See* BALANCE.

beam hole A hole through the shielding of a *nuclear reactor to enable a beam of neutrons or other particles to escape for experimental purposes.

beats A periodic increase and decrease in loudness heard when two notes of slightly different frequency are sounded at the same time. If a note of frequency n is heard at the same time as a note of frequency m, the resulting note will have a frequency of about $(n + m)/2$. However the amplitude of this note will vary from the difference to the sum of the amplitudes of the m and n notes and the frequency (called the **beat frequency**) of this variation will be $(m – n)$. The beating sound produced occurs as the waves successively reinforce and oppose each other as they move in and out of phase. Beating also occurs with radio-frequency waves and is

Beaufort number	description of wind	wind speed (knots)	wind speed (metres per second)
0	calm	<1	0.0– 0.2
1	light air	1– 3	0.3– 1.5
2	light breeze	4– 6	1.6– 3.3
3	gentle breeze	7–10	3.4– 5.4
4	moderate breeze	11–16	5.5– 7.9
5	fresh breeze	17–21	8.0–10.7
6	strong breeze	22–27	10.8–13.8
7	near gale	28–33	13.9–17.1
8	gale	34–40	17.2–20.7
9	strong gale	41–47	20.8–24.4
10	storm	48–55	24.5–28.4
11	violent storm	56–63	28.5–32.6
12	hurricane	⩾64	⩾32.7

Beaufort wind scale.

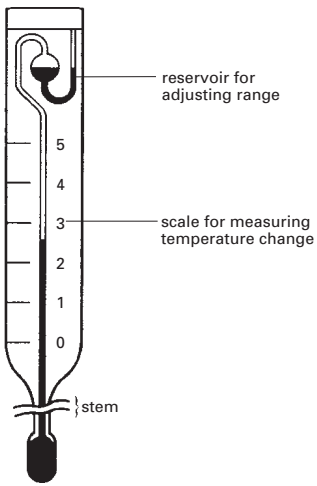
made use of in *heterodyne devices. *See also* INTERFERENCE.

Beaufort wind scale A scale of wind speed that was devised in the early 19th century by Rear Admiral Sir Francis Beaufort (1774–1857). Originally based on observations of the effect of various wind speeds on the sails of a full-rigged frigate, it has since been modified and is now based on observations of the sea surface or, on land, such easily observable indicators as smoke and tree movement. The scale ranges from 0 (calm) to 12 (hurricane).

Becklin–Neugebauer object (BN object) A point in the star-forming part of the Orion nebula that emits infrared radiation (but no visible radiation, probably because it is scattered by the dense dust of the nebula). It is thought to be a young near main-sequence star of type B spectral classification, and one of the youngest stars so far observed.

Beckmann rearrangement The chemical conversion of a ketone *oxime into an *amide, usually using sulphuric acid as a catalyst. The reaction, used in the manufacture of nylon and other polyamides, is named after the German chemist Ernst Beckmann (1853–1923).

Beckmann thermometer A thermometer for measuring small changes of temperature (see illustration). It consists of a mercury-in-glass thermometer with a scale covering only 5 or 6°C calibrated in hundredths of a degree. It has two mercury bulbs, the range of temperature to be measured is varied by running mercury from the upper bulb into the larger lower bulb. It is used particularly for measuring *depression of freezing point or *elevation of boiling point of liquids when solute is added, in order to find relative molecular masses.



Beckmann thermometer.

becquerel Symbol Bq. The SI unit of activity (*see* RADIATION UNITS). The unit is named after A. H. Becquerel.

Becquerel, Antoine Henri (1852–1908) French physicist. His early researches were in optics; in 1896 he accidentally discovered *radioactivity in fluorescent salts of uranium. Three years later he showed that it consists of charged particles that are deflected by a magnetic field. For this work he was awarded the 1903 Nobel Prize for

physics, which he shared with Pierre and Marie *Curie.

b

bees *See* HYMENOPTERA.

beetles *See* COLEOPTERA.

beet sugar *See* SUCROSE.

behaviour The sum of the responses of an organism to internal or external stimuli. The behaviour of an animal can be either instinctive (*see* INSTINCT) or learned. *See* ANIMAL BEHAVIOUR; LEARNING.

behavioural genetics The branch of genetics concerned with determining the relative importance of the genetic constitution of animals as compared to environmental factors in influencing animal behaviour.

bel Ten *decibels.

bell metal A type of *bronze used in casting bells. It consists of 60–85% copper alloyed with tin, often with some zinc and lead included.

Bell's theorem A theorem stating that no local *hidden-variables theory can make predictions in agreement with those of *quantum mechanics. Local hidden variables theories give rise to a result, called **Bell's inequality**, which is one of many similar results concerning the probabilities of two events both occurring in well-separated parts of a system. The British physicist John S. Bell (1928–90) showed in 1964 that quantum mechanics predicts a violation of the inequalities, which are consequences of local hidden-variables theories. Experiments are in agreement with quantum mechanics rather than local hidden variables theories by violating Bell's inequality, in accordance with Bell's theorem. *See also* LEGGETT'S THEOREM; QUANTUM ENTANGLEMENT.

SEE WEB LINKS

- The original 1964 paper in *Physics*

Belousov–Zhabotinskii reaction *See* B–Z REACTION.

Bénard cell A structure associated with a layer of liquid that is confined by two horizontal parallel plates, in which the lateral dimensions are much larger than the width of the layer. Before heating the liquid is homogeneous. However, if after heating from below the temperatures of the plates are T_1 and T_2, at a critical value of the temperature gradient $\Delta T = T_1 - T_2$ the liquid abruptly starts to convect. The liquid spontaneously organizes itself into a set of convection rolls, i.e. the liquid goes round in a series of 'cells'. The existence of such cells was discovered by a French scientist, Henri Bénard, around 1900. *See also* COMPLEXITY.

bending moment (about any point or section of a horizontal beam under load) The algebraic sum of the moments of all the vertical forces to either side of that point or section (*see* MOMENT OF A FORCE).

Benedict's test A biochemical test to detect *reducing sugars in solution, devised by the US chemist S. R. Benedict (1884–1936). **Benedict's reagent** – a mixture of copper(II) sulphate and a filtered mixture of hydrated sodium citrate and hydrated sodium carbonate – is added to the test solution and boiled. A high concentration of reducing sugars induces the formation of a red precipitate; a lower concentration produces a yellow precipitate. Benedict's test is a more sensitive alternative to *Fehling's test.

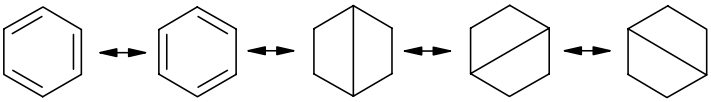
beneficiation (ore dressing) The separation of an ore into the valuable components and the waste material (gangue). This may be achieved by a number of processes, including crushing, grinding, magnetic separation, froth flotation, etc. The dressed ore, consisting of a high proportion of valuable components, is then ready for smelting or some other refining process.

benthos Flora and fauna occurring on the bottom of a sea or lake. Benthic organisms may crawl, burrow, or remain attached to a substrate. *Compare* PELAGIC.

bent sandwich *See* SANDWICH COMPOUND.

benzaldehyde *See* BENZENECARBALDEHYDE.

benzene A colourless liquid hydrocarbon, C_6H_6; r.d. 0.88; m.p. 5.5°C; b.p. 80.1°C. It is now made from gasoline from petroleum by catalytic reforming (formerly obtained from coal tar). Benzene is the archetypal *aromatic compound. It has an unsaturated molecule, yet will not readily undergo addition reactions. On the other hand, it does undergo substitution reactions in which hydrogen atoms are replaced by other atoms or groups. This behaviour occurs because of delocalization of *p*-electrons over the benzene ring, and all the C–C bonds in benzene are equivalent and intermediate in length between single and double bonds. It can be regarded as a resonance hybrid of Kekulé



Benzene.

and Dewar structures (see formulae). In formulae it can be represented by a hexagon with a ring inside it.

benzenecarbaldehyde (benzaldehyde) A yellowish volatile oily liquid, C_6H_5CHO; r.d. 1.04; m.p. –26°C; b.p. 178.1°C. The compound occurs in almond kernels and has an almond-like smell. It is made from methylbenzene (by conversion to dichloromethyl benzene, $C_6H_5CHCl_2$, followed by hydrolysis). Benzenecarbaldehyde is used in flavourings, perfumery, and the dyestuffs industry.

benzenecarbonyl chloride (benzoyl chloride) A colourless liquid, C_6H_5COCl; r.d. 1.21; m.p. 0°C; b.p. 197.2°C. It is an *acyl halide, used to introduce benzenecarbonyl groups into molecules. *See* ACYLATION.

benzenecarbonyl group (benzoyl group) The organic group $C_6H_5CO–$.

benzenecarboxylate (benzoate) A salt or ester of benzenecarboxylic acid.

benzenecarboxylic acid (benzoic acid) A white crystalline compound, C_6H_5COOH; r.d. 1.27; m.p. 122.4°C; b.p. 249°C. It occurs naturally in some plants and is used as a food preservative. Benzenecarboxylic acid has a carboxyl group bound directly to a benzene ring. It is a weak carboxylic acid ($K_a = 6.4 \times 10^{-5}$ at 25°C), which is slightly soluble in water. It also undergoes substitution reactions on the benzene ring.

benzene-1,4-diol (hydroquinone; quinol) A white crystalline solid, $C_6H_4(OH)_2$; r.d. 1.33; m.p. 173–174°C; b.p. 285°C. It is used in making dyes. *See also* QUINHYDRONE ELECTRODE.

benzene hexachloride (BHC) A crystalline substance, $C_6H_6Cl_6$, made by adding chlorine to benzene. It is used as a pesticide and, like *DDT, concern has been expressed at its environmental effects.

benzenesulphonic acid A colourless deliquescent solid, $C_6H_5SO_2OH$, m.p. 43–44°C, usually found as an oily liquid. It is made by treating benzene with concentrated sulphuric acid. Its alkyl derivatives are used as *detergents.

benzil 1,2-diphenylethan-1,2-dione. *See* BENZILIC ACID REARRANGEMENT.

benzilic acid rearrangement An organic rearrangement reaction in which **benzil** (1,2-diphenylethan-1,2-dione) is treated with hydroxide and then acid to give **benzilic acid** (2-hydroxy-2,2-diphenylethanoic acid):

$$C_6H_5.CO.CO.C_6H_5 \rightarrow (C_6H_5)_2C(OH).COOH$$

In the reaction a phenyl group ($C_6H_5–$) migrates from one carbon atom to another. The reaction was discovered in 1828 by Justus von Liebig; it was the first rearrangement reaction to be described.

benzoate *See* BENZENECARBOXYLATE.

benzodiazepines A group of related psychoactive drugs. They are used medically in the treatment of anxiety, insomnia, convulsions, and alcohol withdrawal. All are addictive and available only as prescription drugs in the UK. Common examples are *diazepam (Valium) and *flunitrazepam (Rohypnol).

benzoic acid *See* BENZENECARBOXYLIC ACID.

benzopyrene A crystalline aromatic hydrocarbon, $C_{20}H_{12}$; m.p. 179°C. It is found in coal tar and is highly carcinogenic.

benzoquinone *See* CYCLOHEXADIENE-1,4-DIONE.

benzoylation A chemical reaction in which a benzoyl group (benzenecarbonyl group, C_6H_5CO) is introduced into a molecule. *See* ACYLATION.

benzoyl chloride *See* BENZENECARBONYL CHLORIDE.

benzoylecgonine (BZ) A primary metabolite of cocaine, used in drug testing. It can be detected in the urine up to 48 hours after taking cocaine. BZ is tested for by immunoassay or by gas chromatography/mass spectrometry.

benzoyl group *See* BENZENECARBONYL GROUP.

b

benzpyrene A pale yellow solid, $C_{20}H_{12}$, m.p. 179°C, whose molecules consist of five fused benzene rings. It occurs in tars from coal and tobacco smoke and is a *carcinogen.

benzvalene A valence isomer of benzene, C_6H_6, with a bridged structure.

benzyl alcohol *See* PHENYLMETHANOL.

benzylamine (α-aminotoluene; phenylmethylamine) A colourless liquid, $C_6H_5CH_2NH_2$; r.d. 0.981; b.p. 185°C. It behaves in the same way as primary aliphatic amines.

benzyne A highly reactive short-lived compound, C_6H_4, having a hexagonal ring of carbon atoms containing two double bonds and one triple bond. Benzyne, which is the simplest example of an *aryne, is thought to be an intermediate in a number of reactions.

Bergius, Friedrich Karl Rudolf (1884–1949) German organic chemist. While working with Fritz *Haber in Karlsruhe, he become interested in reactions at high pressures. In 1912 he devised an industrial process for making light hydrocarbons by the high-pressure hydrogenation of coal or heavy oil. The work earned him a share of the 1931 Nobel Prize for chemistry with Carl Bosch (1874–1940). The Bergius process proved important for supplying petrol for the German war effort in World War II.

Bergius process A process for making hydrocarbon mixtures (for fuels) from coal by heating powdered coal mixed with tar and iron(III) oxide catalyst at 450°C under hydrogen at a pressure of about 200 atmospheres. In later developments of the process, the coal was suspended in liquid hydrocarbons and other catalysts were used. The process was developed by Friedrich Bergius during World War I as a source of motor fuel.

beriberi A disease caused by a low intake of vitamin B_1 (thiamine; *see* VITAMIN B COMPLEX), resulting in damage to peripheral nerves and heart failure. Beriberi is most common in regions of the Far East where the diet is based on polished white rice, which lacks the thiamine-rich seed coat.

berkelium Symbol Bk. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 97; mass number of the most stable isotope 247 (half-life 1.4×10^3 years); r.d. (calculated) 14. There are eight known isotopes. It was first produced by G. T. Seborg and associates in 1949 by bombarding americium–241 with alpha particles.

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Bernoulli, Daniel (1700–82) Swiss mathematician. In 1724 he published a work on differential equations, which earned him a professorship at St Petersburg. He returned to Basel, Switzerland, in 1733 and began researches on hydrodynamics (*see* BERNOULLI THEOREM), the work for which he is best known. He also initiated the kinetic theory of matter.

Bernoulli theorem At any point in a pipe through which a fluid is flowing the sum of the pressure energy, the kinetic energy, and the potential energy of a given mass of the fluid is constant. This is equivalent to a statement of the law of the conservation of energy. The law was published in 1738 by Daniel Bernoulli.

Bernoulli trial An experiment in which there are two possible independent outcomes, for example, tossing a coin. It is named after the Swiss mathematician Jakob (or Jacques) Bernoulli (1654–1705), who made important contributions to the field of probability theory.

berry A fleshy fruit formed from either one carpel or from several fused together and containing many seeds. The fruit wall may have two or three layers but the inner layer is never hard and stony (as in some drupes). Examples of berries are grapes and tomatoes. A berry, such as a cucumber, that develops a hard outer rind is called a **pepo**. One that is segmented and has a leathery rind, such as a citrus fruit, is called a **hesperidium**. The rind contains oil glands and is lined by the white mesocarp, commonly called **pith**.

Berthollide compound *See* NONSTOICHIOMETRIC COMPOUND.

beryl A hexagonal mineral form of beryllium aluminium silicate, $Be_3Al_2Si_6O_{18}$; the chief ore of beryllium. It may be green, blue, yellow, or white and has long been used as a gemstone. Beryl occurs throughout the world in granite and pegmatites. *Emerald, the green gem variety, occurs more rarely and is of great value. Important sources of

beryl are found in Brazil, Madagascar, and the USA.

beryllate A compound formed in solution when beryllium metal, or the oxide or hydroxide, dissolves in strong alkali. The reaction (for the metal) is often written

$$Be + 2OH^-(aq) \rightarrow BeO_2^{2-}(aq) + H_2(g)$$

The ion BeO_2^{2-} is the beryllate ion. In fact, as with the *aluminates, the ions present are probably hydroxy ions of the type $Be(OH)_4^{2-}$ (the **tetrahydroxoberyllate(II) ion**) together with polymeric ions.

beryllia *See* BERYLLIUM OXIDE.

beryllium Symbol Be. A grey metallic element of *group 2 (formerly IIA) of the periodic table; a.n. 4; r.a.m. 9.012; r.d. 1.85; m.p. 1278°C; b.p. 2970°C. Beryllium occurs as beryl ($3BeO.Al_2O_3.6SiO_2$) and chrysoberyl ($BeO.Al_2O_3$). The metal is extracted from a fused mixture of BeF_2/NaF by electrolysis or by magnesium reduction of BeF_2. It is used to manufacture Be–Cu alloys, which are used in nuclear reactors as reflectors and moderators because of their low absorption *cross section. Beryllium oxide is used in ceramics and in nuclear reactors. Beryllium and its compounds are toxic and can cause serious lung diseases and dermatitis. The metal is resistant to oxidation by air because of the formation of an oxide layer, but will react with dilute hydrochloric and sulphuric acids. Beryllium compounds show high covalent character. The element was isolated independently by F. Wohler and A. A. Bussy in 1828.

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beryllium bronze A hard, strong type of *bronze containing about 2% beryllium, in addition to copper and tin.

beryllium hydroxide A white crystalline compound, $Be(OH)_2$, precipitated from solutions of beryllium salts by adding alkali. Like the oxide, it is amphoteric and dissolves in excess alkali to give *beryllates.

beryllium oxide (beryllia) An insoluble solid compound, BeO; hexagonal; r.d. 3.01; m.p. 2530°C; b.p. 3900°C. It occurs naturally as **bromellite**, and can be made by burning beryllium in oxygen or by the decomposition of beryllium carbonate or hydroxide. It is an important amphoteric oxide, reacting with acids to form salts and with alkalis to form compounds known as *beryllates. Beryllium oxide is used in the production of beryllium and beryllium–copper refractories, transistors, and integrated circuits.

Berzelius, Jöns Jacob (1779–1848) Swedish chemist. After moving to Stockholm he worked with mining chemists and, with them, discovered several elements, including *cerium (1803), *selenium (1817), *lithium (1818), *thorium (1828), and *vanadium (1830). He also worked on atomic weights and electrochemistry and devised the current notation for chemical elements.

Bessel, Friedrich Wilhelm (1784–1846) German astronomer. As an unqualified amateur he catalogued the positions of 50 000 stars and calculated the distance to 61 Cygni from its *parallax. In 1844 he discovered that Sirius is a binary star with a dark companion. Solving the complex mathematics in these studies led him to develop *Bessel functions.

Bessel function A type of function that occurs as a solution to problems involving waves in systems with cylindrical symmetry. Bessel functions have been extensively studied and tabulated and are used in many branches of mathematical physics. They are named after the German astronomer Friedrich Wilhelm Bessel (1784–1846).

Bessemer process A process for converting *pig iron from a *blast furnace into *steel. The molten pig iron is loaded into a refractory-lined tilting furnace (**Bessemer converter**) at about 1250°C. Air is blown into the furnace from the base and *spiegel is added to introduce the correct amount of carbon. Impurities (especially silicon, phosphorus, and manganese) are removed by the converter lining to form a slag. Finally the furnace is tilted so that the molten steel can be poured off. In the modern VLN (very low nitrogen) version of this process, oxygen and steam are blown into the furnace in place of air to minimize the absorption of nitrogen from the air by the steel. The process is named after the British engineer Sir Henry Bessemer (1813–98), who announced it in 1856. *See also* BASIC-OXYGEN PROCESS.

beta adrenoceptor (beta adrenergic receptor) *See* ADRENOCEPTOR.

beta blocker (beta-adrenoceptor antagonist) Any of a group of drugs that bind preferentially to beta *adrenoceptors and hence block their stimulation by the body's own neurotransmitters, adrenaline and noradrenaline. Beta blockers, such as propra-

nolol, oxprenolol, and atenolol, are used to treat disorders of the cardiovascular system, including high blood pressure (hypertension), angina pectoris, and irregularities of heartbeat (arrhythmias). They are also effective in treating anxiety and glaucoma (as eye drops) and in preventing migraine. They tend to dampen the effects of exercise or stress on heart rate, heart output, and blood pressure, as well as improving the oxygenation of the heart muscles. The release of the enzyme *renin from the kidneys is also reduced, leading to an overall fall in arterial blood pressure.

beta decay A type of weak interaction (*see* FUNDAMENTAL INTERACTIONS) in which an unstable atomic nucleus changes into a nucleus of the same nucleon number (*A*) but different proton number (*Z*). There are three types of beta decay: negative beta decay, positive beta decay, and electron capture.
Negative beta decay:

$$^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{Y} + {}^{0}_{-1}\mathrm{e} + {}^{0}_{0}\bar{\nu}$$

A neutron in the nucleus X has decayed into a proton forming a new nucleus Y with the emission of an electron and antineutrino. This process involves a decrease in mass and is energetically favourable; it can also occur outside the nucleus – free neutrons decay with a mean lifetime of about 15 minutes.
Positive beta decay:

$$^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z-1}\mathrm{Y} + {}^{0}_{1}\mathrm{e} + {}^{0}_{0}\nu$$

A proton in the nucleus X transforms into a neutron and a new nucleus Y is formed with the emission of an antimatter electron (positron) and neutrino. This process involves an effective increase in mass for the proton and is not energetically favourable. It cannot occur outside the nucleus – free protons do not undergo this kind of interaction. The process is allowed within the environment of the nucleus because when the nucleus as a whole is taken into account the interaction represents an overall decrease in mass.
Electron capture:

$$^{A}_{Z}\mathrm{X} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{A}_{Z-1}\mathrm{Y} + {}^{0}_{0}\nu$$

A proton in the nucleus X captures an electron from the atomic environment and becomes a neutron, emitting in the process a neutrino. This process also involves an effective increase in mass for the proton and is not energetically favourable; again, it cannot also occur outside the nucleus – free protons do not undergo this kind of interaction. The process is allowed within the environment of the nucleus because, taking into account the whole nucleus, the interaction represents an overall decrease in mass.

beta-iron A nonmagnetic allotrope of iron that exists between 768°C and 900°C.

beta particle An electron or positron emitted during *beta decay. A stream of beta particles is known as **beta radiation**.

betatron A particle *accelerator for producing high-energy electrons (up to 340 MeV) for research purposes, including the production of high-energy X-rays. The electrons are accelerated by electromagnetic induction in a doughnut-shaped (toroidal) ring from which the air has been removed. This type of accelerator was first developed by D. W. Kerst (1911–93) in 1939; the largest such machine, at the University of Illinois, was completed in 1950.

BET isotherm An isotherm that takes account of the possibility that the monolayer in the *Langmuir adsorption isotherm can act as a substrate for further adsorption. The BET isotherm (named after S. Brunauer, P. Emmett, and E. Teller) has the form:

$$V/V_{\mathrm{mon}} = cz/\{(1-z)[1-(1-c)z]\},$$

where $z = p/p^{*}$ (p^{*} is the vapour pressure above a macroscopically thick layer of liquid on the surface), V_{mon} is the volume that corresponds to the surface being covered by a monolayer, V and p are the volume and pressure of the gas respectively, and c is a constant. In the BET isotherm, the isotherm rises indefinitely at high pressures (in contrast to the Langmuir isotherm). It provides a useful approximation over some ranges of pressure but underestimates adsorption for low pressures and overestimates adsorption for high pressures.

Bevatron A colloquial name for the proton *synchrotron at the Berkeley campus of the University of California. It produces energies up to 6 GeV.

BHC *See* BENZENE HEXACHLORIDE.

biaxial crystal *See* DOUBLE REFRACTION.

bicarbonate *See* HYDROGENCARBONATE.

bicarbonate of soda *See* SODIUM HYDROGENCARBONATE.

biceps A muscle that runs along the large bone of the upper arm (*humerus) and is connected to the *radius at one end and the

shoulder bone (*scapula) at the other. Contraction of the biceps causes the arm to flex at the elbow joint (*see* FLEXOR). It works antagonistically with the triceps, which contracts to extend the arm (*see* ANTAGONISM). *See also* VOLUNTARY MUSCLE.

biconcave *See* CONCAVE.

bicuspid valve (mitral valve) A valve, consisting of two flaps, situated between the left atrium and the left ventricle of the heart of birds and mammals. When the left ventricle contracts, forcing blood into the aorta, the bicuspid valve closes the aperture to the left atrium, thereby preventing any backflow of blood. The valve reopens to allow blood to flow from the atrium into the ventricle. *Compare* TRICUSPID VALVE.

biennial A plant that requires two growing seasons to complete its life cycle. During the first year it builds up food reserves, which are used during the second year in the production of flowers and seeds. Examples are carrot and parsnip.

big-bang theory The cosmological theory that all the matter and energy in the universe originated from a state of enormous density and temperature that exploded at a finite moment in the past when space and time came into being. See Feature (pp 86–87).

bilateral symmetry A type of arrangement of the parts and organs of an animal in which the body can be divided into two halves that are mirror images of each other along one plane only (usually passing through the midline at right angles to the dorsal and ventral surfaces). Bilaterally symmetrical animals are characterized by a type of movement in which one end of the body always leads. In botany this type of symmetry is usually called **zygomorphy** when applied to flowers (e.g. foxglove and antirrhinum flowers are zygomorphic). *Compare* RADIAL SYMMETRY.

bile (gall) A bitter-tasting greenish-yellow alkaline fluid produced by the *liver, stored in the *gall bladder, and secreted into the *duodenum of vertebrates. It assists the digestion and absorption of fats by the action of **bile salts**, which chemically reduce fatty substances and decrease the surface tension of fat droplets so that they are broken down and emulsified. Bile may also stimulate gut muscle contraction (*peristalsis). Bile also contains the **bile pigments**, **bilirubin** and **biliverdin**, which are produced by the breakdown of the blood pigment *haemoglobin.

bile duct The tube through which bile passes from the *liver or (when present) the *gall bladder to the duodenum.

bilirubin *See* BILE.

biliverdin *See* BILE.

billion **1.** (in the UK and Germany) One million million, 10^{12}. **2.** (in the USA and France) One thousand million, 10^{9}.

bimetallic strip A strip consisting of two metals of different *expansivity riveted or welded together so that the strip bends on heating. If one end is fixed the other end can be made to open and close an electric circuit, as in a *thermostat.

bimolecular reaction A step in a chemical reaction that involves two molecules. *See* MOLECULARITY.

bimorph cell A device consisting of two plates of piezoelectric material, such as Rochelle salt, joined together so that one expands on the application of a potential difference and the other contracts. The cell thus bends as a result of the applied p.d. The opposite effect is also used, in which the mechanical bending of the cell is used to produce a p.d., as in the crystal microphone and some types of record-player pickups.

binary Describing a compound or alloy formed from two elements.

binary acid An *acid in which the acidic hydrogen atom(s) are bound directly to an atom other than oxygen. Examples are hydrogen chloride (HCl) and hydrogen sulphide (H_2S). Such compounds are sometimes called **hydracids**. *Compare* OXOACID.

binary fission *See* FISSION.

binary notation A number system using only two different digits, 0 and 1. Instead of units, tens, hundreds, etc., as used in the decimal system, digits in the binary notation represent units, twos, fours, eights, etc. Thus one in decimal notation is represented by 0001, two by 0010, four by 0100, and eight by 1000. Because 0 and 1 can be made to correspond to off and on conditions in an electric circuit, the binary notation is widely used in computers.

binary prefixes A set of prefixes for binary powers designed to be used in data pro-

THE BIG-BANG THEORY

b

Newton's work gave a mathematical basis for the universe on a large scale. However, the data available at the time suggested a static unchanging universe. This could not easily be explained in the context of the law of gravitation, since all bodies in the universe attract all other bodies with the force of gravity. Newton realized that there was only one solution to this problem: in a static universe, matter had to be uniformly spread throughout an infinitely large space. In 1826, Heinrich Olbers published a paper containing what is known as *Olbers' paradox; such a universe would lead to a perpetually bright sky on earth.

Space–time

Cosmologists now believe that Newton's model was based on incorrect assumptions about the structure of space, time, and matter. Einstein in his general theory of *relativity (1915) proposed that the universe exists in four-dimensional space–time. This space–time is curved by the presence of matter, and the matter moves by following the resulting curves.

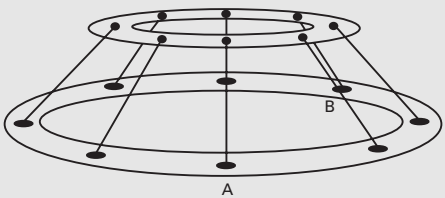
The expanding universe

The discovery by Hubble in 1929 that the universe is expanding provided a starting point for the ideas on which our present understanding of the universe is based. Hubble made his discovery by analysing the *spectra of light from distant galaxies and noting a persistent *red shift, which he explained in terms of the *Doppler effect; an increase in observed wavelengths of light occurs because the light source is receding from the observer. The larger the speed, of recession, the larger the red shifts. Hubble discovered a pattern in his data: the further away the galaxy, the greater the speed of recession. Known as *Hubble's law, this provided the evidence that the universe is expanding and a resolution to Olbers' paradox. If the galaxies and the earth are moving apart, the radiation falling on the earth from the galaxies is reduced. The further galaxies are away from the earth, the smaller their contribution to the radiation falling on the earth.

This model might seem to place the earth at the centre of the universe again. However, it is space itself that is expanding and the galaxies are imbedded in this space. The ring (space) in the diagram has dots (the galaxies). The expansion of the ring means that the view from any one dot is that the other dots are receding at a speed proportional to their distance away. No single dot is at the centre of the system but all dots see the same thing.

Age of the universe

Hubble's law may be stated in the form: $H_0 = v/d$, where v is the speed of recession of the galaxy, d is the earth–galaxy distance, and H_0 is called the **Hubble**



The expansion leads to the recession of B from A along the ring. The speed of recession will be directly proportional to the distance of B from A along the ring.

constant. Assuming that the galaxies have always been moving apart, the age of the universe (T) can be estimated, i.e. $T = 1/H_o$. On this basis the age of the universe would be between 15–18 billion years.

The origin of the universe

This view of the origin of the universe is called the **big-bang theory**, first put forward by Georges Lamaître in the 1930s. The theory suggests that the universe originated as a minute but very hot body and that the temperature has been falling as the expansion has continued. In several papers in the 1940s George Gamow along with Ralph Alpher and Robert Herman predicted that there should be a *microwave background corresponding to a black-body temperature a few degrees above absolute zero. This microwave background was discovered 20 years later. The big-bang theory also explains the amount of helium in the universe.

In 1992, the COBE satellite discovered that there were very small variations in the microwave background. This discovery helped to explain why the universe formed into galaxies and stars. The non-uniformities that began the nucleation of galactic matter in the early universe now appear as the small variations in the microwave background. In 1998 it was discovered that the expansion of the universe is accelerating.

Fundamental forces

It is thought that the four *fundamental interactions in the universe are all manifestations of the same force. This force existed when the big bang, occurred at a temperature above 10^{15}K. As the universe cooled the forces separated as the original symmetries were broken. Gravity was the first to separate, followed by the strong nuclear force, and the weak and electromagnetic forces (see table).

Time from big bang	Temperature (K)	State of the universe/forces
0 second	infinite	The universe is infinitesimally small and infinitely dense (i.e. a mathematical singularity).
10^{-12} second	10^{15}	Weak and electromagnetic forces begin to separate.
10^{-6} second	10^{14}	Quarks and leptons begin to form.
10^{-3} second	10^{12}	Quarks form the hadrons; quark confinement begins.
10^{2} second	10^{7}	Helium nuclei formed by fusion.
10^{5} years	10^{4}	Atomic era; atoms form as protons combine with electrons.
10^{6} years	10^{3}	Matter undergoes gravitational collapse.
.5–1.8 × 10^{10} years	2.7	Present day: cosmic background corresponds to about 2.7K.

The future

Research into the future of the universe is clearly speculative. Whether the universe will continue to expand indefinitely depends on its mean density. Below a critical level (the critical density), gravitational attraction will not be enough to stop the expansion. However, if the mean density is above the critical density the universe is **bound** and an eventual contraction will occur resulting in a **big crunch**. This may precede another big bang initiating the whole cycle again.

cessing and data transmission contexts. They were suggested in 1998 by the International Electrotechnical Commission (IEC) as a way of resolving the ambiguity in use of kilo-, mega-, giga-, etc., in computing. In scientific usage, these prefixes indicate 10^3, 10^6, 10^9, etc. (*see* SI UNITS). In computing, it became common to use the prefix 'kilo-' to mean 2^{10}, so one kilobit was 1024 bits (not 1000 bits). This was extended to larger prefixes, so 'mega-' in computing is taken to be 2^{20} (1 048 576) rather than 10^6 (1 000 000). However, there is a variation in usage depending on the context. In discussing memory capacities megabyte generally means 2^{20} bytes, but in disk storage (and data transmission) megabyte is often taken to mean 10^6 bytes. (In some contexts, as in the capacity of a floppy disk, it has even been quoted as 1 024 000 bytes, i.e. 1000 times a (binary) kilobyte.) The IEC attempted to resolve this confusion by introducing binary prefixes, modelled on the normal decimal prefixes, as follows:

kibi- 2^{10}
mebi- 2^{20}
gebi- 2^{30}
tebi- 2^{40}
pebi- 2^{50}
exbi- 2^{60}

These names are contractions of 'kilobinary', 'megabinary', etc., but are pronounced so that the second syllable rhymes with 'bee'. Using these prefixes, one gebibyte would be 1 073 741 824 bytes and one gigabyte would (unambiguously) be 1 000 000 000 bytes.

binary stars A pair of stars revolving about a common centre of mass. In a **visual binary** the stars are far enough apart to be seen separately by an optical telescope. In an **astrometric binary** one component is too faint to be seen and its presence is inferred from the perturbations in the motion of the other. In a **spectrosopic binary** the stars cannot usually be resolved by a telescope, but the motions can be detected by different Doppler shifts in the spectrum at each side of the binary, according to whether the components are approaching or receding from the observer. *See also* VARIABLE STAR.

binding energy The energy equivalent to the *mass defect when nucleons bind together to form an atomic nucleus. When a nucleus is formed some energy is released by the nucleons, since they are entering a more stable lower-energy state. Therefore the energy of a nucleus consists of the energy equivalent of the mass of its individual nucleons minus the binding energy. The binding energy per nucleon plotted against the mass number provides a useful graph showing that up to a mass number of 50–60, the binding energy per nucleon increases rapidly, thereafter it falls slowly. Energy is released both by fission of heavy elements and by fusion of light elements because both processes entail a rearrangement of nuclei in the lower part of the graph to form nuclei in the higher part of the graph.

binoculars Any optical instrument designed to serve both the observer's eyes at once. **Binocular field glasses** consist of two refracting astronomical *telescopes inside each of which is a pair of prisms to increase the effective length and produce an upright image. Simpler binoculars, such as **opera glasses**, consist of two Galilean telescopes which produce upright images without prisms. Commonly, binoculars are specified by a pair of numbers, such as 10×50. The first number indicates the angular *magnification produced. The second is the diameter of the objective lens in millimetres, and indicates the amount of light gathered by the instrument. **Binocular microscopes** are used in biology and surgery to enable the observer to obtain a stereoscopic view of small objects or parts.

binocular vision The ability, found only in animals with forward-facing eyes, to produce a focused image of the same object simultaneously on the retinas of both eyes. This permits three-dimensional vision and contributes to distance judgment.

binomial distribution The distribution of the number of successes in an experiment in which there are two possible outcomes, success and failure. The probability of k successes is:

$$b(k,n,p) = n!/\,k!(n-k)! \times p^n \times q^{n-k}$$

where p is the probability of success and q ($= 1 - p$) the probability of failure on each trial. These probabilities are given by the terms in the binomial expansion of $(p+q)^n$ (*see* BINOMIAL THEOREM). The distribution has a mean np and variance npq. If n is large and p small it can be approximated by a *Poisson distribution with mean np. If n is large and p is not near 0 or 1, it can be approximated by a *normal distribution with mean np and variance npq. *See also* PASCAL'S DISTRIBUTION.

binomial nomenclature The system of naming organisms using a two-part Latinized (or scientific) name that was devised by the Swedish botanist Linnaeus (Carl Linné); it is also known as the **Linnaean system**. The first part is the generic name (*see* GENUS), the second is the specific epithet or name (*see* SPECIES). The Latin name is usually printed in italics, starting with a capital letter. For example, in the scientific name of the common frog, *Rana temporaria*, *Rana* is the generic name and *temporaria* the specific name. The name of the species may be followed by an abbreviated form of the name of its discoverer; for example, the common daisy is *Bellis perennis* L. (for Linnaeus). There are several International Codes of Taxonomic Nomenclature that lay down the rules for naming organisms. *See also* CLASSIFICATION; TAXONOMY.

binomial theorem (binomial expansion) A rule for the expansion of a binomial expression (expression consisting of the sum of two variables raised to a given power). The general binomial expression $(x + y)^n$ expands to:

$$x^n + nx^{n-1}y + [n(n-1)/2!]x^{n-2}y^2 + \ldots y^n$$

bioaccumulation An increase in the concentration of chemicals, such as *pesticides, in organisms that live in environments contaminated by a wide variety of organic compounds. These compounds are not usually decomposed in the environment (i.e. they are not biodegradable) or metabolized by the organisms, so that their rate of absorption and storage is greater than their rate of excretion. The chemicals are normally stored in fatty tissues. *DDT is known as a **persistent pesticide**, as it is not easily broken down and bioaccumulates along *food chains, so that increasing concentrations occur in individual organisms at each trophic level – a process called **biomagnification**.

bioassay (biological assay) A controlled experiment for the quantitative estimation of a substance by measuring its effect in a living organism. For example, the amount of the plant hormone auxin can be estimated by observing its effect on the curvature of oat coleoptiles – the concentration of the hormone is proportional to the curvature of the coleoptile.

biochemical evolution (molecular evolution) The changes that occur at the molecular level in organisms over a period of time. Brought about by *mutations in genes or chromosomes, it results in functional changes to the proteins encoded by the genes, or even the evolution of novel genes and proteins.

biochemical fuel cell A system that exploits biological reactions for the conversion of biomass (chemical energy) to electricity (electrical energy). One potential application is the generation of electricity from industrial waste and *sewage. **Methyltrophic** organisms (i.e. organisms that use methane or methanol as their sole carbon sources) are being investigated for their potential use in biochemical fuel cells.

biochemical oxygen demand (BOD) The amount of oxygen taken up by microorganisms that decompose organic waste matter in water. It is therefore used as a measure of the amount of certain types of organic pollutant in water. BOD is calculated by keeping a sample of water containing a known amount of oxygen for five days at 20°C. The oxygen content is measured again after this time. A high BOD indicates the presence of a large number of microorganisms, which suggests a high level of pollution.

biochemical taxonomy *See* MOLECULAR SYSTEMATICS.

biochemistry The study of the chemistry of living organisms, especially the structure and function of their chemical components (principally proteins, carbohydrates, lipids, and nucleic acids). Biochemistry has advanced rapidly with the development, from the mid-20th century, of such techniques as chromatography, spectroscopy, X-ray diffraction, radioisotopic labelling, and electron microscopy. Using these techniques to separate and analyse biologically important molecules, the steps of the metabolic pathways in which they are involved (e.g. *glycolysis and the *Krebs cycle) have been determined. This has provided some knowledge of how organisms obtain and store energy, how they manufacture and degrade their biomolecules, how they sense and respond to their environment, and how all this information is carried and expressed by their genetic material. Biochemistry forms an important part of many other disciplines, especially physiology, nutrition, molecular biology, and genetics, and its discoveries have made a profound impact in medicine,

BIOCHEMISTRY

1833	French chemist Anselme Payen (1795–1871) discovers diastase (the first enzyme to be discovered).
1836	Theodor Schwann discovers the digestive enzyme pepsin.
c.1860	Louis Pasteur demonstrates fermentation is caused by 'ferments' in yeasts and bacteria.
1869	German biochemist Johann Friedrich Miescher (1844–95) discovers nucleic acid.
1877	Pasteur's 'ferments' are designated as enzymes.
1890	German chemist Emil Fischer (1852–1919) proposes the 'lock-and-key' mechanism to explain enzyme action.
1901	Japanese chemist Jokichi Takamine (1854–1922) isolates adrenaline (the first hormone to be isolated).
1903	German biologist Eduard Buchner (1860–1917) discovers the enzyme zymase (causing fermentation).
1904	British biologist Arthur Harden (1865–1940) discovers coenzymes.
1909	Russian-born US biochemist Phoebus Levene (1869–1940) identifies ribose in RNA.
1921	Canadian physiologist Frederick Banting (1891–1941) and US physiologist Charles Best (1899–1978) isolate insulin.
1922	Alexander Fleming discovers the enzyme lysozyme.
1925	Russian-born British biologist David Keilin (1887–1963) discovers cytochrome.
1926	US biochemist James Sumner (1877–1955) crystallizes urease (the first enzyme to be isolated).
1929	German chemist Hans Fischer (1881–1945) determines the structure of haem (in haemoglobin).
	K. Lohman isolates ATP from muscle.
1930	US biochemist John Northrop (1891–1987) isolates the stomach enzyme pepsin.
1932	Swedish biochemist Hugo Theorell (1903–82) isolates the muscle protein myoglobin.
1937	Hans Krebs discovers the Krebs cycle.
1940	German-born US biochemist Fritz Lipmann (1899–1986) proposes that ATP is the carrier of chemical energy in many cells.
1943	US biochemist Britton Chance (1913–) discovers how enzymes work (by forming an enzyme–substrate complex).
1952	US biologist Alfred Hershey (1908–97) proves that DNA carries genetic information.
1953	Francis Crick and James Watson discover the structure of DNA.
1955	Frederick Sanger discovers the amino acid sequence of insulin.

1956	US biochemist Arthur Kornberg (1918–2007) discovers the enzyme DNA polymerase.
	US molecular biologist Paul Berg (1926–) identifies the nucleic acid later known as transfer RNA.
1957	British biologist Alick Isaacs (1921–67) discovers interferon.
1959	Austrian-born British biochemist Max Perutz (1914–2002) determines the structure of haemoglobin.
1960	South African-born British molecular biologist Sydney Brenner (1927–) and French biochemist François Jacob (1920–) discover messenger RNA.
1961	British biochemist Peter Mitchell (1920–92) proposes the chemiosmotic theory.
	Brenner and Crick discover that the genetic code consists of a series of base triplets.
1969	US biochemist Gerald Edelman (1929–) discovers the amino acid sequence of immunoglobulin G.
1970	US virologists Howard Temin (1934–94) and David Baltimore (1938–) discover the enzyme reverse transcriptase.
	US molecular biologist Hamilton Smith (1931–) discovers restriction enzymes.
1973	US biochemists Stanley Cohen (1935–) and Herbert Boyer (1936–) use restriction enzymes to produce recombinant DNA.
1977	Sanger determines the complete base sequence of DNA in bacteriophage ϕX174.
1984	British biochemist Alec Jeffreys (1950–) devises DNA profiling.
1985	US biochemist Kary Mullis (1944–) invents the polymerase chain reaction for amplifying DNA.
1986	US pharmacologists Robert Furchgott (1916–2009) and Louis Ignarro (1941–) demonstrate the importance of nitric oxide as a signal molecule in the blood vascular system.
1988	US biochemist Peter Agre (1949–) identifies a water-channel protein (aquaporin) in the plasma membrane of cells.
1994	Beginnings of DNA chip technology.
1998	US biochemist Roderick MacKinnon (1956–) reveals detailed three-dimensional structure of potassium-ion channel in brain cells.
2001	US molecular biologist Harry Noller and colleagues produce first detailed X-ray crystallographic image of a complete ribosome.
2002	First synthetic virus created by Eckard Wimmer and associates, based on human poliovirus.
2004	A team led by David L. Spector produces the first real-time imaging of gene transcription in a living cell, using different fluorescent markers to tag nucleic acids and proteins.

agriculture, industry, and many other areas of human activity. See Chronology.

b

SEE WEB LINKS

- A virtual library of biochemistry, cell biology, and molecular biology

biodegradable *See* POLLUTION.

biodiversity (biological diversity) The existence of a wide variety of species (**species diversity**) or other taxa of plants, animals, and microorganisms in a natural community or habitat, or of communities within a particular environment (**ecological diversity**), or of genetic variation within a species (**genetic diversity**; *see* VARIATION). The maintenance of a high level of biodiversity is important for the stability of ecosystems. Certain habitats, especially rainforests, have a rich species diversity, which is threatened by the continued destruction of habitats (*see* DEFORESTATION; DESERTIFICATION; GREENHOUSE EFFECT). Such ecosystems typically support large numbers of rare species, and population sizes of individual species tend to be small; they are therefore especially vulnerable to habitat destruction. Biodiversity in natural habitats also represents an important pool of species and genetic material of potential use to human societies. For example, wild plants continue to be used as a source of new drugs and other products, and the development of new strains and varieties of crop plants with increased disease resistance usually depends on incorporating genetic material from wild plants.

bioelement Any chemical element that is found in the molecules and compounds that make up a living organism. In the human body the most common bioelements (in decreasing order of occurrence) are oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus. Other bioelements include sodium, potassium, magnesium, and copper. *See* ESSENTIAL ELEMENT.

bioenergetics The study of the flow and the transformations of energy that occur in living organisms. Typically, the amount of energy that an organism takes in (from food or sunlight) is measured and divided into the amount used for growth of new tissues; that lost through death, wastes, and (in plants) transpiration; and that lost to the environment as heat (through respiration).

bioengineering **1.** The use of artificial tissues, organs, and organ components to replace parts of the body that are damaged, lost, or malfunctioning, e.g. artificial limbs, heart valves, and heart pacemakers. *See also* TISSUE ENGINEERING. **2.** The application of engineering knowledge to medicine and zoology.

biofeedback The technique whereby a subject can learn to control certain body functions, such as heart rate or blood pressure, that are usually unconsciously regulated by the autonomic nervous system. It is facilitated by the use of monitoring devices, such as pulse monitors, electroencephalographs, and electromyographs, and can be useful in treating high blood pressure, migraine, epilepsy, and other disorders.

biofilm A colony of bacteria and other microorganisms that adheres to a substrate and is enclosed and protected by secreted slime. Biofilms readily form on virtually any surface, whether nonliving or living, where there is moisture and a supply of nutrients. They are important components of aquatic and terrestrial ecosystems, typically providing nutrients for small organisms at the base of food chains. Moreover, they form in the microenvironment (*rhizosphere) surrounding plant roots, where they assist the plant in absorbing nutrients from the soil. Biofilms can also occur in the body and in industrial installations, for example, on the surface of teeth (as dental plaque) or inside pipelines.

biofuel A gaseous, liquid, or solid fuel that contains an energy content derived from a biological source. The organic matter that makes up living organisms provides a potential source of trapped energy that is increasingly being exploited to supply worldwide energy demand. Biofuels are claimed to have a lower carbon footprint than fossil fuels and thus contribute less to the greenhouse effect. An example of a biofuel is rapeseed oil, which can be used in place of diesel fuel in modified engines. The methyl ester of this oil, **rapeseed methyl ester** (**RME**), can be used in unmodified diesel engines and is sometimes known as **biodiesel**. Other biofuels include *biogas and *gasohol.

biogas A mixture of methane and carbon dioxide resulting from the anaerobic decomposition of such waste materials as domestic, industrial, and agricultural sewage. The decomposition is carried out by methanogenic bacteria (*see* METHANOGEN); these obligate anaerobes produce methane, the main component of biogas, which can be collected and used as an energy source for

domestic processes, such as heating, cooking, and lighting. The production of biogas is carried out in special **digesters**, which are widely used in China and India. As well as providing a source of fuel, these systems also enable *sewage, which contains pathogenic bacteria, to be digested, thereby removing the danger to humans that could otherwise result from untreated domestic and agricultural waste.

biogenesis The principle that a living organism can only arise from other living organisms similar to itself (i.e. that like gives rise to like) and can never originate from nonliving material. *Compare* SPONTANEOUS GENERATION.

biogeochemical cycle (nutrient cycle) The cyclical movement of elements between living organisms (the biotic phase) and their nonliving (abiotic) surroundings (e.g. rocks, water, air). Examples of biogeochemical cycles are the *carbon cycle, *nitrogen cycle, *oxygen cycle, *phosphorus cycle, and *sulphur cycle.

biogeography The branch of biology that deals with the geographical distribution of plants and animals. *See* PLANT GEOGRAPHY; ZOOGEOGRAPHY.

bioinformatics The collection, storage, and analysis of DNA- and protein-sequence data using computerized systems. The data generated by genome projects and protein studies are held in various databanks and made available to researchers throughout the world via the Internet. Many computer programs have been developed to analyse sequence data, enabling the user to identify similarities between newly sequenced material and existing sequences. This allows, for example, predictions about the structure and function of a protein from its amino-acid sequence data or from the nucleotide sequence of its gene. Also, genome-wide sequence analysis allows comparisons to be made between genomes of different species, which provides information about their possible evolutionary relationships. *See also* GENOMICS.

bioinorganic chemistry Biochemistry involving compounds that contain metal atoms or ions. Two common examples of bioinorganic compounds are haemoglobin (which contains iron) and chlorophyll (which contains magnesium). Many enzymes contain metal atoms and bioinorganics are important in a number of biochemical processes, including oxygen transport, electron transfer, and protein folding.

biological clock The mechanism, presumed to exist within many animals and plants, that produces regular periodic changes in behaviour or physiology. Biological clocks underlie many of the *biorhythms seen in organisms (e.g. the sleep–wake cycle, hibernation in animals). They continue to run even when conditions are kept artificially constant, but eventually drift out of step with the natural environment without the specific signals that normally keep them synchronized. Studies in the fruit fly *Drosophila* have revealed the molecular basis of the biological clock, and similar mechanisms are thought to occur in other animals, including mammals, and in plants, fungi, and cyanobacteria.

biological control The control of *pests by biological (rather than chemical) means. This may be achieved, for example, by breeding disease-resistant crops or by introducing a natural enemy of the pest, such as a predator or a parasite. This technique, which may offer substantial advantages over the use of pesticides or herbicides, has been employed successfully on a number of occasions. Examples include the control of the prickly pear cactus (*Opuntia*) in Australia by introducing the cactus moth (*Cactoblastis cactorum*), whose caterpillars feed on the plant's growing shoots, and the use of the ladybird to prey upon the scale insect (*Icerya*), which kills citrus fruit trees. Insect pests have also been subjected to genetic control, by releasing large numbers of males of the pest species that have been sterilized by radiation: infertile matings subsequently cause a decline in the pest population. This method has been used to control the screw worm fly (*Cochliomyia hominivora*), which lays its eggs in the open wounds of domestic cattle. Biological control is considered to reduce a number of the problems associated with chemical control using *pesticides, but care should be taken to avoid upsetting the natural ecological balance; for example, a particular predator may also destroy harmless or beneficial species.

biological rhythm *See* BIORHYTHM.

biological warfare The military use of microorganisms, such as bacteria, viruses, fungi, and other microorganisms, including the agents for anthrax and botulism, to in-

duce disease or death among humans, livestock, and crop plants. Though officially banned in most countries, research continues with the aim of developing virulent strains of existing microorganisms, using genetic engineering and other techniques.

biology The study of living organisms, which includes their structure (gross and microscopical), functioning, origin and evolution, classification, interrelationships, and distribution.

SEE WEB LINKS

- This University of Arizona website contains useful links to various fields of biology, including biochemistry, cell biology, and human biology

bioluminescence The emission of light without heat (*see* LUMINESCENCE) by living organisms. The phenomenon occurs in glow-worms and fireflies, bacteria and fungi, and in many deep-sea fish (among others); in animals it may serve as a means of protection (e.g. by disguising the shape of a fish) or species recognition or it may provide mating signals. The light is produced during the oxidation of a compound called **luciferin** (the composition of which varies according to the species), the reaction being catalysed by an enzyme, **luciferase**. Fience may be continuous (e.g. in bacteria) or intermittent (e.g. in fireflies).

biomass The total mass of all the organisms of a given type and/or in a given area; for example, the world biomass of trees, or the biomass of elephants in the Serengeti National Park. It is normally measured in terms of grams of *dry mass per square metre. *See also* PYRAMID OF BIOMASS.

biome A major ecological community or complex of communities that extends over a large geographical area characterized by a dominant type of vegetation. The organisms of a biome are adapted to the climate conditions associated with the region. There are no distinct boundaries between adjacent biomes, which merge gradually with each other. Examples of biomes are *tundra, tropical *rainforest, *taiga, *grassland (temperate and tropical), and *desert.

biomechanics The application of the principles of *mechanics to living systems, particularly those living systems that have coordinated movements. Biomechanics also deals with the properties of biological materials, such as blood and bone. For example, biomechanics would be used to analyse the stresses on bones in animals, both when the animals are static and when they are moving. Other types of problems in biomechanics include the *fluid mechanics associated with swimming in fish and the *aerodynamics of birds flying. It is sometimes difficult to perform realistic calculations in biomechanics because of complexity in the shape of animals or the large number of *degrees of freedom that need to be considered (for example, the large number of muscles involved in the movement of a human leg).

biomolecule Any molecule that is involved in the maintenance and metabolic processes of living organisms (*see* METABOLISM). Biomolecules include carbohydrate, lipid, protein, nucleic acid, and water molecules; some biomolecules are *macromolecules.

biophysics The study of the physical aspects of biology, including the application of physical laws and the techniques of physics to study biological phenomena. *See also* PHYSICS.

SEE WEB LINKS

- The website of the Biophysical Society

biopoiesis The development of living matter from complex organic molecules that are themselves nonliving but self-replicating. It is the process by which life is assumed to have begun. *See* ORIGIN OF LIFE.

biopolymer A polymer that occurs naturally, such as a *polysaccharide, *protein, or *nucleic acid.

bioreactor (industrial fermenter) A large stainless steel tank used to grow producer microorganisms in the industrial production of enzymes and other chemicals. After the tank is steam-sterilized, an inoculum of the producer cells is introduced into a medium that is maintained by probes at optimum conditions of temperature, pressure, pH, and oxygen levels for enzyme production. An **agitator** (stirrer) mixes the medium, which is constantly aerated. It is essential that the culture medium is sterile and contains the appropriate nutritional requirements for the microorganism. When the nutrients have been utilized the product is separated; if the product is an extracellular compound the medium can be removed during the growth phase of the microorganisms, but an intracellular product must be harvested when the batch culture growth stops. Some bioreactors are designed for *continuous culture.

biorhythm (biological rhythm) A roughly periodic change in the behaviour or physiology of an organism that is generated and maintained by a *biological clock. Well-known examples are the *annual and *circadian rhythms occurring in many animals and plants. **Infradian rhythms**, occurring in many cellular processes, have a periodicity of less than 24 hours. An example of an **ultradian rhythm**, with a periodicity greater than a day, is the reproductive cycle of many animals that corresponds with the 29.5-day lunar cycle.

biosensor A device that uses an immobilized agent to detect or measure a chemical compound. The agents include enzymes, antibiotics, organelles, or whole cells. A reaction between the immobilized agent and the molecule being analysed is transduced into an electronic signal. This signal may be produced in response to the presence of a reaction product, the movement of electrons, or the appearance of some other factor (e.g. light). Biosensors are used in diagnostic tests: these allow quick, sensitive, and specific analysis of a wide range of biological products, including antibiotics, vitamins, and other important biomolecules (such as glucose), as well as the determination of certain *xenobiotics, such as synthetic organic compounds.

biosphere The whole of the region of the earth's surface, the sea, and the air that is inhabited by living organisms.

biostratigraphy The characterization of rock strata on the basis of the fossils they contain. *See also* STRATIGRAPHY.

biosynthesis The production of molecules by a living cell, which is the essential feature of *anabolism.

biosystematics *See* SYSTEMATICS.

biotechnology The development of techniques for the application of biological processes to the production of materials of use in medicine and industry. For example, the production of antibiotics, cheese, and wine rely on the activity of various fungi and bacteria. *Genetic engineering can modify bacterial cells to synthesize completely new substances, e.g. hormones, vaccines, *monoclonal antibodies, etc., or introduce novel traits into plants or animals. *See also* GENETICALLY MODIFIED ORGANISMS (Feature).

biotic factor Any of the factors of an organism's environment that consist of other living organisms and together make up the **biotic environment**. These factors may affect an organism in many ways; for example, as competitors, predators, parasites, prey, or symbionts. In time, the distribution and abundance of the organism will be affected by its interrelationships with the biotic environment. *Compare* ABIOTIC FACTOR.

biotin A vitamin in the *vitamin B complex. It is the *coenzyme for various enzymes that catalyse the incorporation of carbon dioxide into various compounds. Adequate amounts are normally produced by the intestinal bacteria in animals although deficiency can be induced by consuming large amounts of raw egg white. This contains a protein, avidin, that specifically binds biotin, preventing its absorption from the gut. Other sources of biotin include cereals, vegetables, milk, and liver.

biotite An important rock-forming silicate mineral, a member of the *mica group of minerals, in common with which it has a sheetlike crystal structure. It is usually black, dark brown, or green in colour.

bipolar outflow A type of stellar wind (*see* SOLAR WIND) that leaves a star mainly from its poles. Such outflows are commonest in protostars, pre-main-sequence stars and red giants, and account for a great loss of stellar mass. They may take the form of radio-emitting molecules or long visible jets of gaseous material. It is thought that a disc of dense gas around the star's equatorial regions prevents the outflow of material elsewhere.

biprism A glass prism with an obtuse angle that functions as two acute-angle prisms placed base-to-base. A double image of a single object is thus formed; the device was used by Fresnel to produce two coherent beams for interference experiments.

bipyramid *See* COMPLEX.

birds *See* AVES.

birefringence *See* DOUBLE REFRACTION.

Birkeland–Eyde process A process for the fixation of nitrogen by passing air through an electric arc to produce nitrogen oxides. It was introduced in 1903 by the Norwegian chemists Kristian Birkeland (1867–1913) and Samuel Eyde (1866–1940). The process is economic only if cheap hydroelectricity is available.

birth *See* PARTURITION.

birth control (contraception) The intentional avoidance of pregnancy by methods that do not normally hinder sexual activity. The methods used can be 'natural' or 'artificial'. Natural methods, often used because of religious or moral objections to artificial methods, include the **rhythm method**, in which sexual intercourse is avoided during times when ovulation occurs; and **coitus interruptus**, an unreliable method in which the penis is withdrawn from the vagina before ejaculation. The rhythm method requires a monitoring of the woman's menstrual cycle and may be unsuitable in those women with irregular cycles. Artificial methods use devices or other agents (**contraceptives**) to prevent pregnancy. They include the **condom**, a rubber sheath placed over the penis to trap the sperm; and the **diaphragm**, a rubber cap placed over the cervix. Contraceptives that prevent *implantation include the **intrauterine device** (**IUD**), a metal or plastic coil placed in the uterus by a doctor (which may cause unacceptable bleeding in some women); and the 'morning-after pill', taken within three days after sexual intercourse. Other *oral contraceptives prevent ovulation. *Sterilization is usually considered to be irreversible but attempts at reversing the process are possible. For casual relationships, or relationships involving a partner whose sexual history is not known, health workers advise the use of condoms with all other forms of contraception as this provides the safest means of reducing the risk of infection by *sexually transmitted diseases.

birth rate (natality) The rate at which a particular species or population produces offspring. The birth rate of a species is used to measure its fecundity (reproductive capability). It is also an important factor in controlling the size of a population. *Compare* DEATH RATE.

bisexual (in biology) *See* HERMAPHRODITE.

bismuth Symbol Bi. A white crystalline metal with a pinkish tinge belonging to *group 15 (formerly VB) of the periodic table; a.n. 83; r.a.m. 208.98; r.d. 9.78; m.p. 271.3°C; b.p. 1560°C. The most important ores are bismuthinite (Bi_2S_3) and bismite (Bi_2O_3). Peru, Japan, Mexico, Bolivia, and Canada are major producers. The metal is extracted by carbon reduction of its oxide. Bismuth is the most diamagnetic of all metals and its thermal conductivity is lower than any metal except mercury. The metal has a high electrical resistance and a high Hall effect when placed in magnetic fields. It is used to make low-melting-point casting alloys with tin and cadmium. These alloys expand on solidification to give clear replication of intricate features. It is also used to make thermally activated safety devices for fire-detection and sprinkler systems. More recent applications include its use as a catalyst for making acrylic fibres, as a constituent of malleable iron, as a carrier of uranium–235 fuel in nuclear reactors, and as a specialized thermocouple material. Bismuth compounds (when lead-free) are used for cosmetics and medical preparations. It is attacked by oxidizing acids, steam (at high temperatures), and by moist halogens. It burns in air with a blue flame to produce yellow oxide fumes. C. G. Junine first demonstrated that it was different from lead in 1753.

SEE WEB LINKS

- Information from the WebElements site

bisphosphonates (diphosphonates) A class of medical drugs used in the treatment of osteoporosis and other conditions that involve fragile bones. The bisphosphonates attack osteoclasts (i.e. the bone cells that break down bone tissue). The general formula is $O_3P–C(R^1R^3)–PO_3$. The side chain R^1 is a simple group (–H, –OH, –Cl). R^2 is usually a longer chain (e.g. $–S–C_6H_4–Cl$ or $–(CH_2)_5–NH_2$).

bistability *See* OSCILLATING REACTION.

bistable circuit *See* FLIP-FLOP.

bisulphate *See* HYDROGENSULPHATE.

bisulphite *See* HYDROGENSULPHITE; ALDEHYDES.

bit (binary digit) Either of the digits 0 or 1 as used in the *binary notation. Bits are therefore the basic unit of information in a computer system.

bite angle *See* CHELATE.

Bitnet A computer network originally linking IBM mainframe systems located in North America and with backing from IBM. The network has been substantially extended to other parts of the world, usually on a region-by-region basis, and has been implemented on other computer systems. Complete messages of any length are transmitted from one

computer system to the next, until the destination is reached.

bittern The solution of salts remaining when sodium chloride is crystallized from sea water.

Bitter pattern A microscopic pattern that forms on the surface of a ferromagnetic material that has been coated with a colloidal suspension of small iron particles. The patterns outline the boundaries of the magnetic domains (*see* MAGNETISM). They were first observed by F. Bitter in 1931.

bitumen *See* PETROLEUM.

bituminous coal *See* COAL.

bituminous sand *See* OIL SAND.

biuret test A biochemical test to detect proteins in solution, named after the substance **biuret** ($H_2NCONHCONH_2$), which is formed when urea is heated. Sodium hydroxide is mixed with the test solution and drops of 1% copper(II) sulphate solution are then added slowly. A positive result is indicated by a violet ring, caused by the reaction of *peptide bonds in the proteins or peptides. Such a result will not occur in the presence of free amino acids.

bivalent **1.** (in chemistry) **(divalent)** Having a valency of two. **2.** (in genetics) *See* PAIRING.

Bivalvia (Pelecypoda; Lamellibranchia) A class of aquatic molluscs (the bivalves) that include the oysters, mussels, and clams. They are characterized by a laterally flattened body and a shell consisting of two hinged valves (i.e. a bivalved shell). The enlarged gills are covered with cilia and have the additional function of filtering microscopic food particles from the water flowing over them. Bivalves live on the sea bed or lake bottom and are sedentary, so the head and foot are reduced.

Black, Joseph (1728–99) British chemist and physician, born in France. He studied at Glasgow and Edinburgh, where his thesis (1754) contained the first accurate description of the chemistry of carbon dioxide. In 1757 he discovered latent heat, and was the first to distinguish between heat and temperature.

black body A hypothetical body that absorbs all the radiation falling on it. It thus has an *absorptance and an *emissivity of 1. While a true black body is an imaginary concept, a small hole in the wall of an enclosure at uniform temperature is the nearest approach that can be made to it in practice.

Black-body radiation is the electromagnetic radiation emitted by a black body. It extends over the whole range of wavelengths and the distribution of energy over this range has a characteristic form with a maximum at a certain wavelength. The position of the maximum depends on temperature, moving to shorter wavelengths with increasing temperature. *See* STEFAN'S LAW; WIEN'S DISPLACEMENT LAW.

blackdamp (choke damp) Air left depleted in oxygen following the explosion of firedamp in a mine.

black dwarf A cold celestial object thought to be the remains of a dead star of low mass, that is formed after a *white dwarf star has radiated away all of its heat energy. Black dwarfs are extremely difficult to detect, and because white dwarfs take so long to cool down, it is possible that the universe may not yet be old enough for any black dwarfs to have formed.

black earth *See* CHERNOZEM.

black hole An object in space that has collapsed under its own gravitational forces to such an extent that its *escape velocity is equal to the speed of light. Black holes are believed to be formed in the gravitational collapse of massive stars at the ends of their lives (*see* STELLAR EVOLUTION; SUPERNOVA). If the mass of an evolved stellar core is greater than the analogue of the Chandrasekhar limit for neutron stars then neutron degeneracy pressure is unable to prevent contraction until the gravitational field is sufficiently strong to prevent the escape of electromagnetic radiation. The boundary of the black hole, which is known as the **event horizon**, is the surface in space at which the gravitational field reaches this critical value. Events occurring within this horizon (i.e. in the interior of the black hole) cannot be observed from outside.

The theoretical study of black holes involves the use of general *relativity. It has been shown that a black hole can be characterized uniquely by just three properties: its mass, angular momentum, and electrical charge (this is known as the no-hair theorem). Mathematical expressions have been derived for describing black holes; these are the **Schwarzschild solution** (uncharged nonrotating hole), the **Reissner–Nordstrøm**

solution (charged nonrotating hole), the **Kerr solution** (uncharged rotating hole), and the **Kerr–Newman solution** (charged rotating hole).

The ultimate fate of matter inside the black hole's event horizon is as yet unknown. General relativity predicts that at the centre of the hole there is a **singularity**, a point at which the density becomes infinite and the presently understood laws of physics break down. It is possible that a successful quantum theory of gravity could resolve this problem. However, since any singularity is hidden within the event horizon, it cannot influence the outside universe, so the normal laws of physics, including general relativity, can be used to describe processes outside the black hole.

Observational evidence of objects thought to be black holes comes from their effect on surrounding matter. Thus, if a black hole is part of a binary system with another star it will attract and capture matter from this star. The material leaving the star first forms a rotating **accretion disc** around the black hole, in which the matter becomes compressed and heated to such an extent that it emits X-rays. In the constellation Cygnus there is an X-ray source, Cygnus X-1, which consists of a supergiant star revolving around a small invisible companion with a mass of about ten times that of the sun, and therefore well above the Chandrasekhar limit. The companion is thought to be a black hole. Black holes have also been postulated as the power sources of *quasars and as possible generators of *gravitational waves. It appears that there may be very large black holes at the centres of all galaxies. It has been suggested that black-hole formation could be the cause of gamma-ray bursts, either by one dead star collapsing or by two neutron stars spiralling into each other.

Theoreticians have also postulated the existence of 'mini' black holes (with masses of about 10^{12} kilograms and radii about 10^{-15} metre). Such entities might have been formed shortly after the big bang when the universe was created. Quantum-mechanical effects are important for mini black holes, which emit Hawking radiation (*see* HAWKING PROCESS). *See also* SCHWARZSCHILD RADIUS.

SEE WEB LINKS

- A NASA website with information about black holes

black lead *See* CARBON.

bladder **1.** (in anatomy) **a.** A hollow muscular organ in most vertebrates, also known as the **urinary bladder**, in which urine is stored before being discharged. In mammals urine is conveyed from the *kidneys to the bladder by the *ureters and is discharged to the outside through the *urethra. **b.** Any of various other saclike organs in animals for the storage of liquid or gas. *See* GALL BLADDER; SWIM BLADDER. **2.** (in botany) **a.** A modified submerged leaf of certain aquatic insectivorous plants, such as the bladderwort (*Utricularia*). It forms a hollow with a single opening that is sealed by a valve to trap small aquatic invertebrates after they have been sucked in. **b.** An air-filled cavity in the thallus of certain seaweeds, such as the bladderwrack (*Fucus vesiculosus*).

blanc fixe *See* BARIUM SULPHATE.

Blandford–Znajek process An astrophysical process in which an external magnetic field is able to 'tap' the rotational energy of a rotating black hole, thereby making the black hole a powerful source of energy. There is some evidence that the process occurs around certain types of black hole. It was proposed by Roger Blandford and Roman Znajek in 1977. *See also* PENROSE PROCESS.

blast furnace A furnace for smelting iron ores, such as haematite (Fe_2O_3) or magnetite (Fe_3O_4), to make *pig iron. The furnace is a tall refractory-lined cylindrical structure that is charged at the top with the dressed ore (*see* BENEFICIATION), coke, and a flux, usually limestone. The conversion of the iron oxides to metallic iron is a reduction process in which carbon monoxide and hydrogen are the reducing agents. The overall reaction can be summarized thus:

$$Fe_3O_4 + 2CO + 2H_2 \rightarrow 3Fe + 2CO_2 + 2H_2O$$

The CO is obtained within the furnace by blasting the coke with hot air from a ring of tuyeres about two-thirds of the way down the furnace. The reaction producing the CO is:

$$2C + O_2 \rightarrow 2CO$$

In most blast furnaces hydrocarbons (oil, gas, tar, etc.) are added to the blast to provide a source of hydrogen. In the modern **direct-reduction process** the CO and H_2 may be produced separately so that the reduction process can proceed at a lower temperature. The pig iron produced by a blast furnace contains about 4% carbon and fur-

ther refining is usually required to produce steel or cast iron.

blasting gelatin A high explosive made from nitroglycerine and gun cotton (cellulose nitrate).

blastocoel *See* BLASTULA.

blastocyst *See* BLASTULA; IMPLANTATION.

blastula The stage of *development of an animal embryo that results from *cleavage of a fertilized egg. This stage generally resembles a hollow ball with the dividing cells (**blastomeres**) of the embryo forming a layer (**blastoderm**) around a central cavity (**blastocoel**). Insect eggs have no blastula. In vertebrates the blastula forms a disc (**blastodisc**) on the surface of the yolk. In mammals the blastula stage is known as a **blastocyst**. *See also* GASTRULA.

blazar A very active type of galaxy, named from a combination of *BL* Lacertae object and qu*asar*. Its light output varies greatly, perhaps caused by jets of gas expelled from the nucleus of the galaxy at speeds approaching the speed of light. This effect is known as relativistic beaming and if it is directed towards the earth, it is seen as violent fluctuations in radiation.

bleaching powder A white solid regarded as a mixture of calcium chlorate(I), calcium chloride, and calcium hydroxide. It is prepared on a large scale by passing chlorine gas through a solution of calcium hydroxide. Bleaching powder is sold on the basis of available chlorine, which is liberated when it is treated with a dilute acid. It is used for bleaching paper pulps and fabrics and for sterilizing water.

blende A naturally occurring metal sulphide, e.g. zinc blende ZnS.

blending inheritance The early theory that assumed that hereditary substances from parents merge together in their offspring. Mendel showed that this does not occur (*see* MENDEL'S LAWS). In breeding experiments an appearance of blending may result from codominant alleles (*see* CODOMINANCE) and *quantitative inheritance but close study shows that the alleles retain their identity through successive generations. *Compare* PARTICULATE INHERITANCE.

blind spot The portion of the retina at which blood vessels and nerve fibres enter the optic nerve. There are no rods or cones in this area, so no visual image can be transmitted from it.

block *See* PERIODIC TABLE.

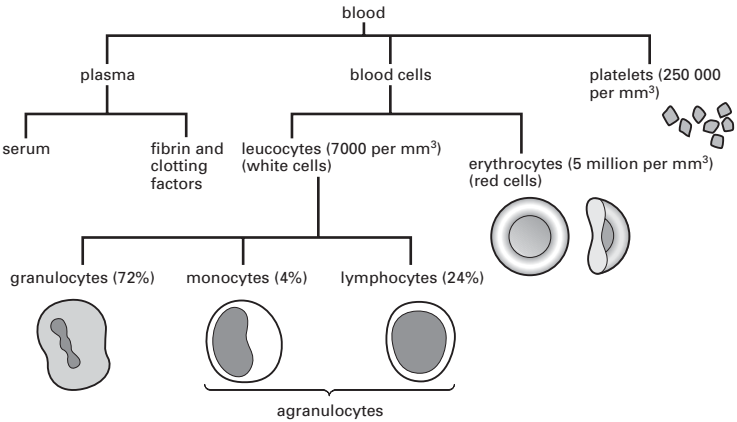
block copolymer *See* POLYMER.

blog (Web log) A publicly accessible journal maintained on the Web by an individual or group. The topics covered in a blog are dictated by the author and so vary widely: some reflect personal interests and concerns, whereas others comment on aspects of current affairs or discuss work of public interest that their author is engaged in. Some have become respected sources of information or opinion, while others are vehicles for corporations or other bodies to disseminate information and obtain feedback. Many blogs include facilities for readers to post comments and to engage in debate; in this function they have tended to replace earlier forms of online discussion, such as Usenet and forums run by online service providers. It is very easy to create and maintain a blog, using freely available software and services, that can be read using a standard Web Browser; and blogs can contain links to other blogs, forming an extended online community. The term 'blog' was only coined in 1997, yet by the mid-2000s blogging had become a mainstream activity not confined only to Internet enthusiasts.

blood A fluid body tissue that acts as a transport medium within an animal. It is contained within a blood *vascular system and in vertebrates is circulated by means of contractions of the *heart. Oxygen and food are carried to tissues, and carbon dioxide and chemical (nitrogenous) waste are transported from tissues to excretory organs for disposal (*excretion). In addition blood carries *hormones and also acts as a defence system. Blood consists of a liquid (*see* BLOOD PLASMA) containing blood cells (*see* ERYTHROCYTE; LEUCOCYTE) and *platelets (see illustration overleaf).

blood–brain barrier The mechanism that controls the passage of substances from the blood to the cerebrospinal fluid bathing the brain and spinal cord. It takes the form of a semipermeable lipid membrane permitting the passage of solutions but excluding particles and large molecules. This barrier provides the central nervous system with a constant environment, while not interfering with the transport of essential metabolites.

blood capillary *See* CAPILLARY.



Blood. Composition of mammalian blood.

blood cell (blood corpuscle) Any of the cells that are normally found in the blood plasma. These include red cells (*see* ERYTHROCYTE) and white cells (*see* LEUCOCYTE).

blood clotting (blood coagulation) The production of a mass of semisolid material at the site of an injury that closes the wound, helping to prevent further blood loss and bacterial invasion. The clot is formed by the action of *clotting factors and *platelets. Damage to tissue triggers a series of reactions involving **thromboplastin** (a glycoprotein), calcium ions, phospholipids (from platelets), and clotting factors, which results in the conversion of *prothrombin in the blood to its enzymically active form **thrombin**. Thrombin catalyses the formation of the insoluble protein **fibrin** from soluble **fibrinogen**; the fibrin forms a fibrous network in which blood cells become enmeshed, producing a clot.

blood groups The many types into which an individual's blood may be classified, based on the presence or absence of certain antigenic proteins (*agglutinogens) on the surface of the red blood cells. Blood of one group contains *antibodies in the serum that react against the agglutinogens on the cells of other groups. **Incompatibility** between groups results in clumping of cells (*agglutination), so knowledge of blood groups is important for blood transfusions. In man, the two most important blood group systems are the *ABO system and the system involving the *rhesus factor.

blood plasma The liquid part of the *blood (i.e. excluding blood cells). It consists of water containing a large number of dissolved substances, including proteins, salts (especially sodium and potassium chlorides and bicarbonates), food materials (glucose, amino acids, fats), hormones, vitamins, and excretory materials. *See also* BLOOD SERUM; LYMPH.

blood platelet *See* PLATELET.

blood pressure The pressure exerted by the flow of blood through the major arteries of the body. This pressure is greatest during the contraction of the ventricles of the heart (**systolic pressure**; *see* SYSTOLE), which forces blood into the arterial system. Pressure falls to its lowest level when the heart is filling with blood (**diastolic pressure**; *see* DIASTOLE). Blood pressure is measured in millimetres of mercury using an instrument called a **sphygmomanometer**. Normal blood pressure for a young average adult human is in the region of 120/80 mmHg (the higher number is the systolic blood pressure; the lower number the diastolic blood pressure), but individual variations are common. Abnormally high blood pressure (**hypertension**) may be associated with disease or it may occur without an apparent cause.

blood serum Blood plasma from which the fibrin and clotting factors have been removed by centrifugation or vigorous stirring, so that it cannot clot. Serum containing a specific antibody or antitoxin may be used in

the treatment or prevention of certain infections. Such serum is generally derived from a nonhuman mammal (e.g. a horse).

blood vascular system The tissues and organs of an animal that transport blood through the body. In vertebrates it consists of the heart and blood vessels. *See* VASCULAR SYSTEM.

blood vessel A tubular structure through which the blood of an animal flows. *See* ARTERY; ARTERIOLE; CAPILLARY; VENULE; VEIN.

blooming The process of depositing a transparent film of a substance, such as magnesium fluoride, on a lens to reduce (or eliminate) the reflection of light at the surface. The film is about one quarter of a wavelength thick and has a lower *refractive index than the lens. The anti-reflection effect is achieved by destructive interference.

blue-green bacteria *See* CYANOBACTERIA.

blueshift A general displacement of spectral lines toward the blue (shorter-wavelength) end of the spectrum. It is a manifestation of the *Doppler effect and is observed in the spectra of celestial objects that are approaching the earth. *Compare* REDSHIFT.

Bluetooth A wireless technology designed to replace cables between cell phones, laptops, and other devices. Bluetooth wireless technology works within a 1-, 10-, or 100-meter range and uses the 2.4 GHz band, which is unlicensed and can be used by many other types of devices, such as cordless phones and baby monitors.

blue vitriol *See* COPPER(II) SULPHATE.

Blu-ray An optical disk format. Developed by a consortium of over 180 companies led by Sony, Blu-ray disks are intended to supersede the *DVD both for the distribution of video and for data storage – they can hold up to 25 Gb on each of up to two layers. Blu-ray achieves this greater capacity by using a 'blue' (actually, a violet) laser rather than the red laser used for DVDs; the shorter wavelength allows the beam to be focused more precisely and so more data to be packed into a given space. Currently (2009) some high-definition DVDs have been released in Blu-ray format, and computer Blu-ray drives are becoming available.

B lymphocyte *See* B CELL.

B-meson Symbol B^0. A meson that consists of a down quark and an anti-bottom quark. It is electrically neutral, has spin zero, and a mass of 5.279 GeV. The antiparticle consists of a bottom quark and an anti-down quark. It is hoped that study of the decays of B-mesons will shed light on the problem of CP violation (*see* CP INVARIANCE).

boat conformation *See* CONFORMATION.

BOD *See* BIOCHEMICAL OXYGEN DEMAND.

Bode, Johann Elert (1747–1826) German astronomer, who became director of the Berlin Observatory. In 1766 his compatriot Johann Titius had discovered an apparently coincidental mathematical relationship involving the distances of the planets from the sun. If 4 is added to each number in the series 0, 3, 6, 12, 24,… and the answers divided by 10, the resulting sequence gives the distances of the planets in astronomical units (earth = 1). Known now as **Bode's law**, or the Titius-Bode law, the formula breaks down after Saturn.

body cavity The internal cavity of the body of an animal, which is present in most invertebrates and all vertebrates and contains the major organs. The body cavity of vertebrates and many invertebrates is the *coelom. In vertebrates the body cavity is divided by a transverse septum just posterior to the heart into the abdominal and thoracic cavities (*see* ABDOMEN; THORAX). In mammals the septum is the *diaphragm.

body-centred cubic (b.c.c.) *See* CUBIC CRYSTAL.

body fluid Any of the fluids found within animals, including blood, lymph, tissue fluid, urine, bile, sweat, and synovial fluid. Body fluids are generally involved with the processes of transport, excretion, or lubrication. They allow the distribution of oxygen and nutrients to the tissues and organs and the transport of waste products from the tissues, enabling their elimination from the body.

boehmite A mineral form of a mixed aluminium oxide and hydroxide, AlO.OH. It is named after the German scientist J. Böhm. *See* ALUMINIUM HYDROXIDE.

Bohr, Niels Henrik David (1885–1962) Danish physicist. In 1913 he published his explanation of how atoms, with electrons orbiting a central nucleus, achieve stability by assuming that their angular momentum is

quantized. Movement of electrons from one orbit to another is accompanied by the absorption or emission of energy in the form of light, thus accounting for the series of lines in the emission *spectrum of hydrogen. For this work Bohr was awarded the 1922 Nobel Prize for physics. *See* BOHR THEORY.

Bohr effect The effect of pH on the dissociation of oxygen from haemoglobin, first discovered by the Danish physiologist Christian Bohr (1855–1911). An increase in carbon dioxide concentration makes the blood more acidic and decreases the efficiency of the uptake of oxygen by haemoglobin molecules. This shifts the *oxygen dissociation curve to the right and increases the tendency of haemoglobin to release oxygen. Thus in actively respiring tissues, where the concentration of carbon dioxide in the blood is high, haemoglobin readily releases its oxygen, while in the lungs, where blood carbon dioxide is low (due to its continual diffusion into the alveoli), haemoglobin readily binds oxygen.

bohrium Symbol Bh. A radioactive *transactinide element; a.n. 107. It was first made in 1981 by Peter Armbruster and a team in Darmstadt, Germany, by bombarding bismuth–209 nuclei with chromium–54 nuclei. Only a few atoms of bohrium have ever been detected.

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- Information from the WebElements site

Bohr theory The theory published in 1913 by Niels Bohr to explain the line spectrum of hydrogen. He assumed that a single electron of mass m travelled in a circular orbit of radius r, at a velocity v, around a positively charged nucleus. The *angular momentum of the electron would then be mvr. Bohr proposed that electrons could only occupy orbits in which this angular momentum had certain fixed values, $h/2\pi$, $2h/2\pi$, $3h/2\pi$,… $nh/2\pi$, where h is the Planck constant. This means that the angular momentum is quantized, i.e. can only have certain values, each of which is a multiple of n. Each permitted value of n is associated with an orbit of different radius and Bohr assumed that when the atom emitted or absorbed radiation of frequency ν, the electron jumped from one orbit to another; the energy emitted or absorbed by each jump is equal to $h\nu$. This theory gave good results in predicting the lines observed in the spectrum of hydrogen and simple ions such as He^+, Li^{2+}, etc. The idea of quantized values of angular momentum was later explained by the wave nature of the electron. Each orbit has to have a whole number of wavelengths around it; i.e. $n\lambda = 2\pi r$, where λ is the wavelength and n a whole number. The wavelength of a particle is given by h/mv, so $nh/mv = 2\pi r$, which leads to $mvr = nh/2\pi$. Modern atomic theory does not allow subatomic particles to be treated in the same way as large objects, and Bohr's reasoning is somewhat discredited. However, the idea of quantized angular momentum has been retained.

boiling point (b.p.) The temperature at which the saturated vapour pressure of a liquid equals the external atmospheric pressure. As a consequence, bubbles form in the liquid and the temperature remains constant until all the liquid has evaporated. As the boiling point of a liquid depends on the external atmospheric pressure, boiling points are usually quoted for standard atmospheric pressure (760 mmHg = 101 325 Pa).

boiling-point–composition diagram A graph showing how the boiling point and vapour composition of a mixture of two liquids depends on the composition of the mixture. The abscissa shows the range of compositions from 100% A at one end to 100% B at the other. The diagram has two curves: the lower one gives the boiling points (at a fixed pressure) for the different compositions. The upper one is plotted by taking the composition of vapour at each temperature on the boiling-point curve. The two curves would coincide for an ideal mixture, but generally they are different because of deviations from *Raoult's law. In some cases, they may show a maximum or minimum and coincide at some intermediate composition, explaining the formation of *azeotropes.

boiling-point elevation *See* ELEVATION OF BOILING POINT.

boiling-water reactor *See* NUCLEAR REACTOR.

Bok globule Any of a class of small near-spherical dark nebulae thought to be dense clouds of gas and dust in a late stage of gravitational collapse. The globules are visible against emission nebulae or a background of stars. They are thought to be the precursors of some low-mass protostars (*see* STELLAR EVOLUTION), sometimes accompanied by

*bipolar outflows. They take their name from the US astronomer Bart Jason Bok (1906–83).

bolide An exceptionally bright meteor that appears to explode on its way through the earth's atmosphere: a detonating fireball.

bolometer A sensitive instrument used to measure radiant heat. The original form consists of two elements, each comprising blackened platinum strips (about 10^{-3} mm thick) arranged in series on an insulated frame to form a zigzag. The two elements are connected into the adjacent arms of a *Wheatstone bridge; one element is exposed to the radiation, the other is shielded from it. The change in the resistance of the exposed element, as detected by the bridge galvanometer, enables the heat reaching it to be calculated.

Modern semiconductor bolometers are now common, in which the platinum is replaced by a strip of semiconductor: this has a much greater (though usually negative) *temperature coefficient of resistance, and makes the system more sensitive.

Boltzmann, Ludwig Eduard (1844–1906) Austrian physicist. He held professorships in Graz, Vienna, Munich, and Leipzig, where he worked on the kinetic theory of gases (*see* MAXWELL–BOLTZMANN DISTRIBUTION) and on thermodynamics (*see* BOLTZMANN EQUATION). He suffered from depression and committed suicide.

Boltzmann constant Symbol k or k_B. The ratio of the universal gas constant (R) to the Avogadro constant (N_A). It may be thought of therefore as the gas constant per molecule:

$$k = R/N_A = 1.380\,658(12) \times 10^{-23}\ \text{J K}^{-1}$$

It is named after Ludwig Boltzmann.

Boltzmann equation An equation used in the study of a collection of particles in *non-equilibrium statistical mechanics, particularly their transport properties. The Boltzmann equation describes a quantity called the **distribution function**, f, which gives a mathematical description of the state and how it is changing. The distribution function depends on a position vector $\boldsymbol{r}$, a velocity vector $\boldsymbol{v}$, and the time t; it thus provides a statistical statement about the positions and velocities of the particles at any time. In the case of one species of particle being present, Boltzmann's equation can be written

$$\partial f/\partial t + \boldsymbol{a}.(\partial f/\partial \boldsymbol{v}) + \boldsymbol{v}.(\partial f/\partial \boldsymbol{r}) = (\partial f/\partial t)_{\text{coll}},$$

where $\boldsymbol{a}$ is the acceleration of bodies between collisions and $(\partial f/\partial t)_{\text{coll}}$ is the rate of change of $f(\boldsymbol{r},\boldsymbol{v},t)$ due to collisions. The Boltzmann equation can be used to calculate *transport coefficients, such as *conductivity. The Boltzmann equation was proposed in 1872.

Boltzmann formula An equation concerning the entropy S of a system derived from statistical mechanics. The formula is $S = k \ln W$, where k is the Boltzmann constant and W is the number of distinguishable ways of describing the system. It expresses in quantitative terms the concept that entropy is a measure of the disorder of a system.

bolus The ball of chewed food bound together with saliva that is formed in the mouth by the action of the tongue. The bolus is shaped to a size that allows it to pass into the oesophagus after being swallowed (*see* DEGLUTITION).

bomb calorimeter An apparatus used for measuring heats of combustion (e.g. calorific values of fuels and foods). It consists of a strong container in which the sample is sealed with excess oxygen and ignited electrically. The heat of combustion at constant volume can be calculated from the resulting rise in temperature.

bond *See* CHEMICAL BOND.

bond energy An amount of energy associated with a bond in a chemical compound. It is obtained from the heat of atomization. For instance, in methane the bond energy of the C–H bond is one quarter of the enthalpy of the process

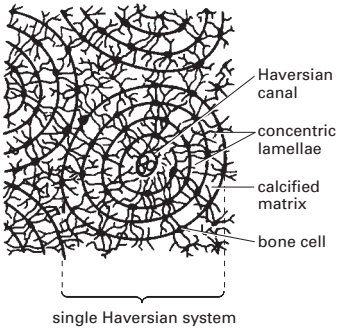
$$CH_4(g) \rightarrow C(g) + 4H(g)$$

Bond energies (or **bond enthalpies**) can be calculated from the standard enthalpy of formation of the compound and from the enthalpies of atomization of the elements. Energies calculated in this way are called **average bond energies** or **bond–energy terms**. They depend to some extent on the molecule chosen; the C–H bond energy in methane will differ slightly from that in ethane. The **bond dissociation energy** is a different measurement, being the energy required to break a particular bond; e.g. the energy for the process:

$$CH_4(g) \rightarrow CH_3{\cdot}(g) + H{\cdot}(g)$$

Bondi, Hermann *See* HOYLE, SIR FRED.

bonding orbital *See* ORBITAL.



Bone. Structure of compact bone.

bone The hard connective tissue of which the *skeleton of most vertebrates is formed. It comprises a matrix of *collagen fibres (30%) impregnated with bone salts (70%), mostly calcium phosphate, in which are embedded bone cells (*see* OSTEOCYTE; OSTEOBLAST; OSTEOCLAST). Bone generally replaces embryonic *cartilage and is of two sorts – compact bone and spongy bone. The outer **compact bone** is formed as concentric layers (**lamellae**) that surround small holes (*Haversian canals): see illustration. The inner **spongy bone** is chemically similar but forms a network of bony bars. The spaces between the bars may contain bone marrow or (in birds) air for lightness. *See also* CARTILAGE BONE; MEMBRANE BONE; PERIOSTEUM.

bone black *See* CHARCOAL.

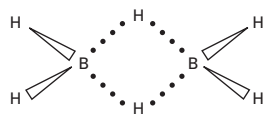
bone marrow A soft tissue contained within the central cavity and internal spaces of a bone. At birth and in young animals the marrow of all bones is concerned with the formation of blood cells: it contains *haemopoietic tissue and is known as **red marrow**. In mature animals the marrow of the long bones ceases producing blood cells and is replaced by fat, being known as **yellow marrow**.

bony fishes *See* OSTEICHTHYES.

bony labyrinth *See* LABYRINTH.

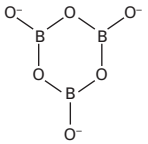
Boolean algebra A form of symbolic logic, devised by George Boole (1815–64) in the middle of the 19th century, which provides a mathematical procedure for manipulating logical relationships in symbolic form. For example in Boolean algebra $a + b$ means *a* or *b*, while *ab* means *a* and *b*. It makes use of *set theory and is extensively used by the designers of computers to enable the bits 0 and 1, as used in the binary notation, to relate to the logical functions the computer needs in carrying out its calculations.

borane (boron hydride) Any of a group of compounds of boron and hydrogen, many of which can be prepared by the action of acid on magnesium boride (MgB_2). Others are made by pyrolysis of the products of this reaction in the presence of hydrogen and other reagents. They are all volatile, reactive, and oxidize readily in air, some explosively so. The boranes are a remarkable group of compounds in that their structures cannot be described using the conventional two-electron covalent bond model (*see* ELECTRON-DEFICIENT COMPOUND). The simplest example is **diborane** (B_2H_6): see formula. Other boranes include B_4H_{10}, B_5H_9, B_5H_{11}, B_6H_{10}, and $B_{10}H_4$. The larger borane molecules have open or closed polyhedra of boron atoms. In addition, there is a wide range of borane derivatives containing atoms of other elements, such as carbon and phosphorus. **Borohydride ions** of the type $B_6H_6^{2-}$ also exist. Boranes and borohydride ions are classified according to their structure. Those with a complete polyhedron are said to have a **closo-structure**. Those in which the polyhedron is incomplete by loss of one vertex have a **nido-structure** (from the Greek for 'nest'). Those with open structures by removal of two or more vertices have an **arachno- structure** (from the Greek for 'spider'). *See also* WADE'S RULES.

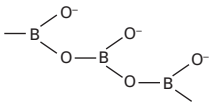


Borane. Diborane, the simplest of the boranes.

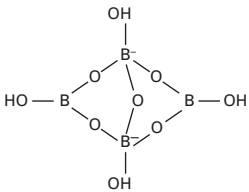
borate Any of a wide range of ionic compounds that have negative ions containing boron and oxygen (see formulae). Lithium borate, for example, contains the simple anion $B(OH)_4^-$. Most borates, however, are inorganic polymers with rings, chains, or other networks based on the planar BO_3 group or the tetrahedral $BO_3(OH)$ group. 'Hydrated' borates are ones containing –OH groups; many examples occur naturally. Anhydrous borates, which contain BO_3 groups,



$B_3O_6^{3-}$ as in $Na_3B_3O_6$



$(BO_2)_n^{n-}$ as in CaB_2O_4



$[B_4O_5(OH)_4]^{2-}$
as in borax $Na_2B_4O_7.10H_2O$

Borate. Structure of some typical borate ions.

can be made by melting together boric acid and metal oxides.

borax (disodium tetraborate-10-water) A colourless monoclinic solid, $Na_2B_4O_7.10H_2O$, soluble in water and very slightly soluble in ethanol; monoclinic; r.d. 1.73; loses $8H_2O$ at 75°C; loses $10H_2O$ at 320°C. The formula gives a misleading impression of the structure. The compound contains the ion $[B_4O_5(OH)_4]^{2-}$ (*see* BORATE). Attempts to recrystallize this compound above 60.8°C yield the pentahydrate. The main sources of borax are the borate minerals **kernite** ($Na_2B_4O_7.4H_2O$) and **tincal** ($Na_2B_4O_7.10H_2O$). The ores are purified by carefully controlled dissolution and recrystallization. On treatment with mineral acids borax gives boric acid.

Borax is a very important substance in the glass and ceramics industries as a raw material for making borosilicates. It is also important as a metallurgical flux because of the ability of molten borates to dissolve metal oxides. In solution it partially hydrolyses to boric acid and can thus act as a buffer. For this reason it is used as a laundry pre-soak. It is used medicinally as a mild alkaline antiseptic and astringent for the skin and mucous membranes.

Disodium tetraborate is the source of many industrially important boron compounds, such as barium borate (fungicidal paints), zinc borate (fire-retardant additive in plastics), and boron phosphate (heterogeneous acid catalyst in the petrochemicals industry).

borax-bead test A simple laboratory test for certain metal ions in salts. A small amount of the salt is mixed with borax and a molten bead formed on the end of a piece of platinum wire. Certain metals can be identified by the colour of the bead produced in the oxidizing and reducing parts of a Bunsen flame. For example, iron gives a bead that is red when hot and yellow when cold in the oxidizing flame and a green bead in the reducing flame.

borax carmine A red dye, used in optical microscopy, that stains nuclei and cytoplasm pink. It is frequently used to stain large pieces of animal tissue.

borazon *See* BORON NITRIDE.

Bordeaux mixture A mixture of copper(II) sulphate and calcium hydroxide in water, used as a fungicide.

Borel sum An integral that is defined so as to represent the sum of a divergent series. The concept enables many of the divergent series that occur in physics, such as perturbation series in quantum field theory, to be mathematically well-defined. It is named after the French mathematician Émile Borel (1871–1956).

boric acid Any of a number of acids containing boron and oxygen. Used without qualification the term applies to the compound H_3BO_3 (which is also called **orthoboric acid** or, technically, **trioxoboric(III) acid**). This is a white or colourless solid that is soluble in water and ethanol; triclinic; r.d. 1.435; m.p. 169°C. It occurs naturally in the condensate from volcanic steam vents (suffioni). Commercially, it is made by treating borate minerals (e.g. kernite, $Na_2B_4O_7.4H_2O$) with sulphuric acid followed by recrystallization.

In the solid there is considerable hydrogen bonding between H_3BO_3 molecules resulting

b

in a layer structure, which accounts for the easy cleavage of the crystals. H_3BO_3 molecules also exist in dilute solutions but in more concentrated solutions polymeric acids and ions are formed (e.g. $H_4B_2O_7$; pyroboric acid or **tetrahydroxomonoxodiboric(III) acid**). The compound is a very weak acid but also acts as a Lewis *acid in accepting hydroxide ions:

$$B(OH)_3 + H_2O \rightleftharpoons B(OH)_4^- + H^+$$

If solid boric acid is heated it loses water and transforms to another acid at 300°C. This is given the formula HBO_2 but is in fact a polymer $(HBO_2)_n$. It is called **metaboric acid** or, technically, **polydioxoboric(III) acid**.

Boric acid is used in the manufacture of glass (borosilicate glass), glazes and enamels, leather, paper, adhesives, and explosives. It is widely used (particularly in the USA) in detergents, and because of the ability of fused boric acid to dissolve other metal oxides it is used as a flux in brazing and welding. Because of its mild antiseptic properties it is used in the pharmaceutical industry and as a food preservative.

boride A compound of boron with a metal. Most metals form at least one boride of the type MB, MB_2, MB_4, MB_6, or MB_{12}. The compounds have a variety of structures; in particular, the hexaborides contain clusters of B_6 atoms. The borides are all hard high-melting materials with metal-like conductivity. They can be made by direct combination of the elements at high temperatures (over 2000°C) or, more usually, by high-temperature reduction of a mixture of the metal oxide and boron oxide using carbon or aluminium. Chemically, they are stable to nonoxidizing acids but are attacked by strong oxidizing agents and by strong alkalis. Magnesium boride (MgB_2) is unusual in that it can be hydrolysed to boranes. Industrially, metal borides are used as refractory materials. The most important are CrB, CrB_2, TiB_2, and ZnB_2. Generally, they are fabricated using high-temperature powder metallurgy, in which the article is produced in a graphite die at over 2000°C and at very high pressure. Items are pressed as near to final shape as possible as machining requires diamond cutters and is extremely expensive.

Born–Haber cycle A cycle of reactions used for calculating the lattice energies of ionic crystalline solids. For a compound MX, the lattice energy is the enthalpy of the reaction

$$M^+(g) + X^-(g) \rightarrow M^+X^-(s)\ \Delta H_L$$

The standard enthalpy of formation of the ionic solid is the enthalpy of the reaction

$$M(s) + \tfrac{1}{2}X_2(g) \rightarrow M^+X^-(s)\ \Delta H_f$$

The cycle involves equating this enthalpy (which can be measured) to the sum of the enthalpies of a number of steps proceeding from the elements to the ionic solid. The steps are:

(1) Atomization of the metal:

$$M(s) \rightarrow M(g)\ \Delta H_1$$

(2) Atomization of the nonmetal:

$$\tfrac{1}{2}X_2(g) \rightarrow X(g)\ \Delta H_2$$

(3) Ionization of the metal:

$$M(g) \rightarrow M^+(g) + e\ \Delta H_3$$

This is obtained from the ionization potential.

(4) Ionization of the nonmetal:

$$X(g) + e \rightarrow X^-(g)\ \Delta H_4$$

This is the electron affinity.

(5) Formation of the ionic solids:

$$M^+(g) + X^-(g) \rightarrow M^+X^-(s)\ \Delta H_L$$

Equating the enthalpies gives:

$$\Delta H_f = \Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_L$$

from which ΔH_L can be found. It is named after the German physicist Max Born (1882–1970) and the chemist Fritz Haber.

bornite An important ore of copper composed of a mixed copper–iron sulphide, Cu_5FeS_4. Freshly exposed surfaces of the mineral are a metallic reddish-brown but a purplish iridescent tarnish soon develops – hence it is popularly known as **peacock ore**. Bornite is mined in Chile, Peru, Bolivia, Mexico, and the USA.

Born–Oppenheimer approximation An *adiabatic approximation used in molecular and solid-state physics in which the motion of atomic nuclei is taken to be so much slower than the motion of electrons that, when calculating the motions of electrons, the nuclei can be taken to be in fixed positions. This approximation was justified using *perturbation theory by Max Born and the US physicist Julius Robert Oppenheimer (1904–67) in 1927.

borohydride ion *See* BORANE.

boron Symbol B. An element of *group 13 (formerly IIIB) of the periodic table; a.n. 5; r.a.m. 10.81; r.d. 2.34–2.37 (amorphous); m.p. 2300°C; b.p. 2550°C. It forms two allotropes; amorphous boron is a brown pow-

der but metallic boron is black. The metallic form is very hard (9.3 on Mohs' scale) and is a poor electrical conductor at room temperature. At least three crystalline forms are possible; two are rhombohedral and the other tetragonal. The element is never found free in nature. It occurs as orthoboric acid in volcanic springs in Tuscany, as borates in kernite ($Na_2B_4O_7.4H_2O$), and as colemanite ($Ca_2B_6O_{11}.5H_2O$) in California. Samples usually contain isotopes in the ratio of 19.78% boron–10 to 80.22% boron–11. Extraction is achieved by vapour-phase reduction of boron trichloride with hydrogen on electrically heated filaments. Amorphous boron can be obtained by reducing the trioxide with magnesium powder. Boron when heated reacts with oxygen, halogens, oxidizing acids, and hot alkalis. It is used in semiconductors and in filaments for specialized aerospace applications. Amorphous boron is used in flares, giving a green coloration. The isotope boron–10 is used in nuclear reactor control rods and shields. The element was discovered in 1808 by Sir Humphry Davy and by J. L. Gay-Lussac and L. J. Thenard.

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boron carbide A black solid, B_4C, soluble only in fused alkali; it is extremely hard, over 9½ on Mohs' scale; rhombohedral; r.d. 2.52; m.p. 2350°C; b.p. >3500°C. Boron carbide is manufactured by the reduction of boric oxide with petroleum coke in an electric furnace. It is used largely as an abrasive, but objects can also be fabricated using high-temperature powder metallurgy. Boron nitride is also used as a neutron absorber because of its high proportion of boron–10.

boron counter A *counter tube containing a **boron chamber**, used for counting slow neutrons. The boron chamber is lined with boron or a boron compound or is filled with the gas boron trifluoride (BF_3). As natural boron contains about 18% of the isotope boron–10, and as this isotope absorbs neutrons with the emission of an alpha particle, the chamber can be coupled with a scaler to count the alpha particles emitted when neutrons enter the chamber.

boron hydride *See* BORANE.

boron nitride A solid, BN, insoluble in cold water and slowly decomposed by hot water; r.d. 2.25 (hexagonal); sublimes above 3000°C. Boron nitride is manufactured by heating boron oxide to 800°C on an acid-soluble carrier, such as calcium phosphate, in the presence of nitrogen or ammonia. It is isoelectronic with carbon and, like carbon, it has a very hard cubic form (**borazon**) and a softer hexagonal form; unlike graphite this is a nonconductor. It is used in the electrical industries where its high thermal conductivity and high resistance are of especial value.

boron trichloride A colourless fuming liquid, BCl_3, which reacts with water to give hydrogen chloride and boric acid; r.d. 1.349; m.p. –107°C; b.p. 12.5°C. Boron trichloride is prepared industrially by the exothermic chlorination of boron carbide at above 700°C, followed by fractional distillation. An alternative, but more expensive, laboratory method is the reaction of dry chlorine with boron at high temperature. Boron trichloride is a Lewis *acid, forming stable addition compounds with such donors as ammonia and the amines and is used in the laboratory to promote reactions that liberate these donors. The compound is important industrially as a source of pure boron (reduction with hydrogen) for the electronics industry. It is also used for the preparation of boranes by reaction with metal hydrides.

borosilicate Any of a large number of substances in which BO_3 and SiO_4 units are linked to form networks with a wide range of structures. Borosilicate glasses are particularly important; the addition of boron to the silicate network enables the glass to be fused at lower temperatures than pure silica and also extends the plastic range of the glass. Thus such glasses as Pyrex have a wider range of applications than soda glasses (narrow plastic range, higher thermal expansion) or silica (much higher melting point). Borosilicates are also used in glazes and enamels and in the production of glass wools.

Bosch, Carl *See* BERGIUS, FRIEDRICH KARL RUDOLF; HABER PROCESS.

Bosch process *See* HABER PROCESS.

Bose–Einstein condensation A phenomenon occurring in a macroscopic system consisting of a large number of *bosons at a sufficiently low temperature, in which a significant fraction of the particles occupy a single quantum state of lowest energy (the ground state). Bose–Einstein condensation can only take place for bosons whose total number is conserved in collisions. Because

of the Pauli exclusion principle, it is impossible for two or more fermions to occupy the same quantum state, and so there is no analogous condensation phenomenon for such particles. Bose–Einstein condensation is of fundamental importance in explaining the phenomenon of *superfluidity. At very low temperatures (around 2×10^{-7} K) a Bose–Einstein condensate can form, in which several thousand atoms become a single entity (a **superatom**). This effect has been observed with atoms of rubidium and lithium and certain other atomic systems at very low temperature. The effect is named after the Indian physicist Satyendra Nath Bose (1894–1974) and Albert Einstein.

Bose–Einstein statistics *See* QUANTUM STATISTICS.

boson An *elementary particle (or bound state of an elementary particle, e.g. an atomic nucleus or an atom) with integral spin; i.e. a particle that conforms to Bose–Einstein statistics (*see* QUANTUM STATISTICS), from which it derives its name. *Compare* FERMION.

botany The scientific study of plants, including their anatomy, morphology, physiology, biochemistry, taxonomy, cytology, genetics, ecology, evolution, and geographical distribution.

bottled gas Gas supplied under pressure in metal cylinders. The term includes pressurized gas (e.g. oxygen and nitrogen cylinders) and gases liquefied under pressure (e.g. liquid butane for use as a fuel). Colour conventions are used to identify the type of gas or, in some cases, the specific gas. The colour indicating the contents is that of the shoulder of the cylinder at the top. The convention is not international, and practice differs in different countries. In the UK, the convention is:
Yellow for toxic or corrosive gases
Red for flammable gases
Light blue for oxidizing gases
Maroon for acetylene
Dark green for argon
Grey for carbon dioxide
Brown for helium
Blue for nitrous oxide
Black for nitrogen
White for oxygen

SEE WEB LINKS

- Information on colour coding of gas containers

botulinum toxin A nerve toxin produced by the bacterium *Clostridium botulinum*, which can cause fatal *food poisoning. It is the most toxic substance known. In minute doses it is used to treat certain conditions involving muscle dysfunction.

boulder clay (till) A mixture of rock and powdered rock formed beneath a moving glacier as it drags rocks beneath it. When the glacier subsequently melts, the boulder clay is left as a surface bed. Its components may be almost any type of rock in a wide range of sizes, from large angular boulders to tiny particles in clay. *See also* MORAINE.

boundary conditions In the general solution of a *differential equation, conditions that are imposed to allow the arbitrary constants to be determined. They thus permit a particular solution to be obtained.

boundary layer The thin layer of fluid formed around a solid body or surface relative to which the fluid is flowing. Adhesion between the molecules of the fluid and that of the body or surface causes the molecules of the fluid closest to the solid to be stationary relative to it. The transfer of heat or mass between a solid and a fluid flowing over it is largely controlled by the nature of the boundary layer.

boundary slip A boundary condition used in fluid mechanics. When a liquid flows over the surface of a solid, and layers of liquid close to the solid are assumed to be stationary relative to the solid; this is called a **no-slip boundary condition**. Such an assumption is a good approximation for macroscopic flow but is not accurate at the molecular scale. When this assumption is not made a **slip boundary condition** occurs. Boundary slip causes the viscosity at the interface to be different from the viscosity in the bulk of the liquid.

bound state A system in which two (or more) parts are bound together in such a way that energy is required to split them. An example of a bound state is a *molecule formed from two (or more) *atoms.

Bourdon gauge A pressure gauge consisting essentially of a C-shaped or spiral tube with an oval cross section. One end of the tube is connected to the fluid whose pressure is to be measured and the other end is sealed. As the pressure inside the tube is increased, the oval tube tends to become circular and this causes the tube to straighten. The movement of the end of the tube is

transferred by a simple mechanism to a needle moving round a dial or to a digital display. With suitable design, Bourdon gauges can be used for high-pressure measurement and also for low pressures. It was invented by Eugène Bourdon (1804–88).

bovine spongiform encephalopathy (BSE) A degenerative disease of the brain that affects cattle and is caused by an abnormal form of a cellular protein (*see* PRION). Known colloquially as 'mad cow disease', it results in a build-up of fibrous tissue in the brain. The infective agent can be transmitted to other cattle via feed containing offal derived from infected animals. It can also, under certain circumstances, be transmitted to other species. *See also* CREUTZFELDT–JAKOB DISEASE.

Bowman's capsule (renal capsule) The cup-shaped end of a kidney *nephron. Its epithelium contains **podocytes**, cells that facilitate the passage of glomerular filtrate from the blood into the nephron. It is named after its discoverer, the British physician Sir William Bowman (1816–92).

Boyle, Robert (1627–91) English chemist and physicist, born in Ireland. After moving to Oxford in 1654 he worked on gases, using an air pump made by Robert *Hooke. With it he proved that sound does not travel in a vacuum. In 1662 he discovered *Boyle's law. In chemistry he worked on *flame tests and acid-base *indicators.

SEE WEB LINKS

- The Robert Boyle project at Birkbeck College, London

Boyle's law The volume (V) of a given mass of gas at a constant temperature is inversely proportional to its pressure (p), i.e. pV = constant. This is true only for an *ideal gas. This law was discovered in 1662 by Robert Boyle. On the continent of Europe it is known as **Mariotte's law** after E. Mariotte (1620–84), who discovered it independently in 1676. *See also* GAS LAWS.

bp *See* BASE PAIR.

Brackett series *See* HYDROGEN SPECTRUM.

bract A modified leaf with a flower or inflorescence in its axil. Bracts are often brightly coloured and may be mistaken for the petals of a flower. For example the showy 'flowers' of poinsettia and *Bougainvillea* are composed of bracts; the true flowers are comparatively inconspicuous. *See also* INVOLUCRE.

bracteole A reduced leaf that arises from the stalk of an individual flower.

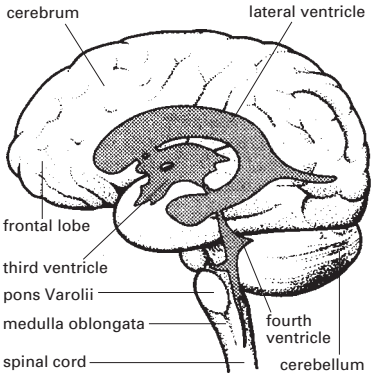
bradykinin *See* KININ.

Bragg, Sir William Henry (1862–1942) British physicist, who with his son **Sir (William) Lawrence Bragg** (1890–1971) was awarded the 1915 Nobel Prize for physics for their pioneering work on *X-ray crystallography. He also constructed an X-ray spectrometer for measuring the wavelengths of X-rays. In the 1920s, while director of the Royal Institution in London, he initiated X-ray diffraction studies of organic molecules.

Bragg's law When a beam of X-rays (wavelength λ) strikes a crystal surface in which the layers of atoms or ions are separated by a distance d, the maximum intensity of the reflected ray occurs when $\sin\theta = n\lambda/2d$, where θ (known as the **Bragg angle**) is the complement of the angle of incidence and n is an integer. The law enables the structure of many crystals to be determined. It was discovered in 1912 by Sir Lawrence Bragg.

Brahe, Tycho (1546–1601) Danish astronomer, generally regarded as the most precise, systematic, and meticulous observer of the heavens in the era before the telescope. He observed the supernova of 1572 ('Tycho's star') in the constellation of Cassiopeia and showed that it was a fixed star, because its position relative to the other fixed stars remained unchanged and it showed no daily parallax. In 1577 Tycho moved to his own observatories on Hven Island (financed by King Frederick II), where, without the benefit of a telescope, he charted the positions of 777 stars. In 1599 he moved to Prague to join the court of the Holy Roman Emperor Rudolf II as imperial mathematician, with *Kepler as his assistant from 1600.

brain **1.** The enlarged anterior part of the vertebrate central nervous system, which is encased within the cranium of the skull. Continuous with the spinal cord, the brain is surrounded by three membranes (*see* MENINGES) and bathed in cerebrospinal fluid, which fills internal cavities (*ventricles). It functions as the main coordinating centre for nervous activity, receiving information (in the form of nerve impulses) from sense organs, interpreting it, and transmitting 'in-



The human brain.

structions' to muscles and other *effectors. It is also the seat of intelligence and memory. The embryonic vertebrate brain is in three sections (*see* FOREBRAIN; HINDBRAIN; MIDBRAIN), which become further differentiated during development into specialized regions. The main parts of the adult human brain are a highly developed *cerebrum in the form of two cerebral hemispheres, a *cerebellum, *medulla oblongata, and *hypothalamus (see illustration). **2.** A concentration of nerve *ganglia at the anterior end of an invertebrate animal.

SEE WEB LINKS

- Multilevel exploration of brain structure and function, sponsored by the Canadian Institutes of Health Research

brain death The permanent absence of vital functions of the brain, which is marked by cessation of breathing and other reflexes controlled by the *brainstem and by a zero reading on an *electroencephalogram. Organs may be removed for transplantation when brain death is established, which may not necessarily be associated with permanent absence of heart beat.

brainstem The part of the brain comprising the *medulla oblongata, the *midbrain, and the *pons. It resembles and is continuous with the spinal cord. The midbrain controls and integrates reflex activities (such as respiration) that originate in higher centres of the brain via a network of nerve pathways (the **reticular formation**).

branched chain *See* CHAIN.

brane world A theory in which the four space–time dimensions of the universe that are apparent make up a surface, called the **brane**, in a higher-dimensional space–time, called the **bulk**. One of the appealing features of the brane world is that it can explain why gravity is much weaker than the other forces, with the nongravitational forces being localized to the brane and the gravitational force not limited to the brane. *See also* EKPYROTIC UNIVERSE; RANDALL–SUNDRUM SCENARIO.

Brans–Dicke theory A modification of the general theory of relativity that combined tensor and scalar qualities and allowed the *gravitational constant G to vary with time in a way that is in accord with *Mach's principle. The Brans–Dicke theory was proposed by the American physicists Carl Brans (1935–) and Robert Dicke (1916–97) in 1961. This type of theory has largely been abandonded since its predictions have not been supported by accurate experimental tests of the general theory of relativity.

brass A group of alloys consisting of copper and zinc. A typical yellow brass might contain about 67% copper and 33% zinc. *See also* DELTA-BRASS.

Brattain, Walter *See* BARDEEN, JOHN.

Braun, Karl Ferdinand (1850–1918) German physicist, who became professor of physics at Strasbourg in 1895. In the early 1900s he used crystals as diodes (later employed in crystal-set radios) and developed the *cathode-ray tube for use as an oscilloscope. He also worked on radio and in 1909 shared the Nobel Prize for physics with *Marconi.

Bravais lattice A lattice defined by the combination of one of the seven possible *crystal systems and one of the possible lattice centrings, i.e. (1) **primitive**, in which only the cell corners are occupied, (2) **body centred**, in which there is a point at the centre, (3) **face centred**, in which there are points at the centres of all the faces, (4) **centred at a single face**, in which there is a point at the centre of one of the faces. The Bravais lattice is named after the French physicist Auguste Bravais (1811–63), who demonstrated that in three spatial dimensions there are 14 possible such lattices.

breakdown The sudden passage of a current through an insulator. The voltage at which this occurs is the **breakdown voltage**.

breaking stress *See* ELASTICITY.

breathing *See* EXPIRATION; INSPIRATION; RESPIRATORY MOVEMENT.

breed A domesticated *variety of an animal or, rarely, a cultivated variety of plant (cultivated plants are usually called varieties or, more correctly, *cultivars). Examples of animal breeds are Friesian cattle and Shetland sheepdogs.

breeder reactor *See* NUCLEAR REACTOR.

breeding The process of sexual *reproduction and bearing offspring. **Selective breeding** of both plants and animals is used in *agriculture to produce offspring that possess the beneficial characters of both parents (*see also* ARTIFICIAL INSEMINATION). *Inbreeding is the production of *homozygous phenotypically uniform offspring by mating between close relatives. Plants that self-fertilize, such as wheat and tomatoes, are inbreeders. *Outbreeding is the production of *heterozygous phenotypically variable offspring by mating between unrelated organisms.

breeding season A specific season of the year in which many animals, including mammals and birds, mate, which ensures that offspring are produced only at a certain time of the year. This timing is important as it enables animals to give birth at a time of the year when environmental conditions and food supply are at their optimum. The breeding season of most animals is in the spring or summer. The stimulus to mate is the result of a photoperiodic response (*see* PHOTOPERIODISM), which is thought to be controlled by day length affecting levels of the hormone *melatonin.

Bremsstrahlung (German: braking radiation) The X-rays emitted when a charged particle, especially a fast electron, is rapidly slowed down, as when it passes through the electric field around an atomic nucleus. The X-rays cover a whole continuous range of wavelengths down to a minimum value, which depends on the energy of the incident particles. Bremsstrahlung are produced by a metal target when it is bombarded by electrons.

brewing The process by which beer is made. Fermentation of sugars from barley grain by the yeasts **Saccharomyces cerevisiae* and *S. uvarum* (or *S. carlsbergensis*) produces alcohol. In the first stage the barley grain is soaked in water, a process known as **malting**. The grain is then allowed to germinate and the natural enzymes of the grain (the amylases and the maltases) convert the starch to maltose and then to glucose. The next stage is **kilning** or **roasting**, in which the grains are dried and crushed. The colour of a beer depends on the temperature used for this process: the higher the temperature, the darker the beer. In the next stage, **mashing**, the crushed grain is added to water at a specific temperature and any remaining starch is converted to sugar; the resultant liquid is the raw material of brewing, called **wort**. The yeast is then added to the wort to convert the sugar to alcohol, followed by hops, which give beer its characteristic flavour. Hops are the female flowers of the vine *Humulus lupulus*; they contain resins (humulones, cohumulones, and adhumulones) that give beer its distinctive bitter taste.

Brewster's law The extent of the polarization of light reflected from a transparent surface is a maximum when the reflected ray is at right angles to the refracted ray. The angle of incidence (and reflection) at which this maximum polarization occurs is called the **Brewster angle** or **polarizing angle**. For this angle i_B, the condition is that $\tan i_B = n$, where n is the refractive index of the transparent medium. The law was discovered in 1811 by the British physicist David Brewster (1781–1868).

bridge **1.** (in chemistry) An atom or group joining two other atoms in a molecule. *See* ALUMINIUM CHLORIDE; BORANE. **2.** (in physics) a type of electrical circuit in which four components are linked in a square, with inputs and outputs at pairs of opposite corners. *See* WHEATSTONE BRIDGE.

bridge rectifier *See* RECTIFIER.

brighteners Substances added to detergents or used to treat textiles or paper in order to brighten the colours or, particularly, to enhance whiteness. Blueing agents are used in laundries to give a slight blue cast to white material in order to counteract yellowing. Fluorescent brighteners are compounds that absorb visible or ultraviolet radiation and fluoresce in the blue region of the optical spectrum.

Brinell hardness A scale for measuring the hardness of metals introduced around 1900 by the Swedish metallurgist Johann

Brinell (1849–1925). A small chromium-steel ball is pressed into the surface of the metal by a load of known weight. The ratio of the mass of the load in kilograms to the area of the depression formed in square millimetres is the **Brinell number**.

Brin process A process formerly used for making oxygen by heating barium oxide in air to form the peroxide and then heating the peroxide at higher temperature (>800°C) to produce oxygen

$$2BaO_2 \rightarrow 2BaO + O_2$$

Britannia metal A silvery alloy consisting of 80–90% tin, 5–15% antimony, and sometimes small percentages of copper, lead, and zinc. It is used in bearings and some domestic articles.

British thermal unit (Btu) The Imperial unit of heat, being originally the heat required to raise the temperature of 1lb of water by 1°F. 1 Btu is now defined as 1055.06 joules.

broadband Communication by a system that supports a wide range of frequencies, so that identical messages can be carried simultaneously. *See also* ADSL.

broken symmetry A situation in which the lowest-energy state of a many-body system or *vacuum state of a relativistic *quantum field theory has a lower symmetry than the equations defining the system. Examples in solid-state physics include ferromagnetism, antiferromagnetism, and superconductivity. In particle physics, the Weinberg–Salam model (*see* ELECTROWEAK THEORY) is an important example of a relativistic quantum field theory with broken symmetry.

A result associated with broken symmetry is **Goldstone's theorem**. This states that a relativistic quantum field theory having continuous symmetry that is broken must include the existence of massless particles called **Goldstone bosons**. In many-body theory Goldstone bosons are *collective excitations. An exception to Goldstone's theorem is provided in the case of broken *gauge theories, such as the Weinberg–Salam model, in which the Goldstone bosons become massive bosons known as *Higgs bosons. In many-body theory, long-range forces provide the analogous exception to Goldstone's theorem, with the Higgs bosons being excitations with a nonzero gap. Such Higgs bosons are found in superconductors.

bromate A salt or ester of a bromic acid.

bromic(I) acid (hypobromous acid) A yellow liquid, HBrO. It is a weak acid and a strong oxidizing agent.

bromic(V) acid A colourless liquid, $HBrO_3$, made by adding sulphuric acid to barium bromate. It is a strong acid.

bromide *See* HALIDE.

bromination A chemical reaction in which a bromine atom is introduced into a molecule. *See also* HALOGENATION.

bromine Symbol Br. A *halogen element; a.n. 35; r.a.m. 79.909; r.d. 3.13; m.p. –7.2°C; b.p. 58.78°C. It is a red volatile liquid at room temperature, having a red-brown vapour. Bromine is obtained from brines in the USA (displacement with chlorine); a small amount is obtained from sea water in Anglesey. Large quantities are used to make 1,2-dibromoethane as a petrol additive. It is also used in the manufacture of many other compounds. Chemically, it is intermediate in reactivity between chlorine and iodine. It forms compounds in which it has oxidation states of 1, 3, 5, or 7. The liquid is harmful to human tissue and the vapour irritates the eyes and throat. The element was discovered in 1826 by Antoine Balard.

SEE WEB LINKS

- Information from the WebElements site

bromoethane (ethyl bromide) A colourless flammable liquid, C_2H_5Br; r.d. 1.46; m.p. –119°C; b.p. 38.4°C. It is a typical *haloalkane, which can be prepared from ethene and hydrogen bromide. Bromoethane is used as a refrigerant.

bromoform *See* TRIBROMOMETHANE; HALOFORMS.

bromomethane (methyl bromide) A colourless volatile nonflammable liquid, CH_3Br; r.d. 1.68; m.p. –93°C; b.p. 3.56°C. It is a typical *haloalkane.

***N*-bromosuccinimide (NBS)** A crystalline solid, C_4O_2NBr, used extensively as a reagent for electrophilic addition of bromine. It acts by producing a small constant supply of bromine in solution

$$C_4O_2NBr + H^+ + Br^- \rightarrow C_4O_2NH + Br_2.$$

bromothymol blue An acid–base *indicator that is yellow in acid solutions and blue in alkaline solutions. It changes colour over the pH range 6–8.

bronchiole A fine respiratory tube in the

lungs of reptiles, birds, and mammals. It is formed by the subdivision of a *bronchus and in reptiles and mammals it terminates in a number of *alveoli.

bronchus (bronchial tube) One of the major air tubes in the *lung. The *trachea divides into two main bronchi, one for each lung, which split into smaller bronchi and then into *bronchioles. The walls of the bronchi are stiffened by rings of cartilage.

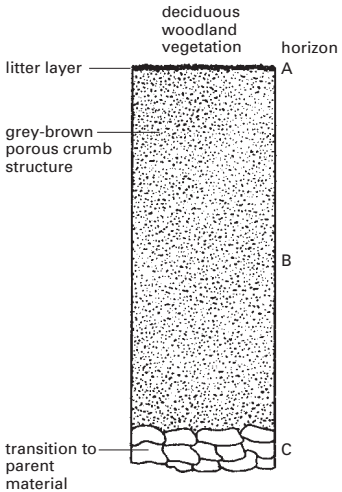
bronze Any of a group of alloys of copper and tin, sometimes with lead and zinc present. The amount of tin varies from 1% to 30%. The alloy is hard and easily cast and extensively used in bearings, valves, and other machine parts. Various improved bronzes are produced by adding other elements; for instance, **phosphor bronzes** contain up to 1% phosphorus. In addition certain alloys of copper and metals other than tin are called bronzes – **aluminium bronze** is a mixture of copper and aluminium. Other special bronzes include *bell metal, *gun metal, and *beryllium bronze.

Brown, Robert (1773–1858) British botanist, born in Scotland. After serving as an army medical officer he met botanist Joseph Banks (1743–1820) in 1798. Three years later Banks recommended him as naturalist on a survey of the Australian coast, during which he collected 4000 plant specimens; it took him five years to classify them. During this work he was the first to distinguish between gymnosperms and angiosperms. Then in 1827, while observing pollen grains in water, he discovered *Brownian movement.

brown algae *See* PHAEOPHYTA.

brown dwarf An astronomical object with a mass intermediate between the mass of a giant planet and that of a small star. The mass of a brown dwarf is large enough to generate energy by gravitational pressure, but not large enough to sustain nuclear fusion. The energy is radiated as electromagnetic radiation. Brown dwarfs are faint objects, which are expected to shine for about 100 million years before cooling. Their masses lie between a few times the mass of Jupiter and 80 times the mass of Jupiter. It has been suggested that brown dwarfs may contribute to the *missing mass of the universe.

brown earth (brown forest soil) A type of soil that is characteristic of those mid-latitude parts of the world that were originally covered with deciduous woodland. It is rich in organic matter derived from the annual leaf fall of deciduous trees and from associated shrubs, herbs, and grasses. Brown earths occur in the NE USA, N China, central Japan, and NW and central Europe. They are important agriculturally, possessing a good crumb structure, mild acidity, and free drainage, and consequently most of the original forest has long since been cleared for agricultural use.



Brown earth profile.

brown fat A darker coloured region of *adipose tissue found in newborn and hibernating animals (in which it may also be called the **hibernating gland**). Compared to normal white *fat, deposits of brown fat are more richly supplied with blood vessels and have numerous mitochondria (hence the brown colour, due to the high concentrations of cytochrome oxidase). They can also be more rapidly converted to heat energy – a process that takes place in the fat cells themselves – especially during arousal from hibernation and during cold stress in young animals. Since the deposits are strategically placed near major blood vessels, the heat they generate warms the blood returning to the heart. Some types of obesity in humans may be linked to a lack of brown fat in affected individuals. *See* THERMOGENESIS.

Brownian movement The continuous random movement of microscopic solid particles (of about 1 micrometre in diameter) when suspended in a fluid medium. First observed by Robert Brown in 1827 when studying pollen grains in water, it was originally thought to be the manifestation of some vital force. It was later recognized to be a consequence of bombardment of the pollen by the continually moving molecules of the liquid. The smaller the particles the more extensive is the motion. The effect is also visible in particles of smoke suspended in a still gas and in the material of dead cells.

SEE WEB LINKS

- A transcript of part of Robert Brown's original 1829 paper
- Jean Perrin's paper

brown-ring test A test for ionic nitrates. The sample is dissolved and iron(II) sulphate solution added in a test tube. Concentrated sulphuric acid is then added slowly so that it forms a separate layer. A brown ring (of $Fe(NO)SO_4$) at the junction of the liquids indicates a positive result.

brucite A mineral form of *magnesium hydroxide, $Mg(OH)_2$.

brush An electrical contact to a moving commutator on a motor or generator. It is made of a specially prepared form of carbon and is kept in contact with the moving part by means of a spring.

brush border A region of surface epithelium that possesses densely packed microvilli (*see* MICROVILLUS), rather like the bristles of a brush. This greatly increases the surface area of the epithelium and facilitates the absorption of materials. Brush borders are found in the convoluted tubules of the kidney and in the lining of the small intestine.

brush discharge A luminous discharge from a conductor that takes the form of luminous branching threads that penetrate into the surrounding gas. It is a form of *corona and it occurs when the electric field near the surface of the conductor exceeds a certain value but is not sufficiently high for a spark to appear.

brusselator A type of chemical reaction mechanism that leads to an *oscillating reaction. It involves the conversion of reactants A and B into products C and B by a series of four steps:

$$A \rightarrow X$$
$$2X + Y \rightarrow 3Y$$
$$B + X \rightarrow Y + C$$
$$X \rightarrow D$$

Autocatalysis occurs as in the *Lotka–Volterra mechanism and the *oregonator. If the concentrations of A and B are maintained constant, the concentrations of X and Y oscillate with time. A graph of the concentration of X against that of Y is a closed loop (the **limit cycle** of the reaction). The reaction settles down to this limit cycle whatever the initial concentrations of X and Y, i.e. the limit cycle is an **attractor** for the system. The reaction mechanism is named after the city of Brussels, where the research group that discovered it is based.

Bryophyta A phylum of simple plants – the mosses – possessing no vascular tissue and rudimentary rootlike organs (rhizoids). They grow in a variety of damp habitats, from fresh water to rock surfaces. Some use other plants for support. Mosses show a marked *alternation of generations between gamete-bearing forms (gametophytes) and spore-bearing forms (sporophytes): they possess erect or prostrate leafy stems (the gametophyte generation, which is *haploid); these give rise to leafless stalks bearing capsules (the sporophyte generation, which is *diploid), the latter being dependent on the former for water and nutrients. Spores formed in the capsules are released and grow to produce new plants.

Formerly, this phylum also included the liverworts (*see* HEPATOPHYTA) and the mosses were classified as a class (Musci) of the Bryophyta. The term 'bryophytes' is still used informally to refer to both the mosses and the liverworts.

SEE WEB LINKS

- A resource devoted to mosses, liverworts, and hornworts from Southern Illinois University, Carbondale

Bryozoa (Ectoprocta) A phylum of aquatic, mainly marine, invertebrates – the moss animals and sea mats. They live in colonies, 50 cm or more across, which are attached to rocks, seaweeds, or shells. The individuals making up the colonies are about 1 mm long and superficially resemble cnidarian *polyps, with a mouth surrounded by ciliated tentacles that trap minute particles of organic matter in the water. Some have a horny or calcareous outer skeleton into

which the body can be withdrawn. Bryozoans are placed in the clade Lophotrochozoa.

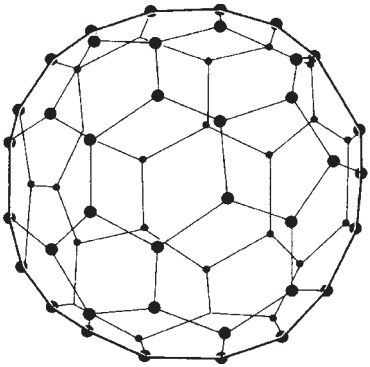
BSE *See* BOVINE SPONGIFORM ENCEPHALOPATHY.

bubble chamber A device for detecting ionizing radiation. It consists of a chamber containing a liquid, often hydrogen, kept at slightly above its boiling point at a preliminary pressure that is high enough to prevent boiling. Immediately before the passage of the ionizing particles the pressure is reduced, and the particles then act as centres for the formation of bubbles, which can be photographed to obtain a record of the particles' tracks. The device was invented in 1952 by Donald Glaser. *Compare* CLOUD CHAMBER.

buccal cavity (oral cavity) The mouth cavity: the beginning of the *alimentary canal, which leads to the pharynx and (in vertebrates) to the oesophagus. In vertebrates it is separated from the nasal cavity by the *palate. In mammals it contains the tongue and teeth, which assist in the mechanical breakdown of food, and the openings of the *salivary gland ducts.

Buchner funnel A type of funnel with an internal perforated tray on which a flat circular filter paper can be placed, used for filtering by suction. It is named after the German chemist Eduard Buchner (1860–1917).

buckminsterfullerene A form of carbon composed of clusters of 60 carbon atoms bonded together in a polyhedral structure composed of pentagons and hexagons (see illustration). Originally it was identified in 1985 in products obtained by firing a high-power laser at a graphite target. It can be made by an electric arc struck between graphite electrodes in an inert atmosphere. The molecule, C_{60}, was named after the US architect Richard Buckminster Fuller (1895–1983) because of the resemblance of the structure to the geodesic dome, which Fuller invented. The molecules are informally called **buckyballs**; more formally, the substance itself is also called **fullerene**. The substance is a yellow crystalline solid (**fullerite**), soluble in benzene.



Buckminsterfullerene structure.

Various fullerene derivatives are known in which organic groups are attached to carbon atoms on the sphere. In addition, it is possible to produce novel enclosure compounds by trapping metal ions within the C_{60} cage. Some of these have semiconducting properties. The electric-arc method of producing C_{60} also leads to a smaller number of fullerenes such as C_{70}, which have less symmetrical molecular structures. It is also possible to produce forms of carbon in which the atoms are linked in a cylindrical, rather than spherical, framework with a diameter of a few nanometres. They are known as **buckytubes** (or **nanotubes**).

SEE WEB LINKS

- Information about IUPAC nomenclature and representation of fullerenes and related compounds

buckyball *See* BUCKMINSTERFULLERENE.

buckytube *See* BUCKMINSTERFULLERENE.

bud **1.** (in botany) A condensed immature shoot with a short stem bearing small folded or rolled leaves. The outer leaves of a bud are often scalelike and protect the delicate inner leaves. A **terminal** (or **apical**) **bud** exists at the tip of a stem or branch while **axillary** (or **lateral**) **buds** develop in the *axils of leaves. However, in certain circumstances buds can be produced anywhere on the surface of a plant. Some buds remain dormant, but may become active if the terminal bud is removed. It is common gardening practice to remove the terminal buds of some shoots to induce the development of lateral shoots from axillary buds. *See also* APICAL DOMINANCE. **2.** (in biology) An outgrowth from a parent organism that breaks away and develops into a new individual in the process of *budding.

budding **1.** (in biology) A method of asexual reproduction in which a new individual is derived from an outgrowth (**bud**) that be-

comes detached from the body of the parent. In animals the process is also called **gemmation**; it is common in cnidarians (e.g. *Hydra*) and also occurs in some sponges and other invertebrates. Among fungi, budding is characteristic of the yeasts. **2.** (in horticulture) A method of grafting in which a bud of the scion is inserted onto the stock, usually beneath the bark.

buffer A solution that resists change in pH when small amounts of an acid or alkali are added over a certain range or when the solution is diluted. Acidic buffers consist of a weak acid with a salt of the acid. The salt provides the negative ion A^-, which is the conjugate base of the acid HA. An example is carbonic acid and sodium hydrogencarbonate. Basic buffers have a weak base and a salt of the base (to provide the conjugate acid). An example is ammonia solution with ammonium chloride.

In an acidic buffer, for example, molecules HA and ions A^- are present. When acid is added most of the extra protons are removed by the base:

$$A^- + H^+ \rightarrow HA$$

When base is added, most of the extra hydroxide ions are removed by reaction with undissociated acid:

$$OH^- + HA \rightarrow A^- + H_2O$$

Thus, the addition of acid or base changes the pH very little. The hydrogen-ion concentration in a buffer is given by the expression

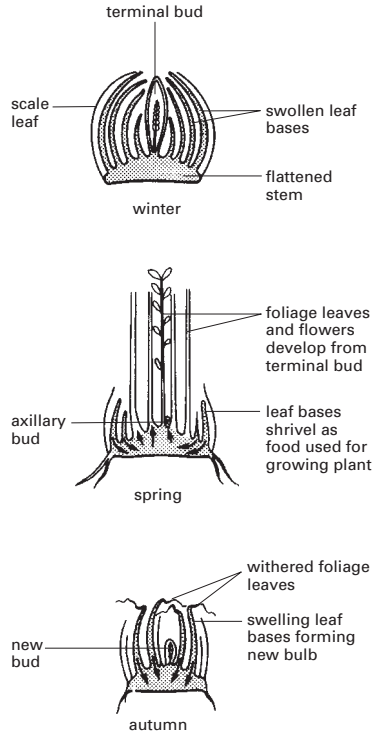
$$K_a = [H^+] = [A^-] / [HA]$$

i.e. it depends on the ratio of conjugate base to acid. As this is not altered by dilution, the hydrogen-ion concentration for a buffer does not change much during dilution.

In the laboratory, buffers are used to prepare solutions of known stable pH. Natural buffers occur in living organisms, where the biochemical reactions are very sensitive to change in pH (*see* ACID–BASE BALANCE). The main natural buffers are H_2CO_3/HCO_3^- and $H_2PO_4^-/HPO_4^{2-}$. Buffer solutions are also used in medicine (e.g. in intravenous injections), in agriculture, and in many industrial processes (e.g. dyeing, fermentation processes, and the food industry).

bugs *See* HEMIPTERA.

bulb An underground plant organ that enables a plant to survive from one growing season to the next. It is a modified shoot with a short flattened stem. A terminal bud develops at the centre of its upper surface, surrounded by swollen leaf bases that contain food stored from the previous growing season. Papery brown scale leaves cover the outside of the bulb. The stored food is used in the growing season when the terminal bud produces foliage leaves and flowers. The new leaves photosynthesize and some of the manufactured food passes into the leaf bases forming a new bulb (see illustration). If more than one bud develops, then additional bulbs form, resulting in vegetative propagation. Examples of bulb-forming plants are daffodil, onion, and tulip. *Compare* CORM.



Development of a bulb.

bulbil A small bulblike organ that may develop in place of a flower, from an axillary bud, or at the base of a stem in certain plants. If it becomes detached it develops into a new plant.

bulk modulus *See* ELASTIC MODULUS.

bulla The rounded hollow projection of

bone from the skull that encloses the *middle ear in mammals.

bumping Violent boiling of a liquid caused by superheating so that bubbles form at a pressure above atmospheric pressure. It can be prevented by putting pieces of porous pot in the liquid to enable bubbles of vapour to form at the normal boiling point.

buna rubber A type of synthetic rubber based on polymerization of butadiene (buta-1,3-diene). The name comes from Bu (for butadiene) and Na (for sodium, which was used as a catalyst in the original polymerization reaction). An improved form, known as **Buna-S**, was developed by copolymerizing butadiene with styrene. In 1934, **Buna-N** was invented, in which the styrene was replaced by acrylonitrile, giving a product with better oil resistance (*see* NITRILE RUBBER).

bunching In quantum optics, the arrival of photons at a detector grouped more closely together than they would be if grouped randomly. Bunching can also be described without quantum effects in terms of fluctuations of the classical electromagnetic field. The arrival of photons at a detector less closely together than randomly is called **antibunching** and is a specifically quantum-mechanical phenomenon.

bundle of His The specialized cardiac muscle fibres in the mammalian heart that receive electrical stimuli from the *atrioventricular node and transmit them throughout the network of *Purkyne fibres. This allows the excitation to reach all parts of the ventricles rapidly and initiates a wave of contraction to expel blood into the aorta and pulmonary artery. It is named after Wilhelm His (1831–1904).

Bunsen, Robert Wilhelm (1811–99) German chemist, who held professorships at Kassel, Marburg, and Heidelberg. His early researches on arsenic-containing compounds cost him an eye in an explosion. He then turned to gas analysis and spectroscopy, enabling him and *Kirchhoff to discover the elements *caesium (1860) and *rubidium (1861). He also popularized the use of the *Bunsen burner.

Bunsen burner A laboratory gas burner having a vertical metal tube into which the gas is led, with a hole in the side of the base of the tube to admit air. The amount of air can be regulated by a sleeve on the tube. When no air is admitted the flame is luminous and smoky. With air, it has a faintly visible hot outer part (the oxidizing part) and an inner blue cone where combustion is incomplete (the cooler reducing part of the flame). The device is named after Robert Bunsen, who used a similar device (without a regulating sleeve) in 1855.

Bunsen cell A *primary cell consisting of a zinc cathode immersed in dilute sulphuric acid and a carbon anode immersed in concentrated nitric acid. The electrolytes are separated by a porous pot. The cell gives an e.m.f. of about 1.9 volts.

buoyancy The upward thrust on a body immersed in a fluid. This force is equal to the weight of the fluid displaced (*see* ARCHIMEDES' PRINCIPLE).

burette A graduated glass tube with a tap at one end leading to a fine outlet tube, used for delivering known volumes of a liquid (e.g. in titration).

Burgess shale A fossil-rich deposit of shale and slate dating from the mid-Cambrian period (about 520 million years ago) and located in the Burgess Pass in the Rocky Mountains of British Columbia, Canada. First excavated in 1909, it has since yielded one of the world's oldest assemblages of fossilized marine invertebrates and early vertebrate animals, as well as algae and sponges. The species described include brachiopods, crustaceans, trilobites, and other arthropods, plus a remarkably well-preserved array of fossil worms and other soft-bodied animals. Many forms are of uncertain classification and have been assigned to new phyla. Such great diversity of fossils in deposits from this period is seen by some biologists as evidence for a burst of rapid evolution (*see* CAMBRIAN EXPLOSION).

Burnet, Sir Frank Macfarlane (1899–1985) Australian virologist, who spent his working life at the Walter and Eliza Hall Institute in Melbourne. In the early 1930s he developed a method of growing influenza virus in chick embryos. He later discovered that immunological tolerance (failure of the immune response) required repeated exposure to the antigen. For this work he shared the 1960 Nobel Prize for physiology or medicine with Sir Peter *Medawar. He also proposed the *clonal selection theory.

bus A set of conducting paths – wires or optical fibres – connecting several components of a computer system and allowing the com-

ponents to send signals to each other. The components take it in turns to transmit.

b

buta-1,3-diene (butadiene) A colourless gaseous hydrocarbon, CH_2:CHCH:CH_2; m.p. –109°C; b.p. –4.5°C. It is made by catalytic dehydrogenation of butane (from petroleum or natural gas) and polymerized in the production of synthetic rubbers. The compound is a conjugated *diene in which the electrons in the pi orbitals are partially delocalized over the whole molecule. It can have trans and cis forms, the latter taking part in *Diels–Alder reactions.

butanal (butyraldehyde) A colourless flammable liquid aldehyde, C_3H_7CHO; r.d. 0.8; m.p. –99°C; b.p. 75.7°C.

butane A gaseous hydrocarbon, C_4H_{10}; d. 0.58 g cm^{-3}; m.p. –138°C; b.p. 0°C. Butane is obtained from petroleum (from refinery gas or by cracking higher hydrocarbons). The fourth member of the *alkane series, it has a straight chain of carbon atoms and is isomeric with 2-methylpropane ($CH_3CH(CH_3)CH_3$, formerly called **isobutane**). It can easily be liquefied under pressure and is supplied in cylinders for use as a fuel gas. It is also a raw material for making buta-1,3-diene (for synthetic rubber).

butanedioic acid (succinic acid) A colourless crystalline fatty acid, $(CH_2)_2(COOH)_2$; r.d. 1.6; m.p. 185°C; b.p. 235°C. A weak carboxylic acid, it is produced by fermentation of sugar or ammonium tartrate and used as a sequestrant and in making dyes. It occurs in living organisms as an intermediate in metabolism, especially in the *Krebs cycle.

butanoic acid (butyric acid) A colourless liquid water-soluble acid, C_3H_7COOH; r.d. 0.96; b.p. 163°C. It is a weak acid ($K_a = 1.5 \times 10^{-5}$ mol dm^{-3} at 25°C) with a rancid odour. Its esters are present in butter and in human perspiration. The acid is used to make esters for flavourings and perfumery.

butanol Either of two aliphatic alcohols with the formula C_4H_9OH. **Butan-1-ol**, $CH_3(CH_2)_3OH$, is a primary alcohol; r.d. 0.81; m.p. –89.5°C; b.p. 117.3°C. **Butan-2-ol**, $CH_3CH(OH)C_2H_5$, is a secondary alcohol; r.d. 0.81; m.p. –114.7°C; b.p. 100°C. Both are colourless volatile liquids obtained from butane and are used as solvents.

butanone (methyl ethyl ketone) A colourless flammable water-soluble liquid, $CH_3COC_2H_5$; r.d. 0.8; m.p. –86.4°C; b.p. 79.6°C. It can be made by the catalytic oxidation of butane and is used as a solvent.

butenedioic acid Either of two isomers with the formula HCOOHC:CHCOOH. Both compounds can be regarded as derivatives of ethene in which a hydrogen atom on each carbon has been replaced by a –COOH group. The compounds show cis–trans isomerism. The trans form is **fumaric acid** (r.d. 1.64; sublimes at 165°C) and the cis form is **maleic acid** (r.d. 1.59; m.p. 139–140°C). Both are colourless crystalline compounds used in making synthetic resins. The cis form is rather less stable than the trans form and converts to the trans form at 120°C. Unlike the trans form it can eliminate water on heating to form a cyclic anhydride containing a –CO.O.CO– group (**maleic anhydride**). Fumaric acid is an intermediate in the *Krebs cycle.

butterflies *See* LEPIDOPTERA.

butterfly effect *See* CHAOS.

buttress root *See* PROP ROOT.

butyl group The organic group $CH_3(CH_2)_3$–.

butyl rubber A type of synthetic rubber obtained by copolymerizing 2-methylpropene (CH_2:$C(CH_3)CH_3$; isobutylene) and methylbuta-1,3-diene (CH_2:$C(CH_3)$CH:CH_2, isoprene). Only small amounts of isoprene (about 2 mole %) are used. The rubber can be vulcanized. Large amounts were once used for tyre inner tubes.

butyraldehyde *See* BUTANAL.

butyric acid *See* BUTANOIC ACID.

Buys Ballot's law A law relating to winds stating that observers with their backs to the wind will experience a lower pressure on the left than on the right in the northern hemisphere, and lower on the right than on the left in the southern hemisphere. The law was propounded by the Dutch meteorologist Christoph Buys Ballot (1817–90) in 1857.

by-product A compound formed during a chemical reaction at the same time as the main product. Commercially useful by-products are obtained from a number of industrial processes. For example, calcium chloride is a by-product of the *Solvay process for making sodium carbonate. Propanone is a by-product in the manufacture of *phenol.

byte A subdivision of a *word in a computer, it usually consists of eight *bits. A kilobyte is 1024 bytes (not 1000 bytes).

BZ *See* BENZOYLECGONINE.

B–Z reaction (Belousov–Zhabotinskii reaction) A chemical reaction that shows a periodic colour change between magenta and blue with a period of about one minute. It occurs with a mixture of sulphuric acid, potassium bromate(V), cerium sulphate, and propanedioic acid. The colour change is caused by alternating oxidation–reductions in which cerium changes its oxidation state (Ce^{3+} gives a magenta solution while Ce^{4+} gives a blue solution). The B–Z reaction is an example of a chemical *oscillating reaction – a reaction in which there is a regular periodic change in the concentration of one or more reactants. The mechanism is highly complicated, involving a large number of steps. *See* BRUSSELATOR.