A

aa *See* LAVA.

AAR *See* AMINO ACID RACEMIZATION.

AAS *See* ATOMIC ABSORPTION SPECTROSCOPY.

ab- A prefix attached to the name of a practical electrical unit to provide a name for a unit in the electromagnetic system of units (*see* ELECTROMAGNETIC UNITS), e.g. abampere, abcoulomb, abvolt. The prefix is an abbreviation of the word 'absolute' as this system is also known as the **absolute system**. *Compare* STAT-. In modern practice both absolute and electrostatic units have been replaced by *SI units.

abdomen The posterior region of the body trunk of animals. In vertebrates it contains the stomach and intestines and the organs of excretion and reproduction. It is particularly well defined in mammals, being separated from the *thorax by the *diaphragm. In many arthropods, such as insects and spiders, it may be segmented.

Abelian group *See* GROUP.

aberration **1.** (in optics) A defect in the image formed by a lens or curved mirror. In **chromatic aberration** the image formed by a lens (but not a mirror) has coloured fringes as a result of the different extent to which light of different colours is refracted by glass. It is corrected by using an *achromatic lens. In **spherical aberration**, the rays from the object come to a focus in slightly different positions as a result of the curvature of the lens or mirror. For a mirror receiving light strictly parallel with its axis, this can be corrected by using a parabolic surface rather than a spherical surface. Spherical aberration in lenses is minimized by making both surfaces contribute equally to the ray deviations, and can be lessened (though with reduced image brightness) by the use of diaphragms to let light pass only through the centre part of the lens. *See also* ASTIGMATISM; COMA. **2.** (in astronomy) The apparent displacement in the position of a star as a result of the earth's motion round the sun. Light appears to come from a point that is slightly displaced in the direction of the earth's motion. The angular displacement $\alpha = v/c$, where v is the earth's orbital velocity and c is the speed of light.

abiogenesis The origin of living from nonliving matter, as by *biopoiesis. *See also* SPONTANEOUS GENERATION.

abiotic factor Any of the nonliving factors that make up the **abiotic environment** in which living organisms occur. They include all the aspects of climate, geology, and atmosphere that may affect the biotic environment. *Compare* BIOTIC FACTOR.

abomasum The fourth and final chamber of the stomach of ruminants. It leads from the *omasum and empties into the small intestine. The abomasum is referred to as the 'true stomach' as it is in this chamber that protein digestion occurs, in acidic conditions. *See* RUMINANTIA.

ABO system One of the most important human *blood group systems. The system is based on the presence or absence of *antigens A and B on the surface of red blood cells and of *antibodies against these in blood serum. A person whose blood contains either or both these antibodies cannot receive a transfusion of blood containing the corresponding antigens as this would cause the red cells to clump (*see* AGGLUTINATION). The table overleaf illustrates the basis of the system: people of blood group O are described as 'universal donors' as they can give blood to those of any of the other groups. *See also* IMMUNE RESPONSE.

abscisic acid A naturally occurring plant hormone that appears to be involved primarily in seed maturation, stress responses (e.g. to heat and waterlogging), and in regulating closure of leaf pores (stomata). In seeds, it promotes the synthesis of storage protein and prevents premature germination. In leaves, abscisic acid is produced in large amounts when the plant lacks sufficient water, promoting closure of stomata and hence reducing further water losses. It was formerly believed to play a central role in *abscission, hence the name.

a

Group	Antigens on red cell surface	Antibodies in serum	Blood group of people donor can receive blood from	Blood group of people donor can give blood to
A	A	anti-B	A, O	A, AB
B	B	anti-A	B, O	B, AB
AB	A and B	none	A, B, AB, O	AB
O	neither A nor B	anti-A and anti-B	O	A, B, AB, O

ABO system.

abscissa *See* CARTESIAN COORDINATES.

abscission The separation of a leaf, fruit, or other part from the body of a plant. It involves the formation of an **abscission zone**, at the base of the part, within which a layer of cells (**abscission layer**) breaks down. This process is suppressed so long as sufficient amounts of *auxin, a plant hormone, flow from the part through the abscission zone. However, if the auxin flow declines, for example due to injury or ageing, abscission is activated. Ethylene (*ethene) acts as the primary trigger for abscission, inducing cells in the abscission zone to produce cellulase enzymes that degrade cell walls.

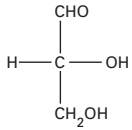
absolute **1.** Not dependent on or relative to anything else, e.g. *absolute zero. **2.** Denoting a temperature measured on an **absolute scale**, a scale of temperature based on absolute zero. The usual absolute scale now is that of thermodynamic *temperature; its unit, the kelvin, was formerly called the degree absolute (°A) and is the same size as the degree Celsius. In British engineering practice an absolute scale with Fahrenheit-size degrees has been used: this is the Rankine scale.

absolute alcohol *See* ETHANOL.

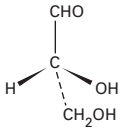
absolute configuration A way of denoting the absolute structure of an optical isomer (*see* OPTICAL ACTIVITY). Two conventions are in use: The D–L convention relates the structure of the molecule to some reference molecule. In the case of sugars and similar compounds, the dextrorotatory form of glyceraldehyde ($HOCH_2CH(OH)CHO$), 2,3-dihydroxypropanal) was used. The rule is as follows. Write the structure of this molecule down with the asymmetric carbon in the centre, the –CHO group at the top, the –OH on the right, the $–CH_2OH$ at the bottom, and the –H on the left. Now imagine that the central carbon atom is at the centre of a tetrahedron with the four groups at the corners and that the –H and –OH come out of the paper and the –CHO and $–CH_2OH$ groups go into the paper. The resulting three-dimensional structure was taken to be that of *d*-glyceraldehyde and called D-glyceraldehyde. Any compound that contains an asymmetric carbon atom having this configuration belongs to the D-series. One having the opposite configuration belongs to the L-series. It is important to note that the prefixes D- and L- do not stand for dextrorotatory and laevorotatory (they are not the same as *d*- and *l*-). In fact the arbitrary configuration assigned to D-glyceraldehyde is now known to be the correct one for the dextrorotatory form, although this was not known at the time. However, all D-compounds are not dextrorotatory. For instance, the acid obtained by oxidizing the –CHO group of glyceraldehyde is glyceric acid (1,2-dihydroxypropanoic acid). By convention, this belongs to the D-series, but it is in fact laevorotatory; i.e. its name can be written as D-glyceric acid or *l*-glyceric acid. To avoid confusion it is better to use + (for dextrorotatory) and – (for laevorotatory), as in D-(+)-glyceraldehyde and D-(–)-glyceric acid.

The D–L convention can also be used with alpha amino acids (compounds with the $–NH_2$ group on the same carbon as the –COOH group). In this case the molecule is imagined as being viewed along the H–C bond between the hydrogen and the asymmetric carbon atom. If the clockwise order of the other three groups is $–CO$OH, $–R$, $–NH_2$, the amino acid belongs to the D-series; otherwise it belongs to the L-series. This is known as the **CORN rule**.

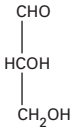
The R–S convention is a convention based on priority of groups attached to the chiral carbon atom. The order of priority is I, Br, Cl, SO_3H, $OCOCH_3$, OCH_3, OH, NO_2, NH_2,



planar formula

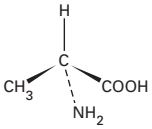


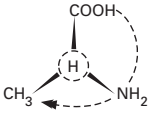
structure in 3 dimensions



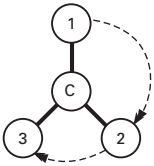
Fischer projection

D-(+)-glyceraldehyde (2,3-dihydroxypropanal)

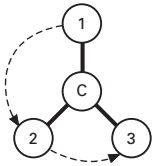




D-alanine (R is CH_2 in the CORN rule). The molecule is viewed with H on top



R–configuration



S–configuration

R–S system. The lowest priority group is behind the chiral carbon atom

Absolute configuration.

$COOCH_3$, $CONH_2$, $COCH_3$, CHO, CH_2OH, C_6H_5, C_2H_5, CH_3, H, with hydrogen lowest. The molecule is viewed with the group of lowest priority behind the chiral atom. If the clockwise arrangement of the other three groups is in descending priority, the compound belongs to the R-series; if the descending order is anticlockwise it is in the S-series. D-(+)-glyceraldehyde is R-(+)-glyceraldehyde. See illustration.

SEE WEB LINKS

- Information about IUPAC nomenclature for the R–S system

absolute expansivity *See* EXPANSIVITY.

absolute humidity *See* HUMIDITY.

absolute permittivity *See* PERMITTIVITY.

absolute pitch (perfect pitch) The ability of a person to identify and reproduce a note without reference to a tuned musical instrument.

absolute space Space that exists as a background to events and processes and is not affected by objects or other entities in the universe. The idea underpins Newtonian physics, although many physicists have always regarded absolute space as an undesirable concept and suggested, as in *Mach's principle, that fundamental physics should be described by *relational theories.

absolute temperature *See* ABSOLUTE; TEMPERATURE.

absolute time Time that exists independently of any events or processes in the universe. Like *absolute space, absolute time is a basic concept in Newtonian physics.

absolute value (modulus) The square root of the sum of the squares of the real

a

numbers in a *complex number, i.e. the absolute value of the complex number $z = x + iy$ is $|z| = \sqrt{(x^2 + y^2)}$.

absolute zero Zero of thermodynamic *temperature (0 kelvin) and the lowest temperature theoretically attainable. It is the temperature at which the kinetic energy of atoms and molecules is minimal. It is equivalent to –273.15°C or –459.67°F. *See also* ZERO-POINT ENERGY; CRYOGENICS.

absorbed dose *See* DOSE.

absorptance Symbol α. The ratio of the radiant or luminous flux absorbed by a body to the flux falling on it. Formerly called **absorptivity**, the absorptance of a *black body is by definition 1.

absorption **1.** (in chemistry) The take up of a gas by a solid or liquid, or the take up of a liquid by a solid. Absorption differs from *adsorption in that the absorbed substance permeates the bulk of the absorbing substance. **2.** (in physics) The conversion of the energy of electromagnetic radiation, sound, streams of particles, etc., into other forms of energy on passing through a medium. A beam of light, for instance, passing through a medium, may lose intensity because of two effects: scattering of light out of the beam, and absorption of photons by atoms or molecules in the medium. When a photon is absorbed, there is a transition to an excited state. **3.** (in biology) The movement of fluid or a dissolved substance across a plasma membrane. In many animals, for example, soluble food material is absorbed into cells lining the alimentary canal and thence into the blood. In plants, water and mineral salts are absorbed from the soil by the *roots. *See* OSMOSIS; TRANSPORT PROTEIN.

absorption coefficient **1.** (in physics) *See* LAMBERT'S LAWS. **2.** (in chemistry) The volume of a given gas, measured at standard temperature and pressure, that will dissolve in unit volume of a given liquid.

absorption indicator *See* ADSORPTION INDICATOR.

absorption spectrum *See* SPECTRUM.

absorptivity *See* ABSORPTANCE.

ABS plastic Any of a class of plastics based on acrylonitrile–butadiene–styrene copolymers.

abundance **1.** The ratio of the total mass of a specified element in the earth's crust to the total mass of the earth's crust, often expressed as a percentage. For example, the abundance of aluminium in the earth's crust is about 8%. **2.** The ratio of the number of atoms of a particular isotope of an element to the total number of atoms of all the isotopes present, often expressed as a percentage. For example, the abundance of uranium–235 in natural uranium is 0.71%. This is the **natural abundance**, i.e. the abundance as found in nature before any enrichment has taken place.

abyssal zone The lower depths of the ocean (below approximately 2000 metres), where there is effectively no light penetration. Abyssal organisms are adapted for living under high pressures in cold dark conditions. *See also* APHOTIC ZONE.

a.c. *See* ALTERNATING CURRENT.

acac The symbol for the *acetylacetonato ligand, used in formulae.

accelerant A flammable material used to start and spread a fire in cases of arson. Petrol and paraffin are the substances commonly used. Traces of accelerant are detectable by gas chromatography in forensic work.

acceleration Symbol *a*. The rate of increase of speed or velocity. It is measured in $m\ s^{-2}$. For a body moving linearly with constant acceleration a from a speed u to a speed v,

$$a = (v - u)/t = (v^2 - u^2)/2s$$

where t is the time taken and s the distance covered.

If the acceleration is not constant it is given by $dv/dt = d^2s/dt^2$. If the motion is not linear the vector character of displacement, velocity, and acceleration must be considered. *See also* ROTATIONAL MOTION.

acceleration of free fall Symbol *g*. The acceleration experienced by any massive object falling freely in the earth's gravitational field. Experimentally this is almost constant for all positions near the earth's surface, independent of the nature of the falling body (provided air resistance is eliminated). This is taken to indicate the strict proportionality of *weight (the force causing the acceleration) and inertial *mass, on the basis of Newton's second law of motion (*see* NEWTON'S LAWS OF MOTION). There is some variation of g with latitude, because of the earth's rotation and because the earth is

not completely spherical. The standard value is taken as 9.806 65 m s^{-2}. The acceleration of free fall is also called the **acceleration due to gravity**.

accelerator **1.** (in physics) An apparatus for increasing the kinetic energies of charged particles, used for research in nuclear and particle physics. *See* CYCLOTRON; LINEAR ACCELERATOR; SYNCHROCYCLOTRON; SYNCHROTRON. **2.** (in chemistry) A substance that increases the rate of a chemical reaction, i.e. a catalyst.

SEE WEB LINKS

- A list of world particle accelerators and accelerator laboratories, with links, from the ELSA website at the University of Bonn

acceptor **1.** (in chemistry and biochemistry) A compound, molecule, ion, etc., to which electrons are donated in the formation of a coordinate bond. **2.** (in biochemistry) A *receptor that binds a hormone without any apparent biological response. **3.** (in physics) A substance that is added as an impurity to a *semiconductor because of its ability to accept electrons from the valence bands, causing *p*-type conduction by the mobile positive holes left. *Compare* DONOR.

acceptor levels Energy levels of an acceptor atom in a *semiconductor, such as aluminium, in silicon. These energy levels are very near the top of the valence band, and therefore cause *p*-type conduction. *See also* ENERGY BANDS.

access point (wireless access point) A device that acts as the core of a wireless network. It communicates with wireless nodes within its range and provides the necessary facilities for them to network successfully. Access points commonly also manage a link to a wired network, allowing their nodes to link with corporate networks, the Internet, etc.

acclimation The physiological changes occurring in an organism in response to a change in a particular environmental factor (e.g. temperature), especially under laboratory conditions. Thermal acclimation studies reveal how such properties as metabolic rate, muscle contractility, nerve conduction, and heart rate differ between cold- and warm-acclimated members of the same species. These changes occur naturally during *acclimatization and equip the organism for living in, say, cold or warm conditions.

acclimatization **1.** The progressive adaptation of an organism to any change in its natural environment that subjects it to physiological stress. **2.** The overall sum of processes by which an organism attempts to compensate for conditions that would substantially reduce the amount of oxygen delivered to its cells. *Compare* ACCLIMATION.

accommodation **1.** (in animal physiology) Focusing: the process by which the focal length of the *lens of the eye is changed so that clear images of objects at a range of distances are displayed on the retina. In humans and some other mammals accommodation is achieved by reflex adjustments in the shape of the lens brought about by relaxation and contraction of muscles within the *ciliary body. **2.** (in animal behaviour) Adjustments made by an animal's nervous or sensory systems in response to continuously changing environmental conditions.

accretion The way in which collisions with relatively slow-moving smaller objects add to the mass of a larger celestial object. The process accelerates as the increased mass strengthens the gravitational field of the larger object. For example, the planets are thought to have formed by the accretion of dust particles onto *planetesimals. Other accreting objects probably include black holes and protostars.

accretion disc A disc-shaped rotating mass formed by gravitational attraction. *See* BLACK HOLE; NEUTRON STAR; WHITE DWARF.

accumulator (secondary cell; storage battery) A type of *voltaic cell or battery that can be recharged by passing a current through it from an external d.c. supply. The charging current, which is passed in the opposite direction to that in which the cell supplies current, reverses the chemical reactions in the cell. The common types are the *lead–acid accumulator and the *nickel–iron and nickel–cadmium accumulators. *See also* SODIUM–SULPHUR CELL.

acellular Describing tissues or organisms that are not made up of separate cells but often have more than one nucleus (*see* SYNCYTIUM). Examples of acellular structures are muscle fibres. *Compare* UNICELLULAR.

acentric Describing an aberrant chromosome fragment that lacks a centromere. Such fragments are normally lost because they are unable to orientate properly during cell division.

a

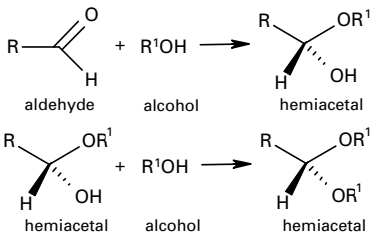
acetaldehyde *See* ETHANAL.

acetaldol *See* ALDOL REACTION.

acetals Organic compounds formed by addition of alcohol molecules to aldehyde molecules. If one molecule of aldehyde (RCHO) reacts with one molecule of alcohol (R′OH) a **hemiacetal** is formed (RCH(OH)OR′). The rings of aldose sugars are hemiacetals. Further reaction with a second alcohol molecule produces a full acetal ($RCH(OR')_2$). It is common to refer to both types of compounds simply as 'acetals'. The formation of acetals is reversible; acetals can be hydrolysed back to aldehydes in acidic solutions. In synthetic organic chemistry aldehyde groups are often converted into acetal groups to protect them before performing other reactions on different groups in the molecule. *See also* KETALS.

SEE WEB LINKS

- Information about IUPAC nomenclature



Formation of acetals.

acetamide *See* ETHANAMIDE.

acetanilide A white crystalline primary amide of ethanoic acid, $CH_3CONHC_6H_5$; r.d. 1.2; m.p. 114.3°C; b.p. 304°C. It is made by reacting phenylamine (aniline) with excess ethanoic acid or ethanoic anhydride and is used in the manufacture of dyestuffs and rubber. The full systematic name is N-**phenylethanamide**.

acetate *See* ETHANOATE.

acetate process *See* RAYON.

acetic acid *See* ETHANOIC ACID.

acetoacetic acid *See* 3-OXOBUTANOIC ACID.

acetoacetic ester *See* ETHYL 3-OXOBUTANOATE.

acetone *See* PROPANONE; KETONE BODY.

acetone–chlor–haemin test (Wagenaar test) A *presumptive test for blood in which a small amount of acetone (propenal) is added to the bloodstain, followed by a drop of hydrochloric acid. Haemoglobin produces derivatives such as haematin and haemin, forming small characteristic crystals that can be identified under a microscope.

acetylacetonato The ion $(CH_3COCHCOCH_3)^-$, functioning as a bidentate ligand coordinating through the two oxygen atoms. In formulae, the symbol **acac** is used.

acetylation *See* ACYLATION.

acetyl chloride *See* ETHANOYL CHLORIDE.

acetylcholine (ACh) One of the main *neurotransmitters of the vertebrate nervous system. It is released at some (**cholinergic**) nerve endings and may be excitatory or inhibitory; it initiates muscular contraction at *neuromuscular junctions. Once acetylcholine has been released it has only a transitory effect because it is rapidly broken down by the enzyme *cholinesterase.

acetylcholinesterase *See* CHOLINESTERASE.

acetyl coenzyme A (acetyl CoA) A compound formed in the mitochondria when an acetyl group (CH_3CO–), derived from the breakdown of fats, proteins, or carbohydrates (via *glycolysis), combines with the thiol group (–SH) of *coenzyme A. Acetyl CoA feeds into the energy generating *Krebs cycle and also plays a role in the synthesis and oxidation of fatty acids.

acetylene *See* ETHYNE.

acetylenes *See* ALKYNES.

acetyl group *See* ETHANOYL GROUP.

acetylide *See* CARBIDE.

achene A dry indehiscent fruit formed from a single carpel and containing a single seed. An example is the feathery achene of clematis. Variants of the achene include the *caryopsis, *cypsela, *nut, and *samara. *See also* ETAERIO.

Acheson process An industrial process for the manufacture of graphite by heating coke mixed with clay. The reaction involves the production of silicon carbide, which loses silicon at 4150°C to leave graphite. The process was patented in 1896 by the US inventor Edward Goodrich Acheson (1856–1931).

achiral Describing a molecule that does not contain a *chirality element.

achondrite A stony meteorite that has no spherical silicate particles (chondrules) found in the meteorites called chondrites. Achondrites do not contain iron or nickel and have a coarser crystal structure than chondrites.

achromatic lens A lens that corrects for chromatic *aberration by using a combination of two lenses, made of different kinds of glass, such that their *dispersions neutralize each other although their *refractions do not. The aberration can be reduced further by using an **apochromatic lens**, which consists of three or more different kinds of glass.

aciclovir (acyclovir; acycloguanosine) A drug used to treat cold sores, shingles, genital blisters, or other lesions caused by herpesvirus infection. It is an analogue of the base guanine and acts by interfering with DNA replication of the virus.

acid **1.** A type of compound that contains hydrogen and dissociates in water to produce positive hydrogen ions. The reaction, for an acid HX, is commonly written:

$$HX \rightleftharpoons H^+ + X^-$$

In fact, the hydrogen ion (the proton) is solvated, and the complete reaction is:

$$HX + H_2O \rightleftharpoons H_3O^+ + X^-$$

The ion H_3O^+ is the **oxonium ion** (or **hydroxonium ion** or **hydronium ion**). This definition of acids comes from the **Arrhenius theory**. Such acids tend to be corrosive substances with a sharp taste, which turn litmus red and give colour changes with other *indicators. They are referred to as **protonic acids** and are classified into **strong acids**, which are almost completely dissociated in water (e.g. sulphuric acid and hydrochloric acid), and **weak acids**, which are only partially dissociated (e.g. ethanoic acid and hydrogen sulphide). The strength of an acid depends on the extent to which it dissociates, and is measured by its *dissociation constant. *See also* BASE.

2. In the **Lowry–Brønsted theory** of acids and bases (1923), the definition was extended to one in which an acid is a proton donor, and a base is a proton acceptor. For example, in

$$HCN + H_2O \rightleftharpoons H_3O^+ + CN^-$$

the HCN is an acid, in that it donates a proton to H_2O. The H_2O is acting as a base in accepting a proton. Similarly, in the reverse reaction H_3O^+ is an acid and CN^- a base. In such reactions, two species related by loss or gain of a proton are said to be **conjugate**. Thus, in the reaction above HCN is the **conjugate acid** of the base CN^-, and CN^- is the **conjugate base** of the acid HCN. Similarly, H_3O^+ is the conjugate acid of the base H_2O. An equilibrium, such as that above, is a competition for protons between an acid and its conjugate base. A strong acid has a weak conjugate base, and vice versa. Under this definition water can act as both acid and base. Thus in

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

the H_2O is the conjugate acid of OH^-. The definition also extends the idea of acid–base reaction to solvents other than water. For instance, liquid ammonia, like water, has a high dielectric constant and is a good ionizing solvent. Equilibria of the type

$$NH_3 + Na^+Cl^- \rightleftharpoons Na^+NH_2^- + HCl$$

can be studied, in which NH_3 and HCl are acids and NH_2^- and Cl^- are their conjugate bases.

3. A further extension of the idea of acids and bases was made in the **Lewis theory** (G. N. Lewis, 1923). In this, a **Lewis acid** is a compound or atom that can accept a pair of electrons and a **Lewis base** is one that can donate an electron pair. This definition encompasses 'traditional' acid–base reactions. In

$$HCl + NaOH \rightarrow NaCl + H_2O$$

the reaction is essentially

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

i.e. donation of an electron pair by OH^-. But it also includes reactions that do not involve ions, e.g.

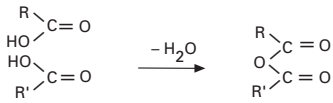
$$H_3N: + BCl_3 \rightarrow H_3NBCl_3$$

in which NH_3 is the base (donor) and BCl_3 the acid (acceptor). The Lewis theory establishes a relationship between acid–base reactions and *oxidation–reduction reactions. *See* HSAB PRINCIPLE. *See also* AQUA ACID; HYDROXOACID; OXOACID.

acid anhydrides (acyl anhydrides) Compounds that react with water to form an acid. For example, carbon dioxide reacts with water to give carbonic acid:

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

A particular group of acid anhydrides are anhydrides of carboxylic acids. They have a general formula of the type R.CO.O.CO.R′,



carboxylic acids acid anhydride

Acid anhydride. Formation of a carboxylic acid anhydride.

where R and R′ are alkyl or aryl groups. For example, the compound ethanoic anhydride ($CH_3.CO.O.CO.CH_3$) is the acid anhydride of ethanoic (acetic) acid. Organic acid anhydrides can be produced by dehydrating acids (or mixtures of acids). They are usually made by reacting an acyl halide with the sodium salt of the acid. They react readily with water, alcohols, phenols, and amines and are used in *acylation reactions.

SEE WEB LINKS

- Information about IUPAC nomenclature

acid–base balance The regulation of the concentrations of acids and bases in blood and other body fluids so that the pH remains within a physiologically acceptable range. This is achieved by the presence of natural *buffer systems, such as the haemoglobin, hydrogencarbonate ions, and carbonic acid in mammalian blood. By acting in conjunction, these effectively mop up excess acids and bases and therefore prevent any large shifts in blood pH. The acid–base balance is also influenced by the selective removal of certain ions by the kidneys and the rate of removal of carbon dioxide from the lungs.

acid–base indicator *See* INDICATOR.

acid dissociation constant *See* DISSOCIATION.

acid dye *See* DYES.

acid halides *See* ACYL HALIDES.

acidic **1.** Describing a compound that is an acid. **2.** Describing a solution that has an excess of hydrogen ions. **3.** Describing a compound that forms an acid when dissolved in water. Carbon dioxide, for example, is an acidic oxide.

acidic hydrogen (acid hydrogen) A hydrogen atom in an *acid that forms a positive ion when the acid dissociates. For instance, in methanoic acid

$$HCOOH \rightleftharpoons H^+ + HCOO^-$$

the hydrogen atom on the carboxylate group is the acidic hydrogen (the one bound directly to the carbon atom does not dissociate).

acidic stains *See* STAINING.

acidimetry Volumetric analysis using standard solutions of acids to determine the amount of base present.

acidity constant *See* DISSOCIATION.

acid rain Precipitation having a pH value of less than about 5.0, which has adverse effects on the fauna and flora on which it falls. Rainwater typically has a pH value of 5.6, due to the presence of dissolved carbon dioxide (forming carbonic acid). Acid rain results from the emission into the atmosphere of various pollutant gases, in particular sulphur dioxide and various oxides of nitrogen, which originate from the burning of fossil fuels and from car exhaust fumes, respectively. These gases dissolve in atmospheric water to form sulphuric and nitric acids in rain, snow, or hail (**wet deposition**). Alternatively, the pollutants are deposited as gases or minute particles (**dry deposition**). Both types of acid deposition affect plant growth – by damaging the leaves and impairing photosynthesis and by increasing the acidity of the soil, which results in the leaching of essential nutrients. This acid pollution of the soil also leads to acidification of water draining from the soil into lakes and rivers, which become unable to support fish life. Lichens are particularly sensitive to changes in pH and can be used as indicators of acid pollution (*see* INDICATOR SPECIES).

acid rock A low-density igneous rock containing a preponderance (more than 65%) of light-coloured *silicate minerals. Examples include granite and rhyolite.

acid salt A salt of a polybasic acid (i.e. an acid having two or more acidic hydrogens) in which not all the hydrogen atoms have been replaced by positive ions. For example, the dibasic acid carbonic acid (H_2CO_3) forms acid salts (hydrogencarbonates) containing the ion HCO_3^-. Some salts of monobasic acids are also known as acid salts. For instance, the compound potassium hydrogendifluoride, KHF_2, contains the ion $[F...H–F]^-$, in which there is hydrogen bonding between the fluoride ion F^- and a hydrogen fluoride molecule.

acid value A measure of the amount of free acid present in a fat, equal to the number of milligrams of potassium hydroxide

needed to neutralize this acid. Fresh fats contain glycerides of fatty acids and very little free acid, but the glycerides decompose slowly with time and the acid value increases.

acinus The smallest unit of a multilobular gland, such as the pancreas. Each acinus in the pancreas is made up of a hollow cluster of **acinar cells**, which produce the digestive enzymes secreted in pancreatic juice. Minute ducts from the pancreatic acini eventually drain into the pancreatic duct.

acoustics **1.** The study of sound and sound waves. **2.** The characteristics of a building, especially an auditorium, with regard to its ability to enable speech and music to be heard clearly within it. For this purpose there should be no obtrusive echoes or resonances and the reverberation time should be near the optimum for the hall. Echoes are reduced by avoiding sweeping curved surfaces that could focus the sound and by breaking up large plane surfaces or covering them with sound-absorbing materials. Resonance is avoided by avoiding simple ratios for the main dimensions of the room, so that no one wavelength of sound is a factor of more than one of them. If the reverberation time is too long, speech will sound indistinct and music will be badly articulated, with one note persisting during the next. However, if it is too short, music sounds dead. It is long in a bare room with hard walls, and can be deliberately reduced by carpets, soft furnishings and sound-absorbent ('acoustic') felt. Reverberation times tend to be reduced by the presence of an audience and this must be taken into account in the design of the building.

SEE WEB LINKS

- The website of the Acoustical Society of America
- The website of the UK Institute of Acoustics

acoustoelectronic devices (electroacoustic devices) Devices in which electronic signals are converted into acoustic waves. Acoustoelectronic devices are used in constructing *delay lines and also in converting digital data from computers for transmission by telephone lines.

acquired characteristics Features that are developed during the lifetime of an individual, e.g. the enlarged arm muscles of a tennis player. Such characteristics are not genetically controlled and cannot be passed on to the next generation. *See also* LAMARCKISM; NEO-LAMARCKISM.

acquired immune deficiency syndrome *See* AIDS.

Acrilan A trade name for a synthetic fibre. *See* ACRYLIC RESINS.

acrolein *See* PROPENAL.

acromegaly A chronic condition developing in adulthood due to overproduction of (or oversensitivity to) *growth hormone, usually caused by a tumour in the pituitary gland. This leads to a gradual enlargement of the bones, causing characteristic coarsening of the facial features and large hands and feet.

acrosome *See* SPERMATOZOON.

acrylamide An inert gel (polyacrylamide) employed as a medium in *electrophoresis. It is used particularly in the separation of macromolecules, such as nucleic acids and proteins.

acrylate *See* PROPENOATE.

acrylic acid *See* PROPENOIC ACID.

acrylic resins Synthetic resins made by polymerizing esters or other derivatives of acrylic acid (propenoic acid). Examples are poly(propenonitrile) (e.g. **Acrilan**), and poly(methyl 2-methylpropenoate) (polymethyl methacrylate, e.g. **Perspex**).

acrylonitrile *See* PROPENONITRILE.

ACTH (adrenocorticotrophic hormone; corticotrophin) A hormone, produced by the anterior *pituitary gland, that controls secretion of certain hormones (the *corticosteroids) by the adrenal glands. Its secretion, which is controlled by corticotrophin-releasing hormone and occurs in short bursts every few hours, is increased by stress.

actin A contractile protein found in muscle tissue, in which it occurs in the form of filaments (called thin filaments). Each thin filament consists of two chains of globular actin molecules, around which is twisted a strand of *tropomyosin and interspersed *troponin. Units of muscle fibre (*see* SARCOMERE) consist of actin and *myosin filaments, which interact to bring about muscle contraction. Actin is also found in the microfilaments that form part of the *cytoskeleton of all cells.

actinic radiation Electromagnetic radiation that is capable of initiating a chemical

a

reaction. The term is used especially of ultraviolet radiation and also to denote radiation that will affect a photographic emulsion.

actinides *See* ACTINOIDS.

actinium Symbol Ac. A radioactive metallic element belonging to group 3 of the periodic table; a.n. 89; mass number of most stable isotope 227 (half-life 21.7 years); m.p. 1050 ± 50°C; b.p. 3200°C (estimated). Actinium–227 occurs in natural uranium to an extent of about 0.715%. Actinium–228 (half-life 6.13 hours) also occurs in nature. There are 22 other artificial isotopes, all radioactive and all with very short half-lives. Its main use is as a source of alpha particles. The element was discovered by A. Debierne in 1899.

SEE WEB LINKS

- Information from the WebElements site

actinium series *See* RADIOACTIVE SERIES.

Actinobacteria (Actinomycetes; Actinomycota) A phylum of Gram-positive mostly anaerobic nonmotile bacteria. Many species are fungus-like, with filamentous cells producing reproductive spores on aerial branches similar to the spores of certain moulds. The phylum includes bacteria of the genera *Actinomyces*, some species of which cause disease in animals (including humans); and *Streptomyces*, which are a source of many important antibiotics (including streptomycin).

actinoid contraction A smooth decrease in atomic or ionic radius with increasing proton number found in the *actinoids.

actinoids (actinides) A series of elements in the *periodic table, generally considered to range in atomic number from thorium (90) to lawrencium (103) inclusive. The actinoids all have two outer *s*-electrons (a $7s^2$ configuration), follow actinium, and are classified together by the fact that increasing proton number corresponds to filling of the 5*f* level. In fact, because the 5*f* and 6*d* levels are close in energy the filling of the 5*f* orbitals is not smooth. The outer electron configurations are as follows:
89 actinium (Ac) $6d^17s^2$
90 thorium (Th) $6d^27s^2$
91 protactinium (Pa) $5f^26d^17s^2$
92 uranium (Ur) $5f^36d7s^2$
93 neptunium (Np) $5f^57s^2$ (or $5f^46d^17s^2$)
94 plutonium (Pu) $5f^67s^2$
95 americium (Am) $5f^77s^2$
96 curium (Cm) $5f^76d^1s^2$
97 berkelium (Bk) $5f^86d7s^2$ (or $5f^97s^2$)
98 californium (Cf) $5f^{10}7s^2$
99 einsteinium (Es) $5f^{11}7s^2$
100 fermium (Fm) $5f^{12}7s^2$
101 mendelevium (Md) $5f^{13}7s^2$
102 nobelium (No) $5f^{14}7s^2$
103 lawrencium (Lw) $5f^{14}6d^1s^2$

The first four members (Ac to Ur) occur naturally. All are radioactive and this makes investigation difficult because of self-heating, short lifetimes, safety precautions, etc. Like the *lanthanoids, the actinoids show a smooth decrease in atomic and ionic radius with increasing proton number. The lighter members of the series (up to americium) have *f*-electrons that can participate in bonding, unlike the lanthanoids. Consequently, these elements resemble the transition metals in forming coordination complexes and displaying variable valency. As a result of increased nuclear charge, the heavier members (curium to lawrencium) tend not to use their inner *f*-electrons in forming bonds and resemble the lanthanoids in forming compounds containing the M^{3+} ion. The reason for this is pulling of these inner electrons towards the centre of the atom by the increased nuclear charge. Note that actinium itself does not have a 5*f* electron, but it is usually classified with the actinoids because of its chemical similarities. *See also* TRANSITION ELEMENTS.

actinometer Any of various instruments for measuring the intensity of electromagnetic radiation. Recent actinometers use the *photoelectric effect but earlier instruments depended either on the fluorescence produced by the radiation on a screen or on the amount of chemical change induced in some suitable substance.

actinomorphy *See* RADIAL SYMMETRY.

Actinomycetes *See* ACTINOBACTERIA.

action at a distance The direct interaction between bodies that are not in physical contact with each other. The concept involves the assumption that the interactions are instantaneous. This assumption is not consistent with the special theory of *relativity, which states that nothing (including interactions) can travel through space faster than the *speed of light in a vacuum. For this reason it is more logical to describe interactions between bodies by *quantum field theories or by the exchange of virtual parti-

cles (*see* VIRTUAL STATE) rather than theories based on action at a distance.

action potential The change in electrical potential that occurs across a plasma membrane during the passage of a nerve *impulse. As an impulse travels in a wavelike manner along the *axon of a nerve, it causes a localized and transient switch in electric potential across the membrane from –60 mV (millivolts; the *resting potential) to +45 mV. The change in electric potential is caused by an influx of sodium ions. Nervous stimulation of a muscle fibre has a similar effect.

action spectrum A graphical plot of the efficiency of electromagnetic radiation in producing a photochemical reaction against the wavelength of the radiation used. For example, the action spectrum for photosynthesis using light shows a peak in the region 670–700 nm. This corresponds to a maximum absorption in the absorption *spectrum of chlorophylls in this region.

activated adsorption Adsorption that involves an activation energy. This occurs in certain cases of chemisorption.

activated alumina *See* ALUMINIUM HYDROXIDE.

activated charcoal *See* CHARCOAL.

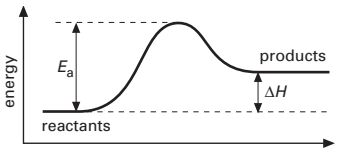
activated complex The association of atoms of highest energy formed in the *transition state of a chemical reaction.

activation analysis An analytical technique that can be used to detect most elements when present in a sample in milligram quantities (or less). In **neutron activation analysis** the sample is exposed to a flux of thermal neutrons in a nuclear reactor. Some of these neutrons are captured by nuclides in the sample to form nuclides of the same atomic number but a higher mass number. These newly formed nuclides emit gamma radiation, which can be used to identify the element present by means of a gamma-ray spectrometer. Activation analysis has also been employed using high-energy charged particles, such as protons or alpha particles.

SEE WEB LINKS

- An overview of neutron activation analysis from the Archaeometry Laboratory, Missouri Research Reactor
- Information about neutron activation analysis from the Worcester Polytechnic Institute

activation energy Symbol E_a. The minimum energy required for a chemical reaction to take place. In a reaction, the reactant molecules come together and chemical bonds are stretched, broken, and formed in producing the products. During this process the energy of the system increases to a maximum, then decreases to the energy of the products (see illustration). The activation energy is the difference between the maximum energy and the energy of the reactants; i.e. it is the energy barrier that has to be overcome for the reaction to proceed. The activation energy determines the way in which the rate of the reaction varies with temperature (*see* ARRHENIUS EQUATION). It is usual to express activation energies in joules per mole of reactants. An activation energy greater than 200 kJ mol^{-1} suggests that a bond has been completely broken in forming the transition state (as in the S_N1 reaction). A lower figure suggests incomplete breakage (as in the S_N2 reaction).



Activation energy. Reaction profile (for an endothermic reaction).

activator **1.** A type of *transcription factor involved in assembling proteins to form an initiation complex at the *promoter of a gene in readiness for transcription. *Compare* REPRESSOR. **2.** A substance that – by binding to an allosteric site on an enzyme (*see* INHIBITION) – enables the active site of the enzyme to bind to the substrate. **3.** Any compound that potentiates the activity of a drug or other foreign substance in the body.

active device **1.** An electronic component, such as a transistor, that is capable of amplification. **2.** An artificial *satellite that receives information and retransmits it after amplification. **3.** A radar device that emits microwave radiation and provides information about a distant body by receiving a reflection of this radiation. *Compare* PASSIVE DEVICE.

active galactic nucleus *See* ACTIVE GALAXY.

active galaxy A galaxy that contains an

a

active galactic nucleus (**AGN**), i.e. a central region that gives off a great deal of electromagnetic radiation. This emission is thought to be due to the accretion of matter into a supermassive *black hole, at the centre of the galaxy. *See also* RELATIVISTIC JETS.

active immunity *Immunity acquired due to the body's response to a foreign antigen.

active mass *See* MASS ACTION.

active site (active centre) **1.** A site on the surface of a catalyst at which activity occurs. **2.** The site on the surface of an *enzyme molecule that binds and acts on the substrate molecule. The properties of an active site are determined by the three-dimensional arrangement of the polypeptide chains of the enzyme and their constituent amino acids. These govern the nature of the interaction that takes place and hence the degree of substrate specificity and susceptibility to *inhibition.

active transport The movement of substances through membranes in living cells, often against a *concentration gradient: a process requiring metabolic energy. Organic molecules and inorganic ions are transported into and out of both cells and their organelles. The substance binds to a *transport protein embedded in the membrane, which carries it through the membrane and releases it on the opposite side. Active transport serves chiefly to maintain the normal balance of ions in cells, especially the concentration gradients of sodium and potassium ions crucial to the activity of nerve and muscle cells. *Compare* FACILITATED DIFFUSION.

activity **1.** Symbol *a*. A thermodynamic function used in place of concentration in equilibrium constants for reactions involving nonideal gases and solutions. For example, in a reaction

$$A \rightleftharpoons B + C$$

the true equilibrium constant is given by

$$K = a_B a_C / a_A$$

where a_A, a_B, and a_C are the activities of the components, which function as concentrations (or pressures) corrected for nonideal behaviour. **Activity coefficients** (symbol γ) are defined for gases by $\gamma = a/p$ (where p is pressure) and for solutions by $\gamma = aX$ (where X is the mole fraction). Thus, the equilibrium constant of a gas reaction has the form

$$K_p = \gamma_B p_B \gamma_C p_C / \gamma_A p_A$$

The equilibrium constant of a reaction in solution is

$$K_c = \gamma_B X_B \gamma_C X_C / \gamma_A X_A$$

The activity coefficients thus act as correction factors for the pressures or concentrations. The activity is given by an equation

$$\mu = \mu^{\ominus} + RT \ln a$$

where μ is chemical potential. *See also* FUGACITY.

2. Symbol *A*. The number of atoms of a radioactive substance that disintegrate per unit time. The **specific activity** (*a*) is the activity per unit mass of a pure radioisotope. *See* RADIATION UNITS.

activity series *See* ELECTROMOTIVE SERIES.

acyclic Describing a compound that does not have a ring in its molecules.

acyclovir (acycloguanosine) *See* ACICLOVIR.

acyl anhydrides *See* ACID ANHYDRIDES.

acylation The process of introducing an acyl group (RCO–) into a compound. The usual method is to react an alcohol with an acyl halide or a carboxylic acid anhydride; e.g.

$$RCOCl + R'OH \rightarrow RCOOR' + HCl$$

The introduction of an acetyl group (CH_3CO–) is **acetylation**, a process used for protecting –OH groups in organic synthesis.

acyl fission The breaking of the carbon–oxygen bond in an acyl group. It occurs in the hydrolysis of an *ester to produce an alcohol and a carboxylic acid.

acylglycerol *See* GLYCERIDE.

acyl group A group of the type RCO–, where R is an organic group. An example is the acetyl group CH_3CO–.

acyl halides (acid halides) Organic compounds containing the group –CO.X, where X is a halogen atom (see formula). Acyl chlorides, for instance, have the general formula RCOCl. The group RCO– is the **acyl group**. In systematic chemical nomenclature acylhalide names end in the suffix *-oyl*; for example, ethanoyl chloride, CH_3COCl. Acyl

Acyl halide. X is a halogen atom.

halides react readily with water, alcohols, phenols, and amines and are used in *acylation reactions. They are made by replacing the –OH group in a carboxylic acid by a halogen using a halogenating agent such as PCl_5.

SEE WEB LINKS

- Information about IUPAC nomenclature

Ada A high-level computer programming language developed in the late 1970s for the US military. It was originally employed in missile control systems and is now used in various other real-time applications. Ada was named after Augusta Ada Lovelace (1815–52), the mathematician daughter of Lord Byron, who worked with Charles *Babbage on his mechanical computer, the 'analytical engine'.

SEE WEB LINKS

- The Ada 2005 Language Reference Manual

adamantane A colourless crystalline hydrocarbon, $C_{10}H_{16}$; m.p. 269°C. It is found in certain petroleum fractions. The structure contains three symmetrically fused cyclohexane rings.

Adams, John Couch (1819–92) British astronomer who became professor of astronomy and geometry at Cambridge University in 1858. He is best known for his prediction (1845) of the existence and position of the planet *Neptune, worked out independently the following year by Urbain Leverrier (1811–77). The planet was discovered in 1846 by Johann Galle (1812–1910), using Leverrier's figures. Adams's priority was not acknowledged.

Adams catalyst A dark brown powder, a hydrated form of platinum(IV) oxide (PtO_2), produced by heating chloroplatinic acid (H_2PtCl_6) with sodium nitrate ($NaNO_3$). Platinum nitrate is produced, and this decomposes to platinum(IV) oxide with evolution of NO_2 and oxygen. It is used in hydrogenations of alkenes to alkanes, nitro compounds to aminos, and ketones to alcohols. The actual catalyst is not the oxide but finely divided *platinum black, which forms during the hydrogenation reaction.

adaptation **1.** (in evolution) Any change in the structure or functioning of successive generations of a population that makes it better suited to its environment. *Natural selection of heritable adaptations ultimately leads to the development of new species. Increasing adaptation of a species to a particular environment tends to diminish its ability to adapt to any sudden change in that environment. **2.** (in physiology) The alteration in the degree of sensitivity (either an increase or a decrease) of a sense organ to suit conditions more extreme than normally encountered. An example is the adjustment of the eye to vision in very bright or very dim light.

adaptive optics (AO) Computer-aided techniques for making virtually instantaneous corrective adjustments to the shape of a deformable mirror in a ground-based optical or near-infrared telescope in order to reduce or eliminate distortions of an image caused by dynamic turbulence in the earth's atmosphere. Adaptive optics also has applications outside astronomy. For example, in ophthalmology it can be used to measure aberration within the human eye and help to provide sharp images of the retina at the cellular level.

adaptive radiation (divergent evolution) The evolution from one species of animals or plants of a number of different forms. As the original population increases in size it spreads out from its centre of origin to exploit new habitats and food sources. In time this results in a number of populations each adapted to its particular habitat: eventually these populations will differ from each other sufficiently to become new species. A good example of this process is the evolution of the Australian marsupials into species adapted as carnivores, herbivores, burrowers, fliers, etc. On a smaller scale, the adaptive radiation of the Galapagos finches provided Darwin with crucial evidence for his theory of evolution (*see* DARWIN'S FINCHES).

addition polymerization *See* POLYMERIZATION.

addition reaction A chemical reaction in which one molecule adds to another. Addition reactions occur with unsaturated compounds containing double or triple bonds, and may be *electrophilic or *nucleophilic. An example of electrophilic addition is the reaction of hydrogen chloride with an alkene, e.g.

$$HCl + CH_2{:}CH_2 \rightarrow CH_3CH_2Cl$$

An example of nucleophilic addition is the addition of hydrogen cyanide across the carbonyl bond in aldehydes to form *cyanohydrins. **Addition–elimination** reactions are ones in which the addition is followed by

elimination of another molecule (*see* CONDENSATION REACTION).

additive A substance added to another substance or material to improve its properties in some way. Additives are often present in small amounts and are used for a variety of purposes, as in preventing corrosion, stabilizing polymers, etc. **Food additives** are used to enhance the taste and colour of foods and improve their texture and keeping qualities. *See* FOOD PRESERVATION.

additive process *See* COLOUR.

adduct A compound formed by an addition reaction. The term is used particularly for compounds formed by coordination between a Lewis acid (acceptor) and a Lewis base (donor). *See* ACID.

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

adenosine A nucleoside comprising one adenine molecule linked to a D-ribose sugar molecule. The phosphate-ester derivatives of adenosine, AMP, ADP, and *ATP, are of fundamental biological importance as carriers of chemical energy.

adenosine diphosphate (ADP) *See* ATP.

adenosine monophosphate (AMP) *See* ATP; CYCLIC AMP.

adenosine triphosphate *See* ATP; CYCLIC AMP.

adenovirus One of a group of DNA-containing viruses found in rodents, fowl, cattle, monkeys, and humans. In humans they produce acute respiratory-tract infections with symptoms resembling those of the common cold. They are also implicated in the formation of tumours (*see* ONCOGENIC).

adenylate cyclase The enzyme that catalyses the formation of *cyclic AMP. It is bound to the inner surface of the plasma membrane. Many hormones and other chemical messengers exert their physiological effects by increased synthesis of cyclic AMP through the activation of adenylate cyclase. The hormone binds to a receptor on the outer surface of the plasma membrane, which then activates adenylate cyclase on the inner surface via a *G protein.

ADH *See* ANTIDIURETIC HORMONE.

adhesive A substance used for joining surfaces together. Adhesives are generally colloidal solutions, which set to gels. There are many types including animal glues (based on collagen), vegetable mucilages, and synthetic resins (e.g. *epoxy resins).

adiabatic approximation An approximation used in *quantum mechanics when the time dependence of parameters such as the inter-nuclear distance between atoms in a molecule is slowly varying. This approximation means that the solution of the *Schrödinger equation at one time goes continuously over to the solution at a later time. This approximation was formulated by Max Born and the Soviet physicist Vladimir Alexandrovich Fock (1898–1974) in 1928. The *Born–Oppenheimer approximation is an example of the adiabatic approximation.

adiabatic demagnetization A technique for cooling a paramagnetic salt, such as potassium chrome alum, to a temperature near *absolute zero. The salt is placed between the poles of an electromagnet and the heat produced during magnetization is removed by liquid helium. The salt is then isolated thermally from the surroundings and the field is switched off; the salt is demagnetized adiabatically and its temperature falls. This is because the demagnetized state, being less ordered, involves more energy than the magnetized state. The extra energy can come only from the internal, or thermal, energy of the substance. It is possible to obtain temperatures as low as 0.005 K in this way.

adiabatic process Any process that occurs without heat entering or leaving a system. In general, an adiabatic change involves a fall or rise in temperature of the system. For example, if a gas expands under adiabatic conditions, its temperature falls (work is done against the retreating walls of the container). The **adiabatic equation** describes the relationship between the pressure (p) of an ideal gas and its volume (V), i.e. $pV^{\gamma} = K$, where γ is the ratio of the principal specific *heat capacities of the gas and K is a constant.

adipic acid *See* HEXANEDIOIC ACID.

adipose tissue A body tissue comprising cells containing *fat and oil. It is found chiefly below the skin (*see* SUBCUTANEOUS TISSUE) and around major organs (such as the kidneys and heart), acting as an energy reserve, providing insulation and protection, and generating heat. Secretion of the hor-

mone *leptin by adipose tissue regulates the amount of adipose tissue and adjusts the body's energy balance. *See* BROWN FAT; THERMOGENESIS.

admittance Symbol *Y*. The reciprocal of *impedance. It is measured in siemens.

adolescence The period in human development that occurs during the teenage years, between the end of childhood and the start of adulthood, and is characterized by various physical and emotional changes associated with development of the reproductive system. It starts at **puberty**, when the reproductive organs begin to function, and is marked by the start of menstruation (*see* MENSTRUAL CYCLE) in females and the appearance of the *secondary sexual characteristics in both sexes. In males the secondary sexual characteristics are controlled by the hormone testosterone and include deepening of the voice due to larynx enlargement, the appearance of facial and pubic hair, rapid growth of the skeleton and muscle, and an increase in *sebaceous gland secretions. In females the secondary sexual characteristics are controlled by oestrogens and include growth of the breasts, broadening of the pelvis, redistribution of fat in the body, and appearance of pubic hair.

ADP *See* ATP.

adrenal cortex The outer layer of the *adrenal gland, in which several steroid hormones, the *corticosteroids, are produced.

adrenal glands A pair of endocrine glands situated immediately above the kidneys (hence they are also known as the **suprarenal glands**). The inner portion of the adrenals, the **medulla**, secretes the hormones *adrenaline and *noradrenaline; the outer **cortex** secretes small amounts of sex hormones (*androgens and *oestrogens) and various *corticosteroids, which have a wide range of effects on the body. *See also* ACTH.

adrenaline (epinephrine) A hormone, produced by the medulla of the *adrenal glands, that increases heart activity, improves the power and prolongs the action of muscles, and increases the rate and depth of breathing to prepare the body for 'fright, flight, or fight'. At the same time it inhibits digestion and excretion and stimulates mobilization of body fat (*lipolysis) and energy metabolism (*glycolysis). Similar effects are produced by stimulation of the *sympathetic nervous system. Adrenaline causes these effects by binding to *adrenoceptors on target cells. It can be administered by injection to relieve bronchial asthma and reduce blood loss during surgery by constricting blood vessels.

adrenal medulla The inner part of the *adrenal gland, in which *adrenaline is produced.

adrenergic **1.** Describing a cell (especially a neuron) or a cell receptor that is stimulated by *adrenaline, *noradrenaline, or related substances. *See* ADRENOCEPTOR. **2.** Describing a nerve fibre or neuron that releases adrenaline or noradrenaline when stimulated. *Compare* CHOLINERGIC.

adrenoceptor (adrenoreceptor; adrenergic receptor) Any cell receptor that binds and is activated by the catecholamines adrenaline or noradrenaline. Adrenoceptors are therefore crucial in mediating the effects of catecholamines as neurotransmitters or hormones. There are two principal types of adrenoceptor, alpha (α) and beta (β). The **alpha adrenoceptors** fall into two main subtypes: α_1-adrenoceptors, which mediate the contraction of smooth muscle and hence cause constriction of blood vessels; and α_2-adrenoceptors, which occur, for example, in presynaptic neurons at certain nerve synapses, where they inhibit release of noradrenaline from the neuron. The **beta adrenoceptors** also have two main subtypes: β_1-adrenoceptors, which stimulate cardiac muscle causing a faster and stronger heartbeat; and β_2-adrenoceptors, which mediate relaxation of smooth muscle in blood vessels, bronchi, the uterus, bladder, and other organs. Activation of β_2-adrenoceptors thus causes widening of the airways (bronchodilation) and blood vessels (vasodilation). *See also* BETA BLOCKER.

adrenocorticotrophic hormone *See* ACTH.

Adrian, Edgar Douglas, Baron (1889–1977) British neurophysiologist, who became a professor at Cambridge in 1937, where he remained until his retirement. He is best known for his work on nerve impulses, establishing that messages are conveyed by changes in the frequency of the impulses. He shared the 1932 Nobel Prize for physiology or medicine with Sir Charles *Sherrington for this work.

ADSL (asymmetric digital subscriber line) A mechanism by which *broadband commu-

nication via the Internet can be made available via pre-existing telephone lines, while allowing simultaneous use of the line for normal telephone calls. Data communication via ADSL is asymmetric in that upstream (transmitting) communication is slower than downstream (receiving) communication, typically half as fast. Commonly available downstream data rates in the UK are 512 Kbps, 1 Mbps, and 2 Mbps. Faster rates are available in other countries. ADSL coexists with standard telephone operation on the same line by the use of band separation filters at each telephone socket.

adsorbate A substance that is adsorbed on a surface.

adsorbent A substance on the surface of which a substance is adsorbed.

adsorption The formation of a layer of gas, liquid, or solid on the surface of a solid or, less frequently, of a liquid. There are two types depending on the nature of the forces involved. In **chemisorption** a single layer of molecules, atoms, or ions is attached to the adsorbent surface by chemical bonds. In **physisorption** adsorbed molecules are held by the weaker *van der Waals' forces. Adsorption is an important feature of surface reactions, such as corrosion, and heterogeneous catalysis. The property is also utilized in adsorption *chromatography.

adsorption indicator (absorption indicator) A type of indicator used in reactions that involve precipitation. The yellow dye fluorescein is a common example, used for the reaction

$$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

As silver nitrate solution is added to the sodium chloride, silver chloride precipitates. As long as Cl^- ions are in excess, they adsorb on the precipitate particles. At the end point, no Cl^- ions are left in solution and negative fluorescein ions are then adsorbed, giving a pink colour to the precipitate. The technique is sometimes known as **Fajans' method**.

adsorption isotherm An equation that describes how the amount of a substance adsorbed onto a surface depends on its pressure (if a gas) or its concentration (if in a solution), at a constant temperature. Several adsorption isotherms are used in surface chemistry including the *BET isotherm and the *Langmuir adsorption isotherm. The different isotherms correspond to different assumptions about the surface and the adsorbed molecules.

adulterant *See* CUTTING AGENT.

advanced gas-cooled reactor (AGR) *See* NUCLEAR REACTOR.

adventitious Describing organs or other structures that arise in unusual positions. For example, ivy has adventitious roots growing from its stems.

aerial (antenna) The part of a radio or television system from which radio waves are transmitted into the atmosphere or space (**transmitting aerial**) or by which they are received (**receiving aerial**). A **directional** or **directive aerial** is one in which energy is transmitted or received more effectively from some directions than others, whereas an **omnidirectional aerial** transmits and receives equally well in all directions.

aerobe *See* AEROBIC RESPIRATION.

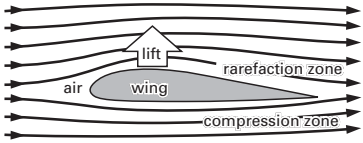
aerobic respiration A type of *respiration in which foodstuffs (usually carbohydrates) are completely oxidized to carbon dioxide and water, with the release of chemical energy, in a process requiring atmospheric oxygen. The reaction can be summarized by the equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

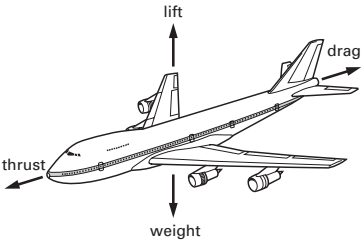
The chemical energy released is stored mainly in the form of *ATP. The first stage of aerobic respiration is *glycolysis, which takes place in the cytosol of cells and also occurs in fermentations and other forms of *anaerobic respiration. Further oxidation in the presence of oxygen is via the *Krebs cycle and *electron transport chain, enzymes for which are located in the *mitochondria of eukaryote cells. Most organisms have aerobic respiration (i.e. they are **aerobes**); exceptions include certain bacteria and yeasts.

aerodynamics The study of the motion of gases (particularly air) and the motion of solid bodies in air. Aerodynamics is particularly concerned with the motion and stability of aircraft. Another application of aerodynamics is to the *flight of birds and insects. The branch of aerodynamics concerned with the flow of gases through compressors, ducts, fans, orifices, etc., is called **internal aerodynamics**.

Aerodynamic drag is the force that opposes the motion of a body moving relative to a gas and is a function of the density of the gas, the square of the relative velocity, the



section through an aircraft wing



forces on an aircraft

Aerodynamics.

surface area of the body, and a quantity called the **drag coefficient**, which is a function of the *Reynolds number. **Aerodynamic lift** is an upward force experienced by a body moving through a gas and is a function of the same variables as aerodynamic drag.

aerogel A low-density porous transparent material that consists of more than 90% air. Usually based on metal oxides or silica, aerogels are used as drying agents and insulators.

aerogenerator *See* WIND POWER.

aerosol A colloidal dispersion of a solid or liquid in a gas. The commonly used aerosol sprays contain an inert propellant liquefied under pressure. Halogenated alkanes containing chlorine and fluorine (*chlorofluorocarbons, or CFCs) were formerly used in aerosol cans. They have now largely been replaced by volatile hydrocarbons because of their effect on the *ozone layer.

aerospace The earth's atmosphere and the space beyond it.

aerotaxis *See* TAXIS.

aestivation **1.** (in zoology) A state of inactivity occurring in some animals, notably lungfish, during prolonged periods of drought or heat. Feeding, respiration, movement, and other bodily activities are considerably slowed down. *See also* DORMANCY. *Compare* HIBERNATION. **2.** (in botany) The arrangement of the parts of a flower bud, especially of the sepals and petals.

aetiology The study of causes, especially the causes of medical conditions.

afferent Carrying (nerve impulses, blood, etc.) from the outer regions of a body or organ towards its centre. The term is usually applied to types of nerve fibres or blood vessels. *Compare* EFFERENT.

aflatoxin Any of four related toxic compounds produced by the mould *Aspergillus flavus*. Aflatoxins bind to DNA and prevent replication and transcription. They can cause acute liver damage and cancers: humans may be poisoned by eating stored peanuts and cereals contaminated with the mould.

AFM *See* ATOMIC FORCE MICROSCOPY.

afterbirth The *placenta, *umbilical cord, and *extraembryonic membranes, which are expelled from the womb after a mammalian fetus is born. In most nonhuman mammals the afterbirth, which contains nutrients and might otherwise attract predators, is eaten by the female.

after-heat Heat produced by a nuclear reactor after it has been shut down. The after-heat is generated by radioactive substances formed in the fuel elements.

agamospermy *See* APOMIXIS.

agar An extract of certain species of red seaweeds that is used as a gelling agent in microbiological *culture media, foodstuffs, medicines, and cosmetic creams and jellies. **Nutrient agar** consists of a broth made from beef extract or blood that is gelled with agar and used for the cultivation of bacteria, fungi, and some algae.

agate A variety of *chalcedony that forms in rock cavities and has a pattern of concentrically arranged bands or layers that lie parallel to the cavity walls. These layers are frequently alternating tones of brownish-red. **Moss agate** does not show the same banding and is a milky chalcedony containing mosslike or dendritic patterns formed by inclusions of manganese and iron oxides. Agates are used in jewellery and for ornamental purposes.

ageing *See* SENESCENCE.

age of the earth The time since the earth

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emerged as a planet of the sun, estimated by *dating techniques to be about 4.6×10^9 years. The oldest known rocks on earth are estimated by their *radioactive age to be about 3.5×10^9 years old. The earth is older than this because of the long time it took to cool. An estimate for the cooling time is included in the estimate for the age of the earth.

age of the universe A time determined by the reciprocal of the value of the *Hubble constant to be about 13.7 billion years. The calculation of the Hubble constant, and hence the age of the universe, depends on which theory of *cosmology is used. Usually, the age of the universe is calculated by assuming that the *expansion of the universe can be described by the *big-bang theory.

agglutination The clumping together by antibodies of microscopic foreign particles, such as red blood cells or bacteria, so that they form a visible pellet-like precipitate. Agglutination is a specific reaction, i.e. a particular antigen will only clump in the presence of its specific antibody; it therefore provides a means of identifying unknown bacteria and determining *blood group. When blood of incompatible blood groups (e.g. group A and group B – *see* ABO SYSTEM) is mixed together agglutination of the red cells occurs (**haemagglutination**). This is due to the reaction between antibodies in the plasma (**agglutinins**) and *agglutinogens (antigens) on the surface of the red cells.

agglutinogen Any of the antigens that are present on the outer surface of red blood cells (erythrocytes). There are more than 100 different agglutinogens and they form the basis for identifying the different *blood groups. Antibodies in the plasma, known as **agglutinins**, react with the agglutinogens in blood of an incompatible blood group (*see* AGGLUTINATION).

aggression Behaviour aimed at intimidating or injuring another animal of the same or a competing species. Aggression between individuals of the same species often starts with a series of ritualized displays or contests that can end at any stage if one of the combatants withdraws, leaving the victor with access to a disputed resource (e.g. food, a mate, or *territory) or with increased social dominance (*see* DOMINANT). It is also often seen in *courtship. Aggression or threat displays usually appear to exaggerate the performer's size or strength; for example, many fish erect their fins and mammals and birds may erect hairs or feathers. Special markings may be prominently exhibited, and **intention movements** may be made: dogs bare their teeth, for example. Some animals have evolved special structures for use in aggressive interactions (e.g. antlers in deer) but these are seldom used to cause actual injury; the opponent usually flees first or adopts *appeasement postures. Fights 'to the death' are comparatively rare. *See* AGONISTIC BEHAVIOUR; DISPLAY BEHAVIOUR; RITUALIZATION.

AGN Active galactic nucleus. *See* ACTIVE GALAXY.

agnathan Any jawless craniate animal. Agnathans were formerly classified in the subphylum (or superclass) Agnatha, with the living representatives – lampreys and hagfishes – constituting the class Cyclostomata. However, it is now accepted that the lampreys are more closely related to the jawed vertebrates than to the hagfishes, and the agnathans are now placed in two distinct clades of the subphylum *Craniata, the hagfishes forming the class Myxini (Hyperotreti) and the lampreys the Hyperoartia. The closest living relatives of the latter are the jawed vertebrates (Gnathostomata), which with the lampreys constitute the superclass Vertebrata. Fossil agnathans, covered in an armour of bony plates, are the oldest known fossil vertebrates. They have been dated from the Silurian and Devonian periods, 440–345 million years ago.

agonist A drug, hormone, neurotransmitter, or other signal molecule that forms a complex with a *receptor site, thereby triggering an active response from a cell. *Compare* ANTAGONIST.

agonistic behaviour Any form of behaviour associated with *aggression, including threat, attack, *appeasement, or flight. It is often associated with defence of a territory; for example, a threat display by the defending individual is often met with an appeasement display from the intruder, thus avoiding harmful conflict.

AGR Advanced gas-cooled reactor. *See* NUCLEAR REACTOR.

agranulocyte Any white blood cell (*see* LEUCOCYTE) with a nongranular cytoplasm and a large spherical nucleus; *lymphocytes and *monocytes are examples. Agranulo-

cytes are produced either in the lymphatic system or in the bone marrow and account for 30% of all leucocytes. *Compare* GRANULOCYTE.

agriculture The study and practice of cultivating land for the growing of crops and the rearing of livestock. The increasing demands for food production since the mid-20th century have seen many developments in agricultural technology and practices that have greatly increased crop and livestock production. However, these advances in modern **intensive farming** techniques have had their impact on the environment, particularly with increased use of *fertilizers and *pesticides. The now widespread practice of crop **monoculture** (in which one crop is grown densely over an extensive area) has required an increase in the use of *pesticides, as monoculture provides an ideal opportunity for crop pests. Monoculture also requires vast areas of land, which has meant that natural habitats have been destroyed. *Deforestation has resulted from the clearing of forests for crop production and cattle rearing. Advances in technology have included ploughing machines with hydraulic devices that can control the depth to which the soil is ploughed, and seed drills that automatically implant seeds in the soil so that ploughing is not necessary. Food supply in many less-developed countries relies on **subsistence farming**, in which the crops and livestock produced are used solely to feed the farmer and his family. In such countries a system known as **slash and burn** is common, in which the vegetation in an area is cut down and then burnt, thus returning the minerals to the soil. The area can then be used for crop cultivation until the soil fertility drops, at which point it is then abandoned for a number of years and another site is cultivated.

The selective *breeding of crop plants and farm animals has had an enormous impact on productivity in agriculture. Modern varieties of crop plants have increased nutritional value and greater resistance to disease, while animals have been selectively bred to enhance their yields of milk, meat, and other products. Developments in genetic engineering have enabled the introduction to commercial cultivation of genetically modified crop plants, such as tomatoes and soya, which contain foreign genes to enhance crop growth, nutritional properties, or storage characteristics. Genetic modification can also confer resistance to herbicides, thereby allowing more effective weed control, as well as improved resistance to insects and other pests and to diseases. The application of similar technology to animal production is being researched. *See also* GENETICALLY MODIFIED ORGANISMS (Feature).

Agrobacterium tumefaciens A Gram-negative soil bacterium that infects a wide range of plants and causes *galls, especially at the root/stem junction (crown gall). It is of interest because the bacterial cells contain a *plasmid, the **Ti plasmid** (tumour-inducing plasmid), a segment of which is transferred to cells of the plant host. This T-DNA (transfer DNA) segment, which comprises the genes responsible for the gall, becomes integrated into the genome of infected plant cells. Possession of the Ti plasmid has made *A. tumefaciens* an important tool in genetic engineering for the introduction of foreign genes into plant tissue. The tumour-inducing genes are usually replaced with the gene of interest, and a marker gene (e.g. the antibiotic resistance gene) is added to enable selection of transformed cells. *See* GENETICALLY MODIFIED ORGANISMS (Feature).

AI **1.** *See* ARTIFICIAL INTELLIGENCE. **2.** *See* ARTIFICIAL INSEMINATION.

AIDS (acquired immune deficiency syndrome) A disease of humans characterized by defective cell-mediated *immunity and increased susceptibility to infections. It is caused by the retrovirus *HIV (human immunodeficiency virus). This infects and destroys helper *T cells, which are essential for combating infections. HIV is transmitted in blood, semen, and vaginal fluid; the major routes of infection are unprotected vaginal and anal intercourse, intravenous drug abuse, and the administration of contaminated blood and blood products. A person infected with HIV is described as **HIV-positive**; after the initial infection the virus can remain dormant for up to ten years before AIDS develops. *Antiviral drugs can delay the development of full-blown AIDS, in some cases for many years.

air *See* EARTH'S ATMOSPHERE.

air bladder *See* SWIM BLADDER.

air mass (in meteorology) An area of the atmosphere that in the horizontal field possesses more or less uniform properties, especially temperature and humidity, and

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extends for hundreds of kilometres. The transition zone at which one air mass meets another is known as a *front. Air masses develop over extensive areas of the earth's surface, known as source regions, where conditions are sufficiently uniform to impart similar characteristics to the overlying air. These areas are chiefly areas of high pressure. As an air mass moves away from its source region it undergoes modification.

air pollution (atmospheric pollution) The release into the atmosphere of substances that cause a variety of harmful effects to the natural environment. Most air pollutants are gases that are released into the troposphere, which extends about 8 km above the surface of the earth. The burning of *fossil fuels, for example in power stations, is a major source of air pollution as this process produces such gases as sulphur dioxide and carbon dioxide. Released into the atmosphere, carbon dioxide is the major contributor to the *greenhouse effect; methane, derived from livestock and rice cultivation, is another significant greenhouse gas. Sulphur dioxide and nitrogen oxides, released in car exhaust fumes, are air pollutants that are responsible for the formation of *acid rain; nitrogen oxides also contribute to the formation of *photochemical smog. *See also* OZONE LAYER; POLLUTION.

air sac **1.** Any one of a series of thin-walled sacs in birds that are connected to the lungs and increase the efficiency of ventilation. Some of the air sacs penetrate the internal cavities of bones. **2.** A structural extension to the *trachea in insects, which increases the surface area available for the exchange of oxygen and carbon dioxide in respiration.

alabaster *See* GYPSUM.

alanine *See* AMINO ACID.

albedo **1.** The ratio of the radiant flux reflected by a surface to that falling on it. **2.** The probability that a neutron entering a body of material will be reflected back through the same surface as it entered.

albinism Hereditary lack of pigmentation (*see* MELANIN) in an organism. Albino animals and human beings have no colour in their skin, hair, or eyes (the irises appear pink from underlying blood vessels). The *allele responsible is *recessive to the allele for normal pigmentation.

albumen *See* ALBUMIN.

albumin One of a group of globular proteins that are soluble in water but form insoluble coagulates when heated. Albumins occur in egg white (the protein component of which is known as **albumen**), blood, milk, and plants. Serum albumins, which constitute about 55% of blood plasma protein, help regulate the osmotic pressure and hence plasma volume. They also bind and transport fatty acids. α-lactalbumin is a protein in milk.

albuminous cell *See* COMPANION CELL.

alburnum *See* SAPWOOD.

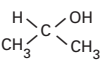
alcoholic fermentation *See* FERMENTATION.

alcohols Organic compounds that contain the –OH group. In systematic chemical nomenclature alcohol names end in the suffix *-ol*. Examples are methanol, CH_3OH, and ethanol, C_2H_5OH. **Primary alcohols** have two hydrogen atoms on the carbon joined to the –OH group (i.e. they contain the group $–CH_2–OH$); **secondary alcohols** have one hydrogen on this carbon (the other two bonds being to carbon atoms, as in $(CH_3)_2CHOH$); **tertiary alcohols** have no hydrogen on this carbon (as in $(CH_3)_3COH$): see formulae. The different types of alcohols may differ in the way they react chemically. For example, with potassium dichromate(VI) in sulphuric acid the following reactions occur

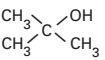
primary alcohol → aldehyde → carboxylic acid
secondary alcohol → ketone
tertiary alcohol – no reaction

Other characteristics of alcohols are reaction with acids to give *esters and dehydration to give *alkenes or *ethers. Alcohols that have two –OH groups in their molecules are

primary alcohol (methanol)



secondary alcohol (propan-2-ol)



tertiary alcohol (2-methylpropan-2-ol)

Examples of alcohols.

diols (or **dihydric alcohols**), those with three are **triols** (or **trihydric alcohols**), etc.

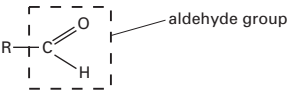
SEE WEB LINKS

- Information about IUPAC nomenclature

aldehydes Organic compounds that contain the group –CHO (the **aldehyde group**; i.e. a carbonyl group (C=O) with a hydrogen atom bound to the carbon atom). In systematic chemical nomenclature, aldehyde names end with the suffix *-al*. Examples of aldehydes are methanal (formaldehyde), HCOH, and ethanal (acetaldehyde), CH_3CHO. Aldehydes are formed by oxidation of primary *alcohols; further oxidation yields carboxylic acids. They are reducing agents and tests for aldehydes include *Fehling's test and *Tollens reagent. Aldehydes have certain characteristic addition and condensation reactions. With sodium hydrogensulphate(IV) they form addition compounds of the type $[RCOH(SO_3)H]^- Na^+$. Formerly these were known as **bisulphite addition compounds.** They also form addition compounds with hydrogen cyanide to give *cyanohydrins and with alcohols to give *acetals and undergo condensation reactions to yield *oximes, *hydrazones, and *semicarbazones. Aldehydes readily polymerize. *See also* KETONES.

SEE WEB LINKS

- Information about IUPAC nomenclature



Aldehyde structure.

aldohexose *See* MONOSACCHARIDE.

aldol *See* ALDOL REACTION.

aldol reaction A reaction of aldehydes of the type

$$2RCH_2CHO \rightleftharpoons RCH_2CH(OH)CHRCHO$$

where R is a hydrocarbon group. The resulting compound is a hydroxy-aldehyde, i.e. an aldehyde–alcohol or **aldol**, containing alcohol (–OH) and aldehyde (–CHO) groups on adjacent carbon atoms. The reaction is base-catalysed, the first step being the formation of a carbanion of the type RHC^-CHO, which adds to the carbonyl group of the other aldehyde molecule. For the carbanion to form, the aldehyde must have a hydrogen atom on the carbon next to the carbonyl group.

Aldols can be further converted to other products; in particular, they are a source of unsaturated aldehydes. For example, the reaction of ethanal gives 3-hydroxybutenal (**acetaldol**):

$$2CH_3CHO \rightleftharpoons CH_3CH(OH)CH_2CHO$$

This can be further dehydrated to 2-butenal (**crotonaldehyde**):

$$CH_3CH(OH)CH_2CHO \rightarrow H_2O + CH_3CH{:}CHCHO$$

aldose *See* MONOSACCHARIDE.

aldosterone A hormone produced by the adrenal glands (*see* CORTICOSTEROID) that controls excretion of sodium by the kidneys and thereby maintains the balance of salt and water in the body fluids. *See also* ANGIOTENSIN.

algae Any of various unrelated simple organisms that contain chlorophyll (and can therefore carry out photosynthesis) and live in aquatic habitats and in moist situations on land. The algal body may be unicellular or multicellular (filamentous, ribbon-like, or platelike). Molecular studies have confirmed that red and green algae are related to modern plants, whereas other algal groups, such as brown algae, are not. Algae are assigned to separate phyla based primarily on the composition of the cell wall, the nature of the stored food reserves, and the other photosynthetic pigments present. *See* BACILLARIOPHYTA; CHLOROPHYTA; PHAEOPHYTA; RHODOPHYTA.

The organisms formerly known as blue-green algae are now classified as bacteria (*see* CYANOBACTERIA).

algal bloom (bloom) The rapid increase in populations of algae and other phytoplankton, in particular the *Cyanobacteria, that occurs in inland water systems, such as lakes. The density of the organisms may be such that it may prevent light from passing to lower depths in the water system. Blooms are caused by an increase in levels of nitrate, a mineral ion essential for algal and bacterial growth. The source of increased nitrate may be from agricultural *fertilizers, which are leached into water systems from the land, or *sewage effluent. Blooms contribute to the eutrophication of water systems. *See also* EUTROPHIC.

algebra The branch of mathematics in which variable quantities and numbers are represented by symbols. Statements are usu-

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ally made in the form of equations, which are manipulated into convenient forms and solved according to a set of strictly logical rules.

algebraic sum The total of a set of quantities paying due regard to sign, e.g. the algebraic sum of 3 and –4 is –1.

Algol An early high-level block-structured computer programming language. Algol 60 dates from about 1960. Algol 68, of 1968, is a more powerful abstract language. The final version, Algol W, was the precursor of Pascal. The name is short for *algo*rithmic *l*anguage (*see* ALGORITHM).

algorithm A method of solving a problem, involving a finite series of steps. In computing practice the algorithm denotes the expression on paper of the proposed computing process (often by means of a flowchart) prior to the preparation of the program. If no algorithm is possible a *heuristic solution has to be sought.

alicyclic compound A compound that contains a ring of atoms and is aliphatic. Cyclohexane, C_6H_{12}, is an example.

alignment (in bioinformatics) The process of matching up base sequences (e.g. of genes) or amino acid sequences (of proteins) to reveal similarities and differences between them. It enables researchers to compare, for example, a newly sequenced gene or protein fragment with well-characterized sequences and is a key step in identifying the nature, possible function, and evolutionary relationships of novel genes and proteins. Alignment is performed by any of various computer programs and makes use of the vast amount of sequence data stored on public databases, which can be accessed via the Internet. In a pairwise alignment, just two sequences are compared, whereas multiple sequence alignment compares three or more. The program compares the sequences and computes the best alignment(s), allowing for gaps and mismatches.

alimentary canal (digestive tract; gut) A tubular organ in animals that is divided into a series of zones specialized for the ingestion, *digestion, and *absorption of food and for the elimination of indigestible material (see illustration overleaf). In most animals the canal has two openings, the mouth (for the intake of food) and the *anus (for the elimination of waste). Simple animals, such as cnidarians (e.g. *Hydra* and jellyfish) and flatworms, have only one opening to their alimentary canal, which must serve both functions.

aliphatic compounds Organic compounds that are *alkanes, *alkenes, or *alkynes or their derivatives. The term is used to denote compounds that do not have the special stability of *aromatic compounds. All noncyclic organic compounds are aliphatic. Cyclic aliphatic compounds are said to be **alicyclic**.

alizarin An orange-red dye, $C_{14}H_8O_4$, which forms *lakes when heavy metal salts are added to its alkaline solutions. It occurs naturally in madder, but is generally synthesized from *anthraquinone.

alkali A *base that dissolves in water to give hydroxide ions.

alkali metals (group 1 elements) The elements of group 1 (formerly IA) of the *periodic table: lithium (Li), sodium (Na), potassium (K), rubidium (Rb), caesium (Cs), and francium (Fr). All have a characteristic electron configuration that is a noble gas structure with one outer *s*-electron. They are typical metals (in the chemical sense) and readily lose their outer electron to form stable M^+ ions with noble-gas configurations. All are highly reactive, with the reactivity (i.e. metallic character) increasing down the group. There is a decrease in ionization energy from lithium (520 kJ mol^{-1}) to caesium (380 kJ mol^{-1}). The second ionization energies are much higher and divalent ions are not formed. Other properties also change down the group. Thus, there is an increase in atomic and ionic radius, an increase in density, and a decrease in melting and boiling point. The standard electrode potentials are low and negative, although they do not show a regular trend because they depend both on ionization energy (which decreases down the group) and the hydration energy of the ions (which increases).

All the elements react with water (lithium slowly; the others violently) and tarnish rapidly in air. They can all be made to react with chlorine, bromine, sulphur, and hydrogen. The hydroxides of the alkali metals are strongly alkaline (hence the name) and do not decompose on heating. The salts are generally soluble. The carbonates do not decompose on heating, except at very high temperatures. The nitrates (except for lithium) decompose to give the nitrite and oxygen:

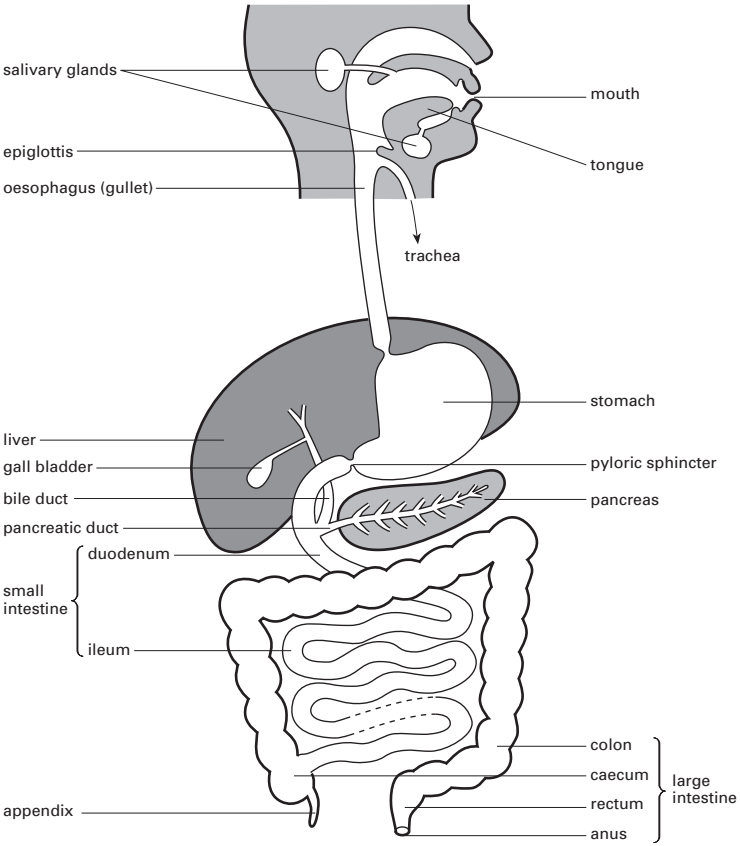
$2MNO_3(s) \rightarrow 2MNO_2(s) + O_2(g)$

Lithium nitrate decomposes to the oxide. In fact lithium shows a number of dissimilarities to the other members of group 1 and in many ways resembles magnesium (*see* DIAGONAL RELATIONSHIP). In general, the stability of salts of oxo acids increases down the group (i.e. with increasing size of the M^+ ion). This trend occurs because the smaller cations (at the top of the group) tend to polarize the oxo anion more effectively than the larger cations at the bottom of the group.

alkalimetry Volumetric analysis using standard solutions of alkali to determine the amount of acid present.

alkaline **1.** Describing an alkali. **2.** Describing a solution that has an excess of hydroxide ions (i.e. a pH greater than 7).

alkaline-earth metals (group 2 elements) The elements of group 2 (formerly IIA) of the *periodic table: beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), and barium (Ba). The elements are sometimes referred to as the 'alkaline earths', although strictly the 'earths' are the oxides of the elements. All have a characteristic electron configuration that is a noble-gas structure with two outer *s*-electrons. They are typical metals (in the chemical sense) and readily lose both outer electrons



The human alimentary canal.

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to form stable M^{2+} ions; i.e. they are strong reducing agents. All are reactive, with the reactivity increasing down the group. There is a decrease in both first and second ionization energies down the group. Although there is a significant difference between the first and second ionization energies of each element, compounds containing univalent ions are not known. This is because the divalent ions have a smaller size and larger charge, leading to higher hydration energies (in solution) or lattice energies (in solids). Consequently, the overall energy change favours the formation of divalent compounds. The third ionization energies are much higher than the second ionization energies, and trivalent compounds (containing M^{3+}) are unknown.

Beryllium, the first member of the group, has anomalous properties because of the small size of the ion; its atomic radius (0.112 nm) is much less than that of magnesium (0.16 nm). From magnesium to radium there is a fairly regular increase in atomic and ionic radius. Other regular changes take place in moving down the group from magnesium. Thus, the density and melting and boiling points all increase. Beryllium, on the other hand, has higher boiling and melting points than calcium and its density lies between those of calcium and strontium. The standard electrode potentials are negative and show a regular small decrease from magnesium to barium. In some ways beryllium resembles aluminium (*see* DIAGONAL RELATIONSHIP).

All the metals are rather less reactive than the alkali metals. They react with water and oxygen (beryllium and magnesium form a protective surface film) and can be made to react with chlorine, bromine, sulphur, and hydrogen. The oxides and hydroxides of the metals show the increasing ionic character in moving down the group: beryllium hydroxide is amphoteric, magnesium hydroxide is only very slightly soluble in water and is weakly basic, calcium hydroxide is sparingly soluble and distinctly basic, strontium and barium hydroxides are quite soluble and basic. The hydroxides decompose on heating to give the oxide and water:

$$M(OH)_2(s) \rightarrow MO(s) + H_2O(g)$$

The carbonates also decompose on heating to the oxide and carbon dioxide:

$$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

The nitrates decompose to give the oxide:

$$2M(NO_3)_2(s) \rightarrow 2MO(s) + 4NO_2(g) + O_2(g)$$

As with the *alkali metals, the stability of salts of oxo acids increases down the group. In general, salts of the alkaline-earth elements are soluble if the anion has a single charge (e.g. nitrates, chlorides). Most salts with a doubly charged anion (e.g. carbonates, sulphates) are insoluble. The solubilities of salts of a particular acid tend to decrease down the group. (Solubilities of hydroxides increase for larger cations.)

alkaloid One of a group of nitrogenous organic compounds, mostly derived from plants, and having diverse pharmacological properties. They are biosynthesized from amino acids and classified according to some structural feature. A simple classification is into:
the pyridine group (e.g. coniine, nicotine)
the tropine group (e.g. atropine, cocaine)
the quinoline group (e.g. quinine, strychnine, brucine)
the isoquinoline group (e.g. morphine, codeine)
the phenylethylamine group (e.g. methamphetamine, mescaline, ephedrine)
the indole group (e.g. tryptamine, lysergic acid)
the purine group (e.g. caffeine, theobromine, theophylline)

alkanal An aliphatic aldehyde.

alkanes (paraffins) Saturated hydrocarbons with the general formula C_nH_{2n+2}. In systematic chemical nomenclature alkane names end in the suffix *-ane*. They form a *homologous series (the **alkane series**) methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}), etc. The lower members of the series are gases; the high-molecular weight alkanes are waxy solids. Alkanes are present in natural gas and petroleum. They can be made by heating the sodium salt of a carboxylic acid with soda lime:

$$RCOO^-Na^+ + Na^+OH^- \rightarrow Na_2CO_3 + RH$$

Other methods include the *Wurtz reaction and *Kolbe's method. Generally the alkanes are fairly unreactive. They form haloalkanes with halogens when irradiated with ultraviolet radiation.

SEE WEB LINKS

- Information about IUPAC nomenclature
- Further details about nomenclature

alkanol An aliphatic alcohol.

alkenes (olefines; olefins) Unsaturated hydrocarbons that contain one or more double carbon–carbon bonds in their molecules. In systematic chemical nomenclature alkene names end in the suffix *-ene*. Alkenes that have only one double bond form a homologous series (the **alkene series**) starting ethene (ethylene), $CH_2{:}CH_2$, propene, $CH_3CH{:}CH_2$, etc. The general formula is C_nH_{2n}. Higher members of the series show isomerism depending on position of the double bond; for example, butene (C_4H_8) has two isomers, which are (1) but-1-ene ($C_2H_5CH{:}CH_2$) and (2) but-2-ene ($CH_3CH{:}CHCH_3$): see formulae.

Alkenes can be made by dehydration of alcohols (passing the vapour over hot pumice):

$$RCH_2CH_2OH - H_2O \rightarrow RCH{:}CH_2$$

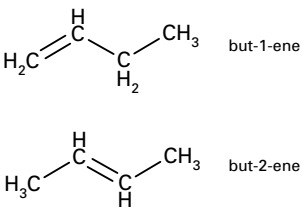
An alternative method is the removal of a hydrogen atom and halogen atom from a haloalkane by potassium hydroxide in hot alcoholic solution:

$$RCH_2CH_2Cl + KOH \rightarrow KCl + H_2O + RCH{:}CH_2$$

Alkenes typically undergo *addition reactions to the double bond. They can be tested for by the *Baeyer test. *See also* HYDROGENATION; OXO PROCESS; OZONOLYSIS; ZIEGLER PROCESS.

SEE WEB LINKS

- Information about IUPAC nomenclature



Alkenes. Butene isomers.

alkoxides Compounds formed by reaction of alcohols with sodium or potassium metal. Alkoxides are saltlike compounds containing the ion $R{-}O^-$.

alkyd resin A type of *polyester resin used in paints and other surface coating. The original alkyd resins were made by copolymerizing phthalic anhydride with glycerol, to give a brittle cross-linked polymer. The properties of such resins can be modified by adding monobasic acids or alcohols during the polymerization.

alkylation A chemical reaction that introduces an *alkyl group into an organic molecule. The *Friedel–Crafts reaction results in alkylation of aromatic compounds.

alkylbenzenes Organic compounds that have an alkyl group bound to a benzene ring. The simplest example is methylbenzene (toluene), $CH_3C_6H_5$. Alkyl benzenes can be made by the *Friedel–Crafts reaction.

alkyl group A group obtained by removing a hydrogen atom from an alkane, e.g. methyl group, $CH_3{-}$, derived from methane.

alkyl halides *See* HALOALKANES.

alkynes (acetylenes) Unsaturated hydrocarbons that contain one or more triple carbon–carbon bonds in their molecules. In systematic chemical nomenclature alkyne names end in the suffix *-yne*. Alkynes that have only one triple bond form a *homologous series: ethyne (acetylene), CH≡CH, propyne, $CH_3CH{\equiv}CH$, etc. They can be made by the action of potassium hydroxide in alcohol solution on haloalkanes containing halogen atoms on adjacent carbon atoms; for example:

$$RCHClCH_2Cl + 2KOH \rightarrow 2KCl + 2H_2O + RCH{\equiv}CH$$

Like *alkenes, alkynes undergo addition reactions.

SEE WEB LINKS

- Information about IUPAC nomenclature

allantois One of the membranes that develops in embryonic reptiles, birds, and mammals as a growth from the hindgut. It acts as a urinary bladder for the storage of waste excretory products in the egg (in reptiles and birds) and as a means of providing the embryo with oxygen (in reptiles, birds, and mammals) and food (in mammals; *see* PLACENTA). *See also* EXTRAEMBRYONIC MEMBRANES.

allele (allelomorph) One of the alternative forms of a gene. In a diploid cell there are usually two alleles of any one gene (one from each parent), which occupy the same relative position (*locus) on *homologous chromosomes. These alleles may be the same, or one allele may be *dominant to the other (known as the *recessive), i.e. it determines which aspects of a particular characteristic the organism will display. Within a popula-

a

tion there may be many alleles of a gene; each has a unique nucleotide sequence.

allelomorph *See* ALLELE.

allelopathy The secretion by plants of chemicals, such as phenolic and terpenoid compounds, that inhibit the growth or germination of other plants, with which they are competing. For example, the aromatic oils released by certain shrubs of the Californian chaparral pass into the soil and inhibit the growth of herbaceous species nearby. Some plants produce chemicals that are toxic to grazing herbivorous animals.

allenes Compounds that contain the group >C=C=C<, in which three carbon atoms are linked by two adjacent double bonds. The outer carbon atoms are each linked to two other atoms or groups by single bonds. The simplest example is 1,2-propadiene, CH_2CCH_2. Allenes are *dienes with typical reactions of alkenes. Under basic conditions, they often convert to alkynes. In an allene, the two double bonds lie in planes that are perpendicular to each other. Consequently, in an allene of the type $R_1R_2C{:}C{:}CR_3R_4$, the groups R_1 and R_2 lie in a plane perpendicular to the plane containing R_3 and R_4. Under these circumstances, the molecule is chiral and can show optical activity.

allergen An antigen that provokes an abnormal *immune response. Common allergens include pollen and dust (*see* ALLERGY).

allergy A condition in which the body produces an abnormal *immune response to certain *antigens (called **allergens**), which include dust, pollen, certain foods and drugs, or fur. In allergic individuals these substances, which in a normal person would be destroyed by antibodies, react with preexisting antibodies or trigger responses in primed T cells. A common mechanism is binding of allergen to IgE on *mast cells. This causes the latter to secrete *histamine and other vasoactive agents, leading to inflammation and other characteristic symptoms of the allergy (e.g. asthma or hay fever). *See also* ANAPHYLAXIS; MAST CELL.

allogamy Cross-fertilization in plants. *See* FERTILIZATION.

allograft *See* GRAFT.

allometric growth The regular and systematic pattern of growth such that the mass or size of any organ or part of a body can be expressed in relation to the total mass or size of the entire organism according to the allometric equation: $Y = bx^{\alpha}$, where Y = mass of the organ, x = mass of the organism, α = growth coefficient of the organ, and b = a constant.

allopatric Describing or relating to groups of similar organisms that could interbreed but do not because they are geographically separated. *Compare* SYMPATRIC. *See* SPECIATION.

allopolyploid A *polyploid organism, usually a plant, that contains multiple sets of chromosomes derived from different species. Hybrids are usually sterile, because they do not have sets of *homologous chromosomes and therefore *pairing cannot take place. However, if doubling of the chromosome number occurs in a hybrid derived from two diploid ($2n$) species, the resulting tetraploid ($4n$) is a fertile plant. This type of tetraploid is known as an **allotetraploid**; as it contains two sets of homologous chromosomes, pairing and crossing over are now possible. Allopolyploids are of great importance to plant breeders as advantages possessed by different species can be combined. The species of wheat, *Triticum aestivum*, used to make bread is an **allohexaploid** ($6n$), possessing 42 chromosomes, which is six times the original haploid number (n) of 7. *Compare* AUTOPOLYPLOID.

all-or-none response A type of response that may be either complete and of full intensity or totally absent, depending on the strength of the stimulus; there is no partial response. For example, a nerve cell is either stimulated to transmit a complete nervous impulse or else it remains in its resting state; a stinging *thread cell of a cnidarian is either completely discharged or it is not.

allosteric enzyme An enzyme that has two structurally distinct forms, one of which is active and the other inactive. In the active form, the quaternary structure (*see* PROTEIN) of the enzyme is such that a substrate can interact with the enzyme at the active site (*see* ENZYME–SUBSTRATE COMPLEX). The conformation of the substrate-binding site becomes altered in the inactive form and interaction with the substrate is not possible. Allosteric enzymes tend to catalyse the initial step in a pathway leading to the synthesis of molecules. The end product of this synthesis can act as a feedback inhibitor (*see* INHIBITION) and the enzyme is converted to the in-

active form, thereby controlling the amount of product synthesized.

allotropy The existence of elements in two or more different forms (**allotropes**). In the case of oxygen, there are two forms: 'normal' dioxygen (O_2) and ozone, or trioxygen (O_3). These two allotropes have different molecular configurations. More commonly, allotropy occurs because of different crystal structures in the solid, and is particularly prevalent in groups 14, 15, and 16 of the periodic table. In some cases, the allotropes are stable over a temperature range, with a definite transition point at which one changes into the other. For instance, tin has two allotropes: white (metallic) tin stable above 13.2°C and grey (nonmetallic) tin stable below 13.2°C. This form of allotropy is called **enantiotropy**. Carbon also has two allotropes – diamond and graphite – although graphite is the stable form at all temperatures. This form of allotropy, in which there is no transition temperature at which the two are in equilibrium, is called **monotropy**. *See also* POLYMORPHISM.

allowed bands *See* ENERGY BANDS.

allowed transitions *See* SELECTION RULES.

alloy A material consisting of two or more metals (e.g. brass is an alloy of copper and zinc) or a metal and a nonmetal (e.g. steel is an alloy of iron and carbon, sometimes with other metals included). Alloys may be compounds, *solid solutions, or mixtures of the components.

alloy steels *See* STEEL.

alluvial deposits Sediments deposited in a river, which range in particle size from fine silts to coarse gravels.

allyl group *See* PROPENYL GROUP.

Alnico A trade name for a series of alloys, containing iron, aluminium, nickel, cobalt, and copper, used to make permanent magnets.

alpha-iron *See* IRON.

alphamethyltryptamine (AMT) A synthetic derivative of *tryptamine with stimulant and hallucinogenic properties. It is used illegally as a club drug.

alpha-naphthol test A biochemical test to detect the presence of carbohydrates in solution, also known as **Molisch's test** (after the Austrian chemist H. Molisch (1856–1937), who devised it). A small amount of alcoholic alpha-naphthol is mixed with the test solution and concentrated sulphuric acid is poured slowly down the side of the test tube. A positive reaction is indicated by the formation of a violet ring at the junction of the liquids.

alpha particle A helium–4 nucleus emitted by a larger nucleus during the course of the type of radioactive decay known as **alpha decay**. As a helium–4 nucleus consists of two protons and two neutrons bound together as a stable entity the loss of an alpha particle involves a decrease in *nucleon number of 4 and decrease of 2 in the *atomic number, e.g. the decay of a uranium–238 nucleus into a thorium–234 nucleus. A stream of alpha particles is known as an **alpha-ray** or **alpha-radiation**.

alternating current (a.c.) An electric current that reverses its direction with a constant *frequency (f). If a graph of the current against time has the form of a *sine wave, the current is said to be **sinusoidal**. Alternating current, unlike direct current, is therefore continuously varying and its magnitude is either given as its peak value (I_0) or its *root-mean-square value ($I_0/\sqrt{2}$ for a sinusoidal current). This r.m.s. value is more useful as it is comparable to a d.c. value in being a measure of the ability of the current to transmit power. The instantaneous value of a sinusoidal current (I) is given by $I = I_0 \sin 2\pi ft$.

If a direct current is supplied to a circuit the only opposition it encounters is the circuit's *resistance. However, an alternating current is opposed not only by the resistance of the circuit but also by its *reactance. This reactance is caused by *capacitance and *inductance in the circuit. In a circuit consisting of a resistance (R), an inductance (L), and a capacitance (C) all in series, the reactance (X) is equal to $(2\pi fL) - (1/2\pi fC)$. The total opposition to the current, called the *impedance (Z), is then equal to the ratio of the r.m.s. applied p.d. to the r.m.s. current and is given by $\sqrt{(R^2 + X^2)}$.

alternation of generations The occurrence within the *life cycle of an organism of two or more distinct forms (generations), which differ from each other in appearance, habit, and method of reproduction. The phenomenon occurs in some protists and other simple multicellular organisms, certain lower animals (e.g. cnidarians and parasitic

flatworms), and in plants. The malaria parasite (*Plasmodium*), for example, has a complex life cycle involving the alternation of sexually and asexually reproducing generations. In plants the generation with sexual reproduction is called the *gametophyte and the asexual generation is the *sporophyte, either of which may dominate the life cycle, and there is also alternation of the haploid and diploid states. Thus in vascular plants the dominant plant is the diploid sporophyte; it produces spores that germinate into small haploid gametophytes. In mosses the gametophyte is the dominant plant and the sporophyte is the spore-bearing capsule.

alternative splicing The splicing of the RNA transcript of a gene in different ways by the cellular machinery to create distinct mature messenger RNAs (mRNAs) encoding different proteins. Hence, the same gene can give rise to related but variant forms of a protein at different stages of development or in different tissues. Alternative splicing accounts for the disparity between the relatively small number of human genes identified so far, roughly 22 000, and the 35 000 or so different gene transcripts discovered.

alternator An *alternating-current generator consisting of a coil or coils that rotate in the magnetic field produced by one or more permanent magnets or electromagnets. The electromagnets are supplied by an independent direct-current source. The frequency of the alternating current produced depends on the speed at which the coil rotates and the number of pairs of magnetic poles. In the large alternators of power stations the electromagnets rotate inside fixed coils; many bicycle dynamos are alternators with rotating permanent magnets inside fixed coils.

altimeter A device used to measure height above sea level. It usually consists of an aneroid *barometer measuring atmospheric pressure. Aircraft are fitted with altimeters, which are set to the atmospheric pressure at a convenient level, usually sea level, before take off. The height of the aircraft can then be read off the instrument as the aircraft climbs and the pressure falls.

altitude In horizontal coordinate systems, the distance of a celestial object above or below the observer's horizon, expressed as an angle i.e. its elevation. *Compare* AZIMUTH.

altruism Behaviour by an animal that decreases its chances of survival or reproduction while increasing those of another member of the same species. For example, a lapwing puts itself at risk by luring a predator away from the nest through feigning injury, but by so doing saves its offspring. Altruism in its biological sense does not imply any conscious benevolence on the part of the performer. Altruism can evolve through *kin selection, if the recipients of altruistic acts tend on average to be more closely related to the altruist than the population as a whole. Some animals perform altruistic acts in the expectation that the 'favour' will be returned in the future. This **reciprocal altruism** is practised most notably by humans. *See also* INCLUSIVE FITNESS.

ALU (arithmetic/logic unit) The part of the central processor of a *computer in which simple arithmetic and logical operations are performed electronically. For example, the ALU can add, subtract, multiply, or compare two numbers, or negate a number.

alum *See* ALUMINIUM POTASSIUM SULPHATE; ALUMS.

alumina *See* ALUMINIUM OXIDE; ALUMINIUM HYDROXIDE.

aluminate A salt formed when aluminium hydroxide or γ-alumina is dissolved in solutions of strong bases, such as sodium hydroxide. Aluminates exist in solutions containing the aluminate ion, commonly written $[Al(OH)_4]^-$. In fact the ion probably is a complex hydrated ion and can be regarded as formed from a hydrated Al^{3+} ion by removal of four hydrogen ions:

$$[Al(H_2O)_6]^{3+} + 4OH^- \rightarrow 4H_2O + [Al(OH)_4(H_2O)_2]^-$$

Other aluminates and polyaluminates, such as $[Al(OH)_6]^{3-}$ and $[(HO)_3AlOAl(OH)_3]^{2-}$, are also present. *See also* ALUMINIUM HYDROXIDE.

aluminium Symbol Al. A silvery-white lustrous metallic element belonging to *group 3 (formerly IIIB) of the periodic table; a.n. 13; r.a.m. 26.98; r.d. 2.7; m.p. 660°C; b.p. 2467°C. The metal itself is highly reactive but is protected by a thin transparent layer of the oxide, which forms quickly in air. Aluminium and its oxide are amphoteric. The metal is extracted from purified bauxite (Al_2O_3) by electrolysis; the main process uses a *Hall–Heroult cell but other electrolytic methods are under development, including conversion of bauxite with chlorine and electrolysis of the molten chloride. Pure alu-

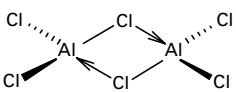
minium is soft and ductile but its strength can be increased by work-hardening. A large number of alloys are manufactured; alloying elements include copper, manganese, silicon, zinc, and magnesium. Its lightness, strength (when alloyed), corrosion resistance, and electrical conductivity (62% of that of copper) make it suitable for a variety of uses, including vehicle and aircraft construction, building (window and door frames), and overhead power cables. Although it is the third most abundant element in the earth's crust (8.1% by weight) it was not isolated until 1825 by H. C. Oersted (1777–1851).

SEE WEB LINKS

- Information from the WebElements site

aluminium acetate *See* ALUMINIUM ETHANOATE.

aluminium chloride A whitish solid, $AlCl_3$, which fumes in moist air and reacts violently with water (to give hydrogen chloride). It is known as the anhydrous salt (hexagonal; r.d. 2.44 (fused solid); m.p. 190°C (2.5 atm.); sublimes at 178°C) or the hexahydrate $AlCl_3.6H_2O$ (rhombic; r.d. 2.398; loses water at 100°C), both of which are deliquescent. Aluminium chloride may be prepared by passing hydrogen chloride or chlorine over hot aluminium or (industrially) by passing chlorine over heated aluminium oxide and carbon. The chloride ion is polarized by the small positive aluminium ion and the bonding in the solid is intermediate between covalent and ionic. In the liquid and vapour phases dimer molecules exist, Al_2Cl_6, in which there are chlorine bridges making coordinate bonds to aluminium atoms (see formula). The $AlCl_3$ molecule can also form compounds with other molecules that donate pairs of electrons (e.g. amines or hydrogen sulphide); i.e. it acts as a Lewis *acid. At high temperatures the Al_2Cl_6 molecules in the vapour dissociate to (planar) $AlCl_3$ molecules. Aluminium chloride is used commercially as a catalyst in the cracking of oils. It is also a catalyst in certain other organic reactions, especially the Friedel–Crafts reaction.



Aluminium chloride. Structure of aluminium trichloride dimer.

aluminium ethanoate (aluminium acetate) A white solid, $Al(OOCCH_3)_3$, which decomposes on heating, is very slightly soluble in cold water, and decomposes in warm water. The normal salt, $Al(OOCCH_3)_3$, can only be made in the absence of water (e.g. ethanoic anhydride and aluminium chloride at 180°C); in water it forms the basic salts $Al(OH)(OOCCH_3)_2$ and $Al_2(OH)_2(OOCCH_3)_4$. The reaction of aluminium hydroxide with ethanoic acid gives these basic salts directly. The compound is used extensively in dyeing as a mordant, particularly in combination with aluminium sulphate (known as **red liquor**); in the paper and board industry for sizing and hardening; and in tanning. It was previously used as an antiseptic and astringent.

aluminium hydroxide A white crystalline compound, $Al(OH)_3$; r.d. 2.42–2.52. The compound occurs naturally as the mineral **gibbsite** (monoclinic). In the laboratory it can be prepared by precipitation from solutions of aluminium salts. Such solutions contain the hexaquoaluminium(III) ion with six water molecules coordinated, $[Al(H_2O)_6]^{3+}$. In neutral solution this ionizes:

$$[Al(H_2O)_6]^{3+} \rightleftharpoons H^+ + [Al(H_2O)_5OH]^{2+}$$

The presence of a weak base such as S^{2-} or CO_3^{2-} (by bubbling hydrogen sulphide or carbon dioxide through the solution) causes further ionization with precipitation of aluminium hydroxide

$$[Al(H_2O)_6]^{3+}(aq) \rightarrow Al(H_2O)_3(OH)_3(s) + 3H^+(aq)$$

The substance contains coordinated water molecules and is more correctly termed **hydrated aluminium hydroxide**. In addition, the precipitate has water molecules trapped in it and has a characteristic gelatinous form. The substance is amphoteric. In strong bases the *aluminate ion is produced by loss of a further proton:

$$Al(H_2O)_3(OH)_3(s) + OH^-(aq) \rightleftharpoons [Al(H_2O)_2(OH)_4]^-(aq) + H_2O(l)$$

On heating, the hydroxide transforms to a mixed oxide hydroxide, AlO.OH (rhombic; r.d. 3.01). This substance occurs naturally as **diaspore** and **boehmite**. Above 450°C it transforms to γ-alumina.

In practice various substances can be produced that are mixed crystalline forms of $Al(OH)_3$, AlO.OH, and aluminium oxide (Al_2O_3) with water molecules. These are known as **hydrated alumina**. Heating the hydrated hydroxide causes loss of water, and

a

produces various **activated aluminas**, which differ in porosity, number of remaining –OH groups, and particle size. These are used as catalysts (particularly for organic dehydration reactions), as catalyst supports, and in chromatography. Gelatinous freshly precipitated aluminium hydroxide was formerly widely used as a mordant for dyeing and calico printing because of its ability to form insoluble coloured *lakes with vegetable dyes. *See also* ALUMINIUM OXIDE.

aluminium oxide (alumina) A white or colourless oxide of aluminium occurring in two main forms. The stable form α-alumina (r.d. 3.97; m.p. 2015°C; b.p. 2980 ± 60°C) has colourless hexagonal or rhombic crystals; γ-alumina (r.d. 3.5–3.9) transforms to the α-form on heating and is a white microcrystalline solid. The compound occurs naturally as **corundum** or **emery** in the α-form with a hexagonal-close-packed structure of oxide ions with aluminium ions in the octahedral interstices. The gemstones ruby and sapphire are aluminium oxide coloured by minute traces of chromium and cobalt respectively. A number of other forms of aluminium oxide have been described (β-, δ-, and ζ-alumina) but these contain alkali-metal ions. There is also a short-lived spectroscopic suboxide AlO. The highly protective film of oxide formed on the surface of aluminium metal is yet another structural variation, being a defective rock-salt form (every third Al missing).

Pure aluminium oxide is obtained by dissolving the ore bauxite in sodium hydroxide solution; impurities such as iron oxides remain insoluble because they are not amphoteric. The hydrated oxide is precipitated by seeding with material from a previous batch and this is then roasted at 1150–1200°C to give pure α-alumina, or at 500–800°C to give γ-alumina. The bonding in aluminium hydroxide is not purely ionic due to polarization of the oxide ion. Although the compound might be expected to be amphoteric, α-alumina is weakly acidic, dissolving in alkalis to give solutions containing aluminate ions; it is resistant to acid attack. In contrast γ-alumina is typically amphoteric dissolving both in acids to give aluminium salts and in bases to give aluminates. α-alumina is one of the hardest materials known (silicon carbide and diamond are harder) and is widely used as an abrasive in both natural (corundum) and synthetic forms. Its refractory nature makes alumina brick an ideal material for furnace linings and alumina is also used in cements for high-temperature conditions. *See also* ALUMINIUM HYDROXIDE.

aluminium potassium sulphate (potash alum; alum) A white or colourless crystalline compound, $Al_2(SO_4)_3.K_2SO_4.24H_2O$; r.d. 1.757; loses $18H_2O$ at 92.5°C; becomes anhydrous at 200°C. It forms cubic or octahedral crystals that are soluble in cold water, very soluble in hot water, and insoluble in ethanol and acetone. The compound occurs naturally as the mineral **kalinite**. It is a double salt and can be prepared by recrystallization from a solution containing equimolar quantities of potassium sulphate and aluminium sulphate. It is used as a mordant for dyeing and in the tanning and finishing of leather goods (for white leather). *See also* ALUMS.

aluminium sulphate A white or colourless crystalline compound, $Al_2(SO_4)_3$, known as the anhydrous compound (r.d. 2.71; decomposes at 770°C) or as the hydrate $Al_2(SO)_3.18H_2O$ (monoclinic; r.d. 1.69; loses water at 86.5°C). The anhydrous salt is soluble in water and slightly soluble in ethanol; the hydrate is very soluble in water and insoluble in ethanol. The compound occurs naturally in the rare mineral **alunogenite** ($Al_2(SO)_3.18H_2O$). It may be prepared by dissolving aluminium hydroxide or china clays (aluminosilicates) in sulphuric acid. It decomposes on heating to sulphur dioxide, sulphur trioxide, and aluminium oxide. Its solutions are acidic because of hydrolysis.

Aluminium sulphate is commercially one of the most important aluminium compounds; it is used in sewage treatment (as a flocculating agent) and in the purification of drinking water, the paper industry, and in the preparation of mordants. It is also a fireproofing agent. Aluminium sulphate is often wrongly called **alum** in these industries.

aluminium trimethyl *See* TRIMETHYLALUMINIUM.

aluminosilicate The chief rock-forming mineral in, for example, some clays, feldspar, mica, and zeolite. Aluminosilicates are also key constituents of china, glass, and cement. Most have a tetrahedral silicate structure with aluminium atoms replacing some of the silicon.

alums A group of double salts with the formula $A_2SO_4.B_2(SO_4)_3.24H_2O$, where A is a

monovalent metal and B a trivalent metal. The original example contains potassium and aluminium (called **potash alum** or simply **alum**); its formula is often written $AlK(SO_4)_2.12H_2O$ (aluminium potassium sulphate-12-water). **Ammonium alum** is $AlNH_4(SO_4)_2.12H_2O$, **chrome alum** is $KCr(SO_4)_2.12H_2O$ (*see* POTASSIUM CHROMIUM SULPHATE), etc. The alums are isomorphous and can be made by dissolving equivalent amounts of the two salts in water and recrystallizing. *See also* ALUMINIUM SULPHATE.

alunogenite A mineral form of hydrated *aluminium sulphate, $Al_2(SO_4)_3.18H_2O$.

Alvarez, Luis Walter (1911–88) US physicist most of whose working life was spent at the University of California, Berkeley. After working on radar and the atomic bomb during World War II, he concentrated on particle physics. In 1959 he built the first large *bubble chamber and developed the technique for using it to study charged particles, for which he was awarded the 1968 Nobel Prize for physics.

Alvarez event The collision of a giant meteorite with the earth 65 million years ago that caused catastrophic changes to the earth's climate and environment and a *mass extinction of species, including the dinosaurs. This hypothesis was advanced in 1980 by Luis Walter *Alvarez and his geologist son Walter Jr, based on the unusually high concentration of the element iridium in a thin layer of clay deposited at the end of the Cretaceous (*see* IRIDIUM ANOMALY). This clay marks the boundary between the Cretaceous period and the more recent Tertiary (the so-called **K–T boundary**). Subsequently, geologists discovered a possible impact crater, roughly 160 km in diameter, along the coast of eastern Mexico, and other evidence has tended to support the hypothesis. Such a collision would have produced a massive tidal wave and fireball and sent a vast cloud of rock and other debris into the atmosphere. The resulting upheaval in the climate is estimated to have caused the extinction of some 75% of all species.

alveolus (*pl.* **alveoli**) **1.** The tiny air sac in the *lung of mammals and reptiles at the end of each *bronchiole. It is lined by a delicate moist membrane, has many blood capillaries, and is the site of exchange of respiratory gases (carbon dioxide and oxygen). **2.** The socket in the jawbone in which a tooth is rooted by means of the *periodontal membrane.

Alzheimer's disease A neurological disease characterized by progressive loss of intellectual ability. The disease, which is named after German physician Alois Alzheimer (1864–1915), is associated with general shrinkage of the brain tissue – with deposits of β-amyloid peptide (a glycoprotein) and abnormal filaments of tau protein associated with *microtubules – and changes in the neurotransmitter systems within the brain that include a loss in the activity of *cholinergic neurons.

AM (amplitude modulation) *See* MODULATION.

amalgam An alloy of mercury with one or more other metals. Most metals form amalgams (iron and platinum are exceptions), which may be liquid or solid. Some are simple solutions; others contain definite intermetallic compounds, such as $NaHg_2$.

amatol A high explosive consisting of a mixture of ammonium nitrate and trinitrotoluene.

amber A yellow or reddish-brown fossil resin. The resin was exuded by certain trees and other plants and often contains preserved insects, flowers, or leaves that were trapped by its sticky surface before the resin hardened. Amber is used for jewellery and ornaments. It also has the property of acquiring an electrical charge when rubbed (the term electricity is derived from *electron*, the Greek name for amber). It occurs throughout the world in rock strata from the Cretaceous to the Pleistocene, but most commonly in Cretaceous and Tertiary rocks.

ambidentate Describing a ligand that can coordinate at two different sites. For example, the NO_2 molecule can coordinate through the N atom (the **nitro ligand**) or through an O atom (the **nitrido ligand**). Complexes that differ only in the way the ligand coordinates display **linkage isomerism**.

ambient Denoting the immediate surroundings or environment. **Ambient light** is light generated by outside sources, such as the sun, in relation to the environment of a specific optical system. **Ambient noise** is the background noise in relation to a particular sound, such as music. **Ambient pressure** and **ambient temperature** are the pressure and temperature of the surroundings, e.g. of

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the atmosphere, in relation to a specific object or system.

ambient computing *See* UBIQUITOUS COMPUTING.

americium Symbol Am. A radioactive metallic transuranic element belonging to the *actinoids; a.n. 95; mass number of most stable isotope 243 (half-life 7.95×10^3 years); r.d. 13.67 (20°C); m.p. 994 ± 4°C; b.p. 2607°C. Ten isotopes are known. The element was discovered by G. T. Seaborg and associates in 1945, who obtained it by bombarding uranium–238 with alpha particles.

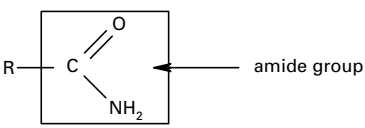
SEE WEB LINKS

- Information from the WebElements site

Ames test (*Salmonella* mutagenesis test) A test to determine the effects of a chemical on the rate of mutation in bacterial cells, and hence its likely potential for causing cancer in other organisms, including humans. Devised by US biologist Bruce Ames (1928–), it is widely used in screening chemicals occurring in the environment for possible carcinogenic activity. The chemical is applied to plates inoculated with a special mutant strain of bacteria, usually *Salmonella typhimurium*, and cells that mutate back to the wild type are detected by the occurrence of colonies able to grow on the medium.

amethyst The purple variety of the mineral *quartz. It is found chiefly in Brazil, the Urals (Russia), Arizona (USA), and Uruguay. The colour is due to impurities, especially iron oxide. It is used as a gemstone.

amides **1.** Organic compounds containing the group –CO.NH_2 (the **amide group**). Compounds containing this group are **primary amides**. **Secondary** and **tertiary amides** can also exist, in which the hydrogen atoms on the nitrogen are replaced by one or two other organic groups respectively. Simple examples of primary amides are ethanamide, CH_3CONH_2, and propanamide, $C_2H_5CONH_2$. They are made by heating the ammonium salt of the corresponding carboxylic acid. Amides can also be made by reaction of ammonia (or an amine) with an acyl halide. **2.** Inorganic compounds containing the ion NH_2^-, e.g. KNH_2 and $Cd(NH_2)_2$. They are formed by the reaction of ammonia with electropositive metals.



Amide structure.

SEE WEB LINKS

- Information about IUPAC nomenclature

amination A chemical reaction in which an amino group (–NH_2) is introduced into a molecule. Examples of amination reaction include the reaction of halogenated hydrocarbons with ammonia (high pressure and temperature) and the reduction of nitro compounds and nitriles.

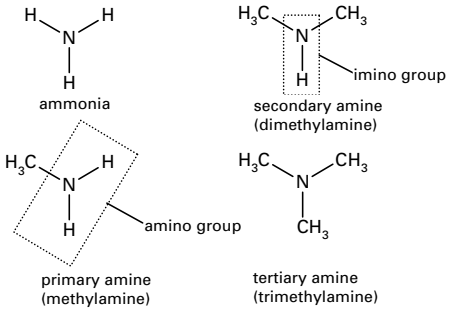
amines Organic compounds derived by replacing one or more of the hydrogen atoms in ammonia by organic groups (see illustration). **Primary amines** have one hydrogen replaced, e.g. methylamine, CH_3NH_2. They contain the functional group –NH_2 (the **amino group**). **Secondary amines** have two hydrogens replaced, e.g. methylethylamine, $CH_3(C_2H_5)NH$. **Tertiary amines** have all three hydrogens replaced, e.g. trimethylamine, $(CH_3)_3N$. Amines are produced by the decomposition of organic matter. They can be made by reducing nitro compounds or amides. *See also* IMINES.

SEE WEB LINKS

- Information about IUPAC nomenclature of primary amines
- Information about IUPAC nomenclature of secondary and tertiary amines

amine salts Salts similar to ammonium salts in which the hydrogen atoms attached to the nitrogen are replaced by one or more organic groups. Amines readily form salts by reaction with acids, gaining a proton to form a positive ammonium ion, They are named as if they were substituted derivatives of ammonium compounds; for example, dimethylamine ($(CH_3)_2NH$) will react with hydrogen chloride to give dimethylammonium chloride, which is an ionic compound $[(CH_3)_2NH_2]^+Cl^-$. When the amine has a common nonsystematic name the suffix *-ium* can be used; for example, phenylamine (aniline) would give $[C_6H_5NH_3]^+Cl^-$, known as anilinium chloride. Formerly, such compounds were sometimes called **hydrochlorides**, e.g. aniline hydrochloride with the formula $C_6H_5NH_2.HCl$.

Salts formed by amines are crystalline substances that are readily soluble in water. Many insoluble *alkaloids (e.g. quinine and atropine) are used medicinally in the form of



Examples of amines.

soluble salts ('hydrochlorides'). If alkali (sodium hydroxide) is added to solutions of such salts the free amine is liberated.

If all four hydrogen atoms of an ammonium salt are replaced by organic groups a **quaternary ammonium compound** is formed. Such compounds are made by reacting tertiary amines with halogen compounds; for example, trimethylamine ($(CH_3)_3N$) with chloromethane (CH_3Cl) gives tetramethylammonium chloride, $(CH_3)_4N^+Cl^-$. Salts of this type do not liberate the free amine when alkali is added, and quaternary hydroxides (such as $(CH_3)_4N^+OH^-$) can be isolated. Such compounds are strong alkalis, comparable to sodium hydroxide.

amino acid Any of a group of water-soluble organic compounds that possess both a carboxyl (–COOH) and an amino ($–NH_2$) group attached to the same carbon atom, called the α-carbon atom. Amino acids can be represented by the general formula $R–CH(NH_2)COOH$. R may be hydrogen or an organic group and determines the properties of any particular amino acid. Through the formation of peptide bonds, amino acids join together to form short chains (*peptides) or much longer chains (*polypeptides). Proteins are composed of various proportions of about 20 commonly occurring amino acids (see table overleaf). The sequence of these amino acids in the protein polypeptides determines the shape, properties, and hence biological role of the protein. Some amino acids that never occur in proteins are nevertheless important, e.g. *ornithine and citrulline, which are intermediates in the urea cycle.

Plants and many microorganisms can synthesize amino acids from simple inorganic compounds, but animals rely on adequate supplies in their diet. The *essential amino acids must be present in the diet whereas others can be manufactured from them.

SEE WEB LINKS

- Interactively depicts molecular structures of all the amino acids using Jmol
- Information about IUPAC nomenclature

amino acid racemization (AAR) A dating technique used in archaeology based on the relative amounts of the optical isomers of an amino acid in a sample. In most organisms, the L-isomer of the amino acid is the one produced by metabolism. When the organism dies, this isomer slowly converts into the D-form, and eventually an equilibrium is reached in which the two forms are present in equal amounts. Measuring the proportions of the L- and D-forms in a sample can, in principle, give an estimate of the time since death. Not all amino acids racemize at the same rate, and the rate of the process depends on other factors, such as moisture and temperature. Most work has been done using leucine or aspartic acid.

A particular application in forensic science involves measuring the D/L ratio of aspartic acid in the dentine of teeth. Once a tooth has fully formed, the dentine is isolated by the enamel and then racemization takes place in the living subject at a fairly constant temperature and moisture level. Measuring the ratio gives a fairly good estimate of the age of the subject (rather than the time since death).

aminobenzene *See* PHENYLAMINE.

amino group *See* AMINES.

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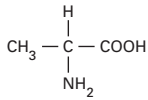
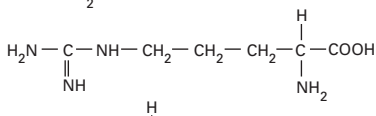
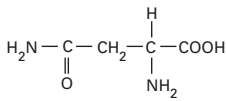
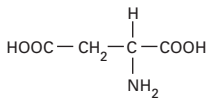
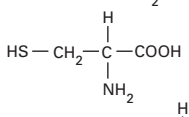
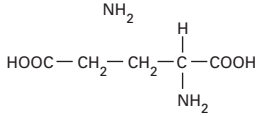
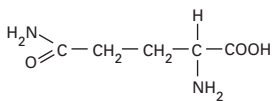
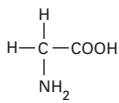
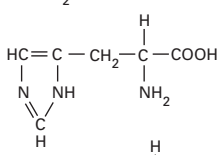
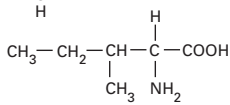
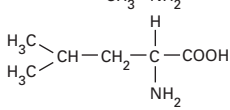
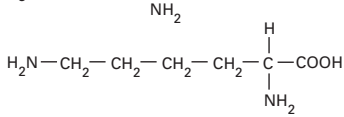
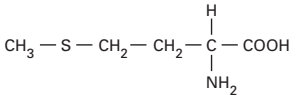
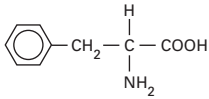
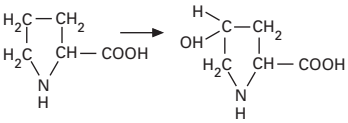
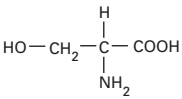
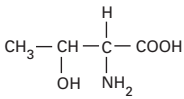
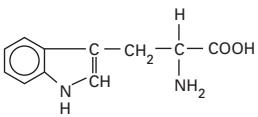
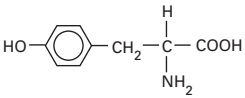
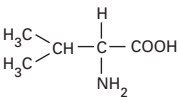
amino acid	abbreviation 3-letter	abbreviation 1-letter	formula
alanine	Ala	A	
arginine	Arg	R	
asparagine	Asn	N	
aspartic acid	Asp	D	
cysteine	Cys	C	
glutamic acid	Glu	E	
glutamine	Gln	Q	
glycine	Gly	G	
*histidine	His	H	
*isoleucine	Ile	I	
*leucine	Leu	L	
*lysine	Lys	K	

*methionine	Met	M	
*phenylalanine	Phe	F	
proline	Pro	P	
serine	Ser	S	
*threonine	Thr	T	
*tryptophan	Trp	W	
*tyrosine	Tyr	Y	
*valine	Val	V	

4–hydroxyproline

*an essential amino acid

Amino acid. The amino acids occurring in proteins.

aminopeptidase Any enzyme that cleaves amino acids from the N-terminus of peptides or polypeptides. For example, membrane-bound aminopeptidases in the small intestine break down peptides and dipeptides into amino acids.

amino sugar Any sugar containing an amino group in place of a hydroxyl group. The **hexosamines** are amino derivatives of hexose sugars and include **glucosamine** (based on glucose) and **galactosamine** (based on galactose). The former is a constituent of *chitin and the latter occurs in cartilage.

α-aminotoluene *See* BENZYLAMINE.

ammeter An instrument that measures electric current. The main types are the **moving-coil** ammeter, the **moving-iron** ammeter, and the **thermoammeter**. The moving-coil instrument is a moving-coil

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*galvanometer fitted with a *shunt to reduce its sensitivity. It can only be used for d.c., but can be adapted for a.c. by using a *rectifier. In moving-iron instruments, a piece of soft iron moves in the magnetic field created when the current to be measured flows through a fixed coil. They can be used with a.c. or d.c. but are less accurate (though more robust) than the moving-coil instruments. In thermoammeters, which can also be used with a.c. or d.c., the current is passed through a resistor, which heats up as the current passes. This is in contact with a thermocouple, which is connected to a galvanometer. This indirect system is mainly used for measuring high frequency a.c. In the **hot-wire** instrument the wire is clamped at its ends and its elongation as it is heated causes a pointer to move over a scale.

ammine A coordination *complex in which the ligands are ammonia molecules. An example of an ammine is the tetraamminecopper(II) ion $[Cu(NH_3)_4]^{2+}$.

ammonia A colourless gas, NH_3, with a strong pungent odour; r.d. 0.59 (relative to air); m.p. –77.7°C; b.p. –33.35°C. It is very soluble in water and soluble in alcohol. The compound may be prepared in the laboratory by reacting ammonium salts with bases such as calcium hydroxide, or by the hydrolysis of a nitride. Industrially it is made by the *Haber process and over 80 million tonnes per year are used either directly or in combination. Major uses are the manufacture of nitric acid, ammonium nitrate, ammonium phosphate, and urea (the last three as fertilizers), explosives, dyestuffs, and resins.

Liquid ammonia has some similarity to water as it is hydrogen bonded and has a moderate dielectric constant, which permits it to act as an ionizing solvent. It is weakly self-ionized to give ammonium ions, NH_4^+ and amide ions, NH_2^-. It also dissolves electropositive metals to give blue solutions, which are believed to contain solvated electrons. Ammonia is extremely soluble in water giving basic solutions that contain solvated NH_3 molecules and small amounts of the ions NH_4^+ and OH^-. The combustion of ammonia in air yields nitrogen and water. In the presence of catalysts NO, NO_2, and water are formed; this last reaction is the basis for the industrial production of nitric acid. Ammonia is a good proton acceptor (i.e. it is a base) and gives rise to a series of ammonium salts, e.g. $NH_3 + HCl \rightarrow NH_4^+ + Cl^-$. It is also a reducing agent.

The participation of ammonia in the *nitrogen cycle is a most important natural process. Nitrogen-fixing bacteria are able to achieve similar reactions to those of the Haber process, but under normal conditions of temperature and pressure. These release ammonium ions, which are converted by nitrifying bacteria into nitrite and nitrate ions.

ammoniacal Describing a solution in which the solvent is aqueous ammonia.

ammonia clock A form of atomic clock in which the frequency of a quartz oscillator is controlled by the vibrations of excited ammonia molecules (*see* EXCITATION). The ammonia molecule (NH_3) consists of a pyramid with a nitrogen atom at the apex and one hydrogen atom at each corner of the triangular base. When the molecule is excited, once every 20.9 microseconds the nitrogen atom passes through the base and forms a pyramid the other side: 20.9 microseconds later it returns to its original position. This vibration back and forth has a frequency of 23 870 hertz and ammonia gas will only absorb excitation energy at exactly this frequency. By using a *crystal oscillator to feed energy to the gas and a suitable feedback mechanism, the oscillator can be locked to exactly this frequency.

ammonia–soda process *See* SOLVAY PROCESS.

ammonite An extinct aquatic mollusc of the class *Cephalopoda. Ammonites were abundant in the Mesozoic era (225–65 million years ago) and are commonly found as fossils in rock strata of that time, being used as *index fossils for the Jurassic period. They were characterized by a coiled shell divided into many chambers, which acted as a buoyancy aid. The external suture lines on these shells increased in complexity with the advance of the group.

ammonium alum *See* ALUMS.

ammonium carbonate A colourless or white crystalline solid, $(NH_4)_2CO_3$, usually encountered as the monohydrate. It is very soluble in cold water. The compound decomposes slowly to give ammonia, water, and carbon dioxide. Commercial 'ammonium carbonate' is a double salt of ammonium hydrogencarbonate and ammonium aminomethanoate (carbamate), $NH_4HCO_3.NH_2COONH_4$. This material is manufactured by heating a mixture of ammonium chloride and calcium carbonate

and recovering the product as a sublimed solid. It readily releases ammonia and is the basis of sal volatile. It is also used in dyeing and wool preparation and in baking powders.

ammonium chloride (sal ammoniac) A white or colourless cubic solid, NH_4Cl; r.d. 1.53; sublimes at 340°C. It is very soluble in water and slightly soluble in ethanol but insoluble in ether. It may be prepared by fractional crystallization from a solution containing ammonium sulphate and sodium chloride or ammonium carbonate and calcium chloride. Pure samples may be made directly by the gas-phase reaction of ammonia and hydrogen chloride. Because of its ease of preparation it can be manufactured industrially alongside any plant that uses or produces ammonia. The compound is used in dry cells, metal finishing, and in the preparation of cotton for dyeing and printing.

ammonium ion The monovalent cation NH_4^+. It may be regarded as the product of the reaction of ammonia (a Lewis base) with a hydrogen ion. The ion has tetrahedral symmetry. The chemical properties of ammonium salts are frequently very similar to those of equivalent alkali-metal salts.

ammonium nitrate A colourless crystalline solid, NH_4NO_3; r.d. 1.72; m.p. 169.6°C; b.p. 210°C. It is very soluble in water and soluble in ethanol. The crystals are rhombic when obtained below 32°C and monoclinic above 32°C. It may be readily prepared in the laboratory by the reaction of nitric acid with aqueous ammonia. Industrially, it is manufactured by the same reaction using ammonia gas. Vast quantities of ammonium nitrate are used as fertilizers (over 20 million tonnes per year) and it is also a component of some explosives.

ammonium sulphate A white rhombic solid, $(NH_4)_2SO_4$; r.d. 1.77; decomposes at 235°C. It is very soluble in water and insoluble in ethanol. It occurs naturally as the mineral **mascagnite**. Ammonium sulphate was formerly manufactured from the 'ammoniacal liquors' produced during coal-gas manufacture but is now produced by the direct reaction between ammonia gas and sulphuric acid. It is decomposed by heating to release ammonia (and ammonium hydrogensulphate) and eventually water, sulphur dioxide, and ammonia. Vast quantities of ammonium sulphate are used as fertilizers.

amniocentesis The taking of a sample of amniotic fluid from a pregnant woman to determine the condition of an unborn baby. A hollow needle is inserted through the woman's abdomen and wall of the uterus and the fluid drawn off. Chemical and microscopical examination of cells shed from the embryo's skin into the fluid are used to detect spina bifida, *Down's syndrome, or other serious biochemical or chromosomal abnormalities.

amnion A membrane that encloses the embryo of reptiles, birds, and mammals within the **amniotic cavity.** This cavity is filled with **amniotic fluid,** in which the embryo is protected from desiccation and from external pressure. *See also* EXTRAEMBRYONIC MEMBRANES.

amniote A vertebrate whose embryos are totally enclosed in a fluid-filled sac – the *amnion. The evolution of the amnion provided the necessary fluid environment for the developing embryo and therefore allowed animals to breed away from water. Amniotes comprise the reptiles, birds, and mammals. *Compare* ANAMNIOTE.

Amoeba A genus of protists formerly placed in the phylum Rhizopoda but now, on the basis of molecular systematics, classified as *amoebozoans. *Amoeba* spp. have temporary body projections called *pseudopodia. These are used for locomotion and feeding and result in a constantly changing body shape (*see* AMOEBOID MOVEMENT). Most species are free-living in soil, mud, or water, where they feed on smaller protoctists and other single-celled organisms, but a few are parasitic. The best known species is the much studied *A. proteus*.

amoebocyte An animal cell whose location is not fixed and is therefore able to wander through the body tissues. Amoebocytes are named after their resemblance, especially in their movement, to *Amoeba* (*see* AMOEBOID MOVEMENT) and they feed on foreign particles (including invading bacteria). They occur, for example, in sponges and mammalian blood (e.g. some *leucocytes).

amoeboid movement The mechanism of movement demonstrated by **Amoeba* and other cells that are capable of changing their shape (e.g. *phagocytes). The cytoplasm of *Amoeba* consists of a central fluid endoplasm surrounded by a more viscous ectoplasm. The fluid endoplasm slides towards

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the front of the cell, forming a *pseudopodium and propelling the cell forward. On reaching the tip of the pseudopodium, the endoplasm is converted into ectoplasm; at the same time the ectoplasm at the rear of the cell is converted into endoplasm and streams forward, thus maintaining continuous movement.

amoebozoans An assemblage of eukaryotic protists, based largely on molecular systematics, that includes the plasmodial (or true) *slime moulds, the dictyostelid cellular slime moulds, the lobose amoebas (e.g. **Amoeba* species), and archamoebas, such as the pelobionts (which lack mitochondria and many other features of eukaryotic cells apart from a membrane-bounded nucleus).

amorphous Describing a solid that is not crystalline; i.e. one that has no long-range order in its lattice. Many powders that are described as 'amorphous' in fact are composed of microscopic crystals, as can be demonstrated by X-ray diffraction. *Glasses are examples of true amorphous solids.

amount concentration *See* CONCENTRATION.

amount of substance Symbol *n*. A measure of the number of entities present in a substance. The specified entity may be an atom, molecule, ion, electron, photon, etc., or any specified group of such entities. The amount of substance of an element, for example, is proportional to the number of atoms present. For all entities, the constant of proportionality is the *Avogadro constant. The SI unit of amount of substance is the *mole.

AMP *See* ATP; CYCLIC AMP.

ampere Symbol A. The SI unit of electric current. The constant current that, maintained in two straight parallel infinite conductors of negligible cross section placed one metre apart in a vacuum, would produce a force between the conductors of 2×10^{-7} N m^{-1}. This definition replaced the earlier international ampere defined as the current required to deposit 0.001 118 00 gram of silver from a solution of silver nitrate in one second. The unit is named after A. M. Ampère.

Ampère, André Marie (1775–1836) French physicist who from 1809 taught at the Ecole Polytechnique in Paris. He is best known for putting electromagnetism (which he called 'electrodynamics') on a mathematical basis. In 1825 he formulated *Ampère's law. The *ampere is named after him.

ampere-hour A practical unit of electric charge equal to the charge flowing in one hour through a conductor passing one ampere. It is equal to 3600 coulombs.

Ampère's law A law of the form

$$dB = (\mu_o I \sin\theta\, dl)/4\pi r^2,$$

where dB is the infinitesimal element of the magnitude of the magnetic flux density at a distance r at a point P from the element length dl of a conductor, μ_o is the magnetic *permeability of free space, I is the current flowing through the conductor, and θ is the angle between the direction of the current and the line joining the element of the conductor and P. It is also called the **Ampère–Laplace law** after the French mathematician Pierre-Simon de Laplace (1749–1827).

Ampère's rule A rule that relates the direction of the electric current passing through a conductor and the magnetic field associated with it. The rule states that if the electric current is moving away from an observer, the direction of the lines of force of the magnetic field surrounding the conductor is clockwise and that if the electric current is moving towards an observer, the direction of the lines of force is counterclockwise. An equivalent statement to Ampère's rule is known as the **corkscrew rule**. A corkscrew, or screwdriver, is said to be right-handed if turning the corkscrew in a clockwise direction drives the screw into the object (such as the cork of a bottle). The corkscrew rule states that a right-handed corkscrew is analogous to an electric current and its magnetic field with the direction of the screw being analogous to electric current; the direction in which the corkscrew is being turned is analogous to the direction of lines of force of the field.

ampere-turn The SI unit of *magnetomotive force equal to the magnetomotive force produced when a current of one ampere flows through one turn of a magnetizing coil.

amphetamine A drug, 1-phenyl-2-aminopropane (or a derivative of this compound), that stimulates the central nervous system by causing the release of the transmitters noradrenaline and dopamine from nerve endings. It inhibits sleep, suppresses the

appetite, and has variable effects on mood; prolonged use can lead to addiction.

Amphibia The class of vertebrate chordates (*see* CHORDATA) that contains the frogs, toads, newts, and salamanders. The amphibians evolved in the Devonian period (about 370 million years ago) as the first vertebrates to occupy the land, and many of their characteristics are adaptations to terrestrial life. All adult amphibians have a passage linking the roof of the mouth with the nostrils so they may breathe air and keep the mouth closed. The moist scaleless skin is used to supplement the lungs in gas exchange. They have no diaphragm, and therefore the muscles of the mouth and pharynx provide the pumping action for breathing. Fertilization is usually external and the eggs are soft and prone to desiccation, therefore reproduction commonly occurs in water. Amphibian larvae are aquatic, having gills for respiration; they undergo metamorphosis to the adult form.

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amphiboles A large group of rock-forming metasilicate minerals. They have a structure of silicate tetrahedra linked to form double endless chains, in contrast to the single chains of the *pyroxenes, to which they are closely related. They are present in many igneous and metamorphic rocks. The amphiboles show a wide range of compositional variation but all of them conform to the general formula: $X_{2-3}Y_5Z_8O_{22}(OH)_2$, where X = Ca, Na, K, Mg, or Fe^{2+}; Y = Mg, Fe^{2+}, Fe^{3+}, Al, Ti, or Mn; and Z = Si or Al. The hydroxyl ions may be replaced by F, Cl, or O. Most amphiboles are monoclinic, including: cummingtonite,

$(Mg,Fe^{2+})_7(Si_8O_{22})(OH)_2$;

tremolite,

$Ca_2Mg_5(Si_8O_{22})(OH,F)_2$;

actinolite,

$Ca_2(Mg,Fe^{2+})_5(Si_8O_{22})(OH,F)_2$;

*hornblende,

$NaCa_2(Mg,Fe^{2+},Fe^{3+},Al)_5((Si,Al)_8O_{22})(OH,F)_2$;

edenite,

$NaCa_2(Mg,Fe^{2+})_5(Si_7AlO_{22})(OH,F)_2$;

riebeckite,

$Na_2,Fe_3{}^{2+}(Si_8O_{22})(OH,F)_2$.

The minerals anthophyllite,

$(Mg,Fe^{2+})_7(Si_8O_{22})(OH,F)_2$,

and gedrite,

$(Mg,Fe^{2+})_6Al(Si,Al)_8O_{22})(OH,F)_2$,

are orthorhombic amphiboles.

amphimixis True sexual reproduction, involving the fusion of male and female gametes and the formation of a zygote. *Compare* APOMIXIS.

amphioxus Another name for the lancelet: *see* CHORDATA.

amphiprotic *See* AMPHOTERIC; SOLVENT.

ampholyte A substance that can act as either an acid, in the presence of a strong base, or a base, when in the presence of a strong acid.

ampholyte ion *See* ZWITTERION.

amphoteric Describing a compound that can act as both an acid and a base (in the traditional sense of the term). For instance, aluminium hydroxide is amphoteric: as a base $Al(OH)_3$ it reacts with acids to form aluminium salts; as an acid H_3AlO_3 it reacts with alkalis to give *aluminates. Oxides of metals are typically basic and oxides of nonmetals tend to be acidic. The existence of amphoteric oxides is sometimes regarded as evidence that an element is a *metalloid. Compounds such as the amino acids, which contain both acidic and basic groups in their molecules, can also be described as amphoteric. Solvents, such as water, that can both donate and accept protons are usually described as **amphiprotic** (*see* SOLVENT).

amplifier A device that increases the strength of an electrical signal by drawing energy from a separate source to that of the signal. The original device used in electronic amplifiers was the *triode valve, in which the cathode–anode current is varied in accordance with the low-voltage signal applied to the valve's control grid. In the more recent *transistor, the emitter–collector current is controlled in much the same way by the signal applied to the transistor's base region. In the most modern devices the complete amplifier circuit is manufactured as a single *integrated circuit. The ratio of the output amplitude (of p.d. or current) of an amplifier (or stage of an amplifier) to the corresponding input amplitude is called the **gain** of the amplifier.

amplitude *See* WAVE.

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amplitude modulation (AM) *See* MODULATION; RADIO.

ampulla **1.** An enlargement at one end of each of the *semicircular canals of the inner ear. Each ampulla contains a group of receptors – sensory hair cells – embedded in a gelatinous cap (**cupula**), which detects movement in one particular dimension, corresponding to the plane of the canal. Movement of the head causes the cupula (and the hairs within it) to bend in a direction opposite to that of the head movement; this stimulates nerve impulses in the receptors, which are interpreted by the brain as movement in a particular dimension. **2.** Any small vesicle or saclike process.

AMT *See* ALPHAMETHYLTRYPTAMINE.

a.m.u. *See* ATOMIC MASS UNIT.

amylase Any of a group of closely related enzymes that degrade starch, glycogen, and other polysaccharides. Plants contain both α- and β-amylases; the name **diastase** is given to the component of malt containing β-amylase, important in the brewing industry. Animals possess only α-amylases, found in pancreatic juice (as **pancreatic amylase**) and also (in humans and some other species) in saliva (as **salivary amylase** or **ptyalin**). Amylases cleave the long polysaccharide chains, producing a mixture of glucose and maltose.

amyl group Formerly, any of several isomeric groups with the formula C_5H_{11}–.

amylopectin A *polysaccharide comprising highly branched chains of glucose molecules. It is one of the constituents (the other being amylose) of *starch.

amylose A *polysaccharide consisting of linear chains of between 100 and 1000 linked glucose molecules. Amylose is a constituent of *starch. In water, amylose reacts with iodine to give a characteristic blue colour.

anabolic steroid Any steroid compound that promotes tissue growth, especially of muscles. Naturally occurring anabolic steroids include the male sex hormones (*androgens). Synthetic forms of these are used medically to help weight gain after debilitating diseases; their use by athletes to build up body muscles can cause liver damage and is banned by most athletic authorities.

anabolism The metabolic synthesis of proteins, fats, and other constituents of living organisms from molecules or simple precursors. This process requires energy in the form of ATP. Drugs that promote such metabolic activity are described as **anabolic** (*see* ANABOLIC STEROID). *See* METABOLISM. *Compare* CATABOLISM.

anaerobe *See* ANAEROBIC RESPIRATION.

anaerobic respiration A type of *respiration in which foodstuffs (usually carbohydrates) are partially oxidized, with the release of chemical energy, in a process not involving atmospheric oxygen. Since the substrate is never completely oxidized the energy yield of this type of respiration is lower than that of *aerobic respiration. It occurs in some yeasts and bacteria and in muscle tissue when oxygen is absent (*see* OXYGEN DEBT). **Obligate anaerobes** are organisms that cannot use free oxygen for respiration; **facultative anaerobes** are normally aerobic but can respire anaerobically during periods of oxygen shortage. Alcoholic *fermentation is a type of anaerobic respiration in which one of the end products is ethanol.

Analar reagent A chemical reagent of high purity with known contaminants for use in chemical analyses.

analgesic A substance that reduces pain without causing unconsciousness, either by reducing the pain threshold or by increasing pain tolerance. There are several categories of analgesic drugs, including morphine and its derivatives (*see* OPIATE), which produce analgesia by acting on the central nervous system; nonsteroidal anti-inflammatory drugs (e.g. *aspirin); and local anaesthetics.

analogous Describing features of unrelated organisms that are superficially similar but have evolved in very different ways. The wings of butterflies and birds are analogous organs.

analyser A device, used in the *polarization of light, that is placed in the eyepiece of a *polarimeter to observe plane-polarized light. The analyser, which may be a *Nicol prism or *Polaroid, can be oriented in different directions to investigate in which plane an incoming wave is polarized or if the light is plane polarized. If there is one direction from which light does not emerge from the analyser when it is rotated, the incoming wave is plane polarized. If the analyser is horizontal when extinction of light takes place, the polarization of light must have

been in the vertical plane. The intensity of a beam of light transmitted through an analyser is proportional to $\cos^2\theta$, where θ is the angle between the plane of polarization and the plane of the analyser. Extinction is said to be produced by 'crossing' the *polarizer and analyser.

analysis The determination of the components in a chemical sample. **Qualitative analysis** involves determining the nature of a pure unknown compound or the compounds present in a mixture. Various chemical tests exist for different elements or types of compound, and systematic analytical procedures can be used for mixtures. **Quantitative analysis** involves measuring the proportions of known components in a mixture. Chemical techniques for this fall into two main classes: *volumetric analysis and *gravimetric analysis. In addition, there are numerous physical methods of qualitative and quantitative analysis, including spectroscopic techniques, mass spectrometry, polarography, chromatography, activation analysis, etc.

analytical geometry (coordinate geometry) A form of geometry in which points are located in a two-dimensional, three-dimensional, or higher-dimensional space by means of a system of coordinates. Curves are represented by an equation for a set of such points. The geometry of figures can thus be analysed by algebraic methods. *See* CARTESIAN COORDINATES; POLAR COORDINATES.

anamniote A vertebrate that lacks an *amnion and whose embryos and larvae must therefore develop in water. Anamniotes comprise the agnathans, fishes, and amphibians. *Compare* AMNIOTE.

anaphase One of several stages of cell division. In *mitosis the chromatids of each chromosome move apart to opposite ends of the spindle. In the first anaphase of *meiosis, the paired homologous chromosomes separate and move to opposite ends; in the second anaphase the chromatids move apart, as in mitosis.

anaphylaxis An abnormal *immune response that occurs when an individual previously exposed to a particular *antigen is re-exposed to the same antigen. Anaphylaxis may follow an insect bite or the injection of a drug (such as penicillin). It is caused by the release of *histamine and similar substances and may produce a localized reaction or a more generalized and severe one, with difficulty in breathing, pallor, or drop in blood pressure, unconsciousness, and possibly heart failure and death. *See also* ALLERGY.

anastigmatic lens **1.** An objective lens for an optical instrument in which all *aberrations, including *astigmatism, are reduced greatly. **2.** A spectacle lens designed to correct astigmatism. It has different radii of curvature in the vertical and horizontal planes.

anatomy The study of the structure of living organisms, especially of their internal parts by means of dissection and microscopical examination. *Compare* MORPHOLOGY.

anchor ring *See* TORUS.

and circuit *See* LOGIC CIRCUITS.

Anderson, Carl David (1905–91) US physicist who became a professor at the California Institute of Technology, where he worked mainly in particle physics. In 1937 he discovered the *positron in *cosmic radiation, and four years later was awarded the Nobel Prize. In 1939 he discovered the mumeson (muon).

Andreev reflection A process occurring at the interface between a normal conductor of electricity and a *superconductor, in which charge is transferred from the normal conductor to the superconductor. This results in the formation of a Cooper pair in the superconductor and a reflected hole in the normal conductor. The process was first described by the Russian physicist Alexander Andreev in 1964. It has possible applications in spintronics and quantum computing.

androecium The male sex organs (*stamens) of a flower. *Compare* GYNOECIUM.

androgen One of a group of male sex hormones that stimulate development of the testes and of male *secondary sexual characteristics (such as growth of facial and pubic hair in men). **Testosterone** is the most important. Androgens are produced principally by the testes when stimulated with *luteinizing hormone but they are also secreted in smaller amounts by the adrenal glands and the ovaries. Injections of natural or synthetic androgens are used to treat hormonal disorders of the testes and breast cancer and to build up body tissue (*see* ANABOLIC STEROID).

anechoic Having a low degree of reverberation with little or no reflection of sound. An

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anechoic chamber is one designed for experiments in acoustics. The walls are covered with small pyramids to avoid the formation of stationary waves between facing surfaces and the whole of the interior surface is covered with an absorbent material to avoid reflections.

anemometer An instrument for measuring the speed of the wind or any other flowing fluid. The simple **vane anemometer** consists of a number of cups or blades attached to a central spindle so that the air, or other fluid, causes the spindle to rotate. The instrument is calibrated to give a wind speed directly from a dial. It can be mounted to rotate about a vertical axis and in this form it also gives an indication of the direction of the wind. A **hot-wire anemometer** consists of an electrically heated wire that is cooled by the flow of fluid passing round it. The faster the flow the lower the temperature of the wire and the lower its resistance. Thus the rate of flow can be calculated by measuring the resistance of the wire.

anemophily Pollination of a flower in which the pollen is carried by the wind. Examples of anemophilous flowers are those of grasses and conifers. *Compare* ENTOMOPHILY; HYDROPHILY.

aneroid barometer *See* BAROMETER.

ANFO Ammonium nitrate–fuel oil. A mixture used extensively as a blasting agent in mining and quarrying. The proportions are approximately 94% ammonium nitrate and 6% fuel oil. ANFO has been used in terrorist attacks (e.g. an attack on the Murrah Federal Building, Oklahoma City, in 1995).

angiosperms *See* ANTHOPHYTA.

angiotensin Any of three related peptide hormones. Angiotensin I is derived, by the action of the enzyme *renin, from a protein (α-globulin) secreted by the liver into the bloodstream. As blood passes through the lungs, another enzyme (**angiotensin-converting enzyme**; **ACE**) splits angiotensin I, forming angiotensin II. This causes constriction of blood vessels and stimulates the release of *antidiuretic hormone and *aldosterone, which increase blood pressure. Angiotensin III, formed by removal of a single amino acid from angiotensin II, also stimulates aldosterone release by the adrenal gland.

angle modulation *See* MODULATION.

angle of incidence **1.** The angle between a ray falling on a surface and the perpendicular (normal) to the surface at the point at which the ray strikes the surface. **2.** The angle between a wavefront and a surface that it strikes.

angle of reflection **1.** The angle between a ray leaving a reflecting surface and the perpendicular (normal) to the surface at the point at which the ray leaves the surface. **2.** The angle between a wavefront and a surface that it leaves.

angle of refraction **1.** The angle between a ray that is refracted at a surface between two different media and the perpendicular (normal) to the surface at the point of refraction. **2.** The angle between a wavefront and a surface at which it has been refracted.

angle-resolved photoelectron spectroscopy (ARPES) A technique for studying the composition and structure of surfaces by measuring both the kinetic energy and angular distribution of photoelectrons ejected from a surface by electromagnetic radiation. *See also* PHOTOELECTRON SPECTROSCOPY.

anglesite A mineral form of *lead(II) sulphate, $PbSO_4$.

angstrom Symbol Å. A unit of length equal to 10^{-10} metre. It was formerly used to measure wavelengths and intermolecular distances but has now been replaced by the nanometre. 1 Å = 0.1 nanometre. The unit is named after Anders Ångström.

Ångström, Anders Jonas (1814–74) Swedish astronomer and physicist who became professor of physics at the University of Uppsala from 1858 until his death. He worked mainly with emission *spectra, demonstrating the presence of hydrogen in the sun. He also worked out the wavelengths of *Fraunhofer lines. Since 1905 spectral wavelengths have been expressed in *angstroms.

angular displacement, velocity, and acceleration *See* ROTATIONAL MOTION.

angular distance A way of expressing sizes or distances in astronomy. Angular diameter is the size of a celestial object; angular distance is the distance between two objects. Both are measured as angles on the *celestial sphere (expressed in degrees, arc-minutes, or arc-seconds).

angular frequency (pulsatance) A quantity proportional to the *frequency of a periodic phenomenon but having the dimensions of angular velocity. The angular frequency in radians per second = frequency in hertz $\times 2\pi$ radians per cycle.

angular magnification (magnifying power) *See* MAGNIFICATION.

angular momentum Symbol *L*. The product of the angular velocity of a body and its *moment of inertia about the axis of rotation, i.e. $L = I\omega$.

anharmonic oscillator An oscillating system (in either *classical physics or *quantum mechanics) that is not oscillating in *simple harmonic motion. In general, the problem of an anharmonic oscillator is not exactly soluble, although many systems approximate to harmonic oscillators and for such systems the **anharmonicity** (the deviation of the system from being a *harmonic oscillator) can be calculated using *perturbation theory. If the anharmonicity is large other approximate or numerical techniques have to be used to solve the problem.

anhydride A compound that produces a given compound on reaction with water. For instance, sulphur trioxide is the (acid) anhydride of sulphuric acid

$$SO_3 + H_2O \rightarrow H_2SO_4$$

See also ACID ANHYDRIDES.

anhydrite An important rock-forming anhydrous mineral form of calcium sulphate, $CaSO_4$. It is chemically similar to *gypsum but is harder and heavier and crystallizes in the rhombic form (gypsum is monoclinic). Under natural conditions anhydrite slowly hydrates to form gypsum. It occurs chiefly in white and greyish granular masses and is often found in the caprock of certain salt domes. It is used as a raw material in the chemical industry and in the manufacture of cement and fertilizers.

anhydrous Denoting a chemical compound lacking water: applied particularly to salts lacking their water of crystallization.

aniline *See* PHENYLAMINE.

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

animal Any member of the kingdom Animalia, which comprises multicellular organisms that develop from embryos formed by the fusion of haploid eggs and sperm. Unable to manufacture their own food, they feed on other organisms or organic matter (holozoic nutrition; *see* HETEROTROPHIC NUTRITION). Animals are therefore typically mobile (to search for food) and have evolved specialized sense organs for detecting changes in the environment; a *nervous system coordinates information received by the sense organs and enables rapid responses to environmental stimuli. Animal *cells lack the cellulose cells walls of *plant cells. Molecular systematics now includes animals in the opisthokonts, an assemblage that also contains the fungi. For a classification of the animal kingdom, see Appendix.

animal behaviour The activities that constitute an animal's response to its external environment. Certain categories of behaviour are seen in all animals (e.g. feeding, reproduction) but these activities involve different movements in different species and develop in different ways. Some movements are highly characteristic of a species (*see* INSTINCT) whereas others are more variable and depend on the interaction between innate tendencies and *learning during the individual's lifetime. Physiologists study how changes in the body (e.g. hormone levels) affect behaviour, psychologists study the mechanisms of learning, and ethologists study the behaviour of the whole animal: how this develops during the individual's lifetime and how it evolved through natural selection (*see* ETHOLOGY).

animal charcoal *See* CHARCOAL.

animal starch *See* GLYCOGEN.

anion A negatively charged *ion, i.e. an ion that is attracted to the *anode in *electrolysis. *Compare* CATION.

anionic detergent *See* DETERGENT.

anionic resin *See* ION EXCHANGE.

anisogamy Sexual reproduction involving the fusion of gametes that differ in size and sometimes also in form. *See also* OOGAMY. *Compare* ISOGAMY.

anisotropic Denoting a medium in which certain physical properties are different in different directions. Wood, for instance, is an anisotropic material: its strength along the grain differs from that perpendicular to the grain. Single crystals that are not cubic are anisotropic with respect to some physical properties, such as the transmission of electromagnetic radiation. *Compare* ISOTROPIC.

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annealing A form of heat treatment applied to a metal to soften it, relieve internal stresses and instabilities, and make it easier to work or machine. It consists of heating the metal to a specified temperature for a specified time, both of which depend on the metal involved, and then allowing it to cool slowly. It is applied to both ferrous and nonferrous metals and a similar process can be applied to other materials, such as glass.

Annelida A phylum of invertebrates comprising the segmented worms (e.g. the earthworm). Annelids have cylindrical soft bodies showing *metameric segmentation, obvious externally as a series of rings separating the segments. Each segment is internally separated from the next by a membrane and bears stiff bristles (*see* CHAETA). Between the gut and other body organs there is a fluid-filled cavity called the *coelom, which acts as a hydrostatic skeleton. Movement is by alternate contraction of circular and longitudinal muscles in the body wall. The phylum contains three classes: *Polychaeta, *Oligochaeta, and *Hirudinea. Molecular systematics now places the annelids in the superphylum Lophotrochozoa, along with other wormlike phyla and the molluscs.

annihilation The destruction of a particle and its *antiparticle as a result of a collision between them. The **annihilation radiation** produced is carried away by *photons or *mesons. For example, in a collision between an electron and a positron the energy produced is carried away by two photons, each having an energy of 0.511 MeV, which is equivalent to the rest-mass energies of the annihilated particles plus their kinetic energies. When nucleons annihilate each other the energy is carried away by mesons.

annual A plant that completes its life cycle in one year, during which time it germinates, flowers, produces seeds, and dies. Examples are the sunflower and marigold. *Compare* BIENNIAL; EPHEMERAL; PERENNIAL.

annual rhythm The occurrence of a process or a function in a living organism on a yearly basis. Events that display an annual rhythm can include life cycles, such as those of *annual plants; mating behaviour; some kinds of movement, such as *migration; or growth patterns, such as the *growth rings of woody plant stems. *See also* BIORHYTHM.

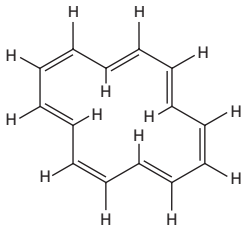
annual ring *See* GROWTH RING.

annular parallax Symbol π. The *parallax of a celestial object resulting from the movement of the earth in its orbit during a year. It is equal to the semimajor axis of the parallatic ellipse described by the apparent movement of the object against the background of distant stars. Annular parallax (in arcseconds) is also approximately equal to the reciprocal of the distance to the object (in parsecs).

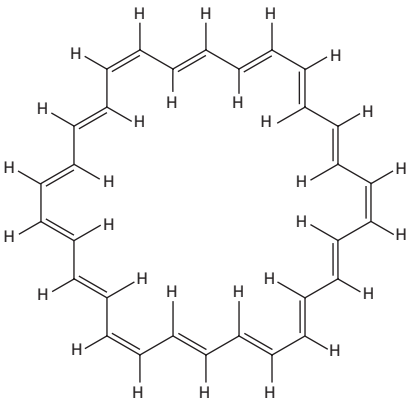
annulenes Organic hydrocarbons that have molecules containing simple single rings of carbon atoms linked by alternating single and double bonds. Such compounds have even numbers of carbon atoms. Cyclooctatetraene, C_8H_8, is the next in the series following benzene. Higher annulenes are usually referred to by the number of carbon atoms in the ring, as in [10]-annulene, $C_{10}H_{10}$, [12]-annulene, $C_{12}H_{12}$, etc. The lower members are not stable as a result of the interactions between hydrogen atoms inside the ring. This is true even for molecules that have the necessary number of pi electrons to be *aromatic compounds. Thus, [10]-annulene has $4n + 2$ pi electrons with $n = 2$, but is not aromatic because it is not planar. [14]-annulene also has a suitable number of pi electrons to be aromatic ($n = 3$) but is not planar because of interaction between the inner hydrogens.

The compound [18]-annulene is large enough to be planar and obeys the Hückel rule ($4n + 2 = 18$, with $n = 4$). It is a brownish red fairly stable reactive solid. NMR evidence shows that it has aromatic character. The annulene with $n = 7$, [30]-annulene, can also exist in a planar form but is highly unstable. *See also* PSEUDOAROMATIC.

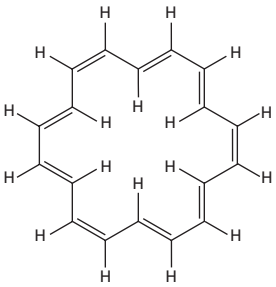
annulus (*pl.* **annuli**) **1.** (in mathematics) The plane figure formed between two concentric circles of different radii, R and r. Its area is $\pi(R^2 - r^2)$. **2.** (in botany) **a.** A ragged ring of tissue that remains on the stalk of a mushroom or toadstool. Also called a **velum**, it is formed from the ruptured membrane that originally covered the lower surface of the cap. **b.** The region of the wall of a fern sporangium that is specialized for spore dispersal. It consists of cells that are thickened except on their outer walls. On drying out, the cells contract and the sporangium ruptures, releasing the spores. The annulus springs back into position when the residual water in the cells vaporizes and any remaining spores are dispersed. **3.** (in zoology) Any of various ring-shaped structures in animals,



[14]-Annulene



[30]-Annulene



[18]-Annulene

Annulenes.

such as any of the segments of an earthworm or other annelid.

anode A positive electrode. In *electrolysis anions are attracted to the anode. In an electronic vacuum tube it attracts electrons from the *cathode and it is therefore from the anode that electrons flow out of the device. In these instances the anode is made positive by external means; however in a *voltaic cell the anode is the electrode that spontaneously becomes positive and therefore attracts electrons to it from the external circuit.

anode sludge *See* ELECTROLYTIC REFINING.

anodizing A method of coating objects made of aluminium with a protective oxide film, by making them the anode in an electrolytic bath containing an oxidizing electrolyte. Anodizing can also be used to produce a decorative finish by formation of an oxide layer that can absorb a coloured dye.

anomaly Any of three angles used to fix at a specific moment in time the position of a body in an elliptical orbit around another body located at one of the foci of the ellipse. For a planet in the solar system, the **true anomaly** is the angle formed by a line joining the planet to the sun and a line joining the sun to the planet's *perihelion; the angle is measured in the direction of the planet's motion. If a circle is superimposed upon the ellipse with its centre at the midpoint of the major axis of the ellipse, then the **eccentric anomaly** is the angle formed by a line connecting the centre of the circle to the perihelion and another joining the centre to a point on the circumference of the circle vertically above the planet. The **mean anomaly** is the angle formed by lines connecting the perihelion and the sun, and an imaginary planet having the same period as the real planet but assumed to be moving at constant speed.

Anoplura *See* SIPHUNCULATA.

ANS *See* AUTONOMIC NERVOUS SYSTEM.

ANSI American National Standards Institute: a US body that accredits organizations to write industrial standards – publicly avail-

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able definitions, requirements, criteria, etc. – following the rules established by ANSI.

SEE WEB LINKS

- The ANSI home page

antagonism **1.** The interaction of two substances (e.g. drugs, hormones, or enzymes) having opposing effects in a system in such a way that the action of one partially or completely inhibits the effects of the other. For example, one group of anti-cancer drugs acts by antagonizing the effects of certain enzymes controlling the activities of the cancer cells. *See also* ANTAGONIST. **2.** An interaction between two muscles, known as **antagonistic muscles**, in which contraction of one prevents that of the other. For example, the *biceps and triceps are an antagonistic pair. *See* VOLUNTARY MUSCLE. **3.** An interaction between two organisms (e.g. moulds or bacteria) in which the growth of one is inhibited by the other. *Compare* SYNERGISM.

antagonist A drug that inhibits the effect of an *agonist in such a way that the combined biological effect of the two substances becomes smaller than the sum of their individual effects. **Competitive antagonists** act by binding to agonist receptors, while **non-competitive antagonists** do not bind to the same receptor sites as the agonist. A **functional antagonist** binds to other receptors that elicit an effect opposite to that of the agonist.

antenna **1.** (*pl.* **antennae**) (in zoology) A long whiplike jointed mobile paired appendage on the head of many arthropods, usually concerned with the senses of smell, touch, etc. In insects, millipedes, and centipedes they are the first pair of head appendages and are specialized and modified in many insects. In crustaceans they are the second pair of head appendages, the first pair (the **antennules**) having the sensory function, while the antennae are modified for swimming and for attachment. **2.** (*pl.* **antennas**) (in radio) *See* AERIAL.

antennule *See* ANTENNA.

anterior **1.** Designating the part of an animal that faces to the front, i.e. that leads when the animal is moving. In humans and other bipedal animals the anterior surface corresponds to the *ventral surface. **2.** Designating the side of a flower or axillary bud that faces away from the flower stalk or main stem, respectively. *Compare* POSTERIOR.

anther The upper two-lobed part of a plant *stamen, usually yellow in colour. Each lobe contains two pollen sacs within which are numerous pollen grains, which are released when the anther ruptures.

antheridium The male sex organ of algae, fungi, bryophytes, and pteridophytes. It produces the male gametes (**antherozoids**). It may consist of a single cell or it may have a wall that is made up of one or several layers forming a sterile jacket around the developing gametes. *Compare* ARCHEGONIUM.

antherozoid (spermatozoid) The motile male gamete of algae, fungi, bryophytes, clubmosses, horsetails, ferns, and certain gymnosperms. Antherozoids usually develop in an *antheridium but in certain gymnosperms, such as *Ginkgo* and *Cycas*, they develop from a cell in the pollen tube.

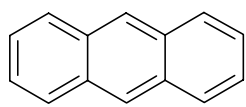
anthocyanin One of a group of *flavonoid pigments. Anthocyanins occur in the cell vacuoles of various plant organs and are responsible for many of the blue, red, and purple colours in plants (particularly in flowers).

Anthophyta (Angiospermophyta; Magnoliophyta) A phylum comprising the flowering plants (angiosperms). Their gametes are produced within *flowers and the ovules (and the seeds into which they develop) are enclosed in a carpel (*compare* CONIFEROPHYTA). The angiosperms are the dominant plant forms of the present day. They show the most advanced structural organization in the plant kingdom, enabling them to inhabit a very diverse range of habitats. There are two classes within this group: the *Monocotyledoneae with one seed leaf (cotyledon) in the seed, and the *Dicotyledoneae with two seed leaves.

SEE WEB LINKS

- A good overview of flowering plant diversity and systematics

anthracene A white crystalline solid, $C_{14}H_{10}$; r.d. 1.28; m.p. 215.8°C; b.p. 341.4°C. It is an aromatic hydrocarbon with three fused rings (see formula), and is obtained by the distillation of crude oils. The main use is in the manufacture of dyes.



Anthracene.

anthracite *See* COAL.

anthraquinone A colourless stable crystalline solid, $C_{14}H_8O_2$, m.p. 285°C. It is made from benzene or naphthalene and used in the manufacture of a large range of dyes.

anthropic principle The principle that the observable universe has to be as it is, rather than any other way, otherwise we would not be able to observe it. There are many versions of the anthropic principle. The **weak anthropic principle** is specifically concerned with the conditions necessary for conscious life on earth and asserts that numerical relations found for fundamental constants, such as the *gravitational constant, have to hold at the present epoch because at any other epoch there would be no intelligent lifeform to measure the constants. The **strong anthropic principle** is concerned with all possible universes and whether intelligent life could exist in any other universe, including the possibility of different fundamental constants and laws of physics. The anthropic principle is viewed with considerable scepticism by many physicists.

antiaromatic *See* PSEUDOAROMATIC.

antiatom An atom in which all the particles of an ordinary atom are replaced by their *antiparticles, i.e. electrons by positrons, protons by antiprotons, and neutrons by antineutrons. An antiatom cannot co-exist with an ordinary atom since the atom and the antiatom would annihilate each other with the production of energy in the form of high-energy *photons.

antibiotics Substances that destroy or inhibit the growth of microorganisms, particularly disease-producing bacteria. Antibiotics are obtained from microorganisms (especially moulds) or synthesized. Common antibiotics include the *penicillins, **streptomycin**, and the **tetracyclines**. They are used to treat various infections but tend to weaken the body's natural defence mechanisms and can cause allergies. Overuse of antibiotics can lead to the development of resistant strains of microorganisms.

antibody A protein (*see* IMMUNOGLOBULIN) produced by certain white blood cells (*plasma cells) in response to entry into the body of a foreign substance (*antigen) in order to render it harmless. An antibody–antigen reaction is highly specific. Antibody production is one aspect of the *immune response and is stimulated by such antigens as invading bacteria, foreign red blood cells (*see* ABO SYSTEM), inhaled pollen grains or dust, and foreign tissue *grafts. *See also* B CELL; IMMUNITY; MONOCLONAL ANTIBODY.

antibonding orbital *See* ORBITAL.

antibunching *See* BUNCHING.

anticholinesterase Any substance that inhibits the enzyme *cholinesterase, which is responsible for the breakdown of the neurotransmitter acetylcholine at nerve synapses. Anticholinesterases, which include certain drugs, nerve gases, and insecticides, cause a build-up of acetylcholine within the synapses, leading to disruption of nerve and muscle function. In vertebrates, these agents often cause death by paralysing the respiratory muscles. *See* PESTICIDE.

anticline *See* FOLD.

anticoagulant A substance that prevents the formation of blood clots. *Heparin is a natural anticoagulant, which is extracted to treat such conditions as thrombosis and embolism. Synthetic anticoagulants include *warfarin.

anticodon A sequence of three nucleotides (trinucleotide) on a strand of transfer *RNA that can form base pairs (*see* BASE PAIRING) with a specific trinucleotide sequence (*see* CODON) on a strand of messenger RNA during *translation. *See also* PROTEIN SYNTHESIS.

anticyclone (high) An area of the atmosphere that is at a higher pressure than the surrounding air. It appears on synoptic charts with a roughly circular closed *isobar at its centre. Winds, which are generally light, circulate in a clockwise direction around the high-pressure centre in the northern hemisphere and in an anticlockwise direction in the southern hemisphere. An anticyclone is characteristically slow moving and is associated with settled weather.

antidiuretic hormone (ADH; vasopressin) A hormone, secreted by the posterior *pituitary gland, that stimulates reabsorption of water by the kidneys and thus controls the concentration of body fluids. ADH is produced by specialized nerve cells in the hypothalamus of the brain and is transported to the posterior pituitary in the bloodstream. Deficiency of ADH results in a disorder known as **diabetes insipidus**, in which large volumes of urine are excreted; it

is treated by administration of natural or synthetic hormone.

antiferromagnetism *See* MAGNETISM.

antifreeze A substance added to the liquid (usually water) in the cooling systems of internal-combustion engines to lower its freezing point so that it does not solidify at sub-zero temperatures. The commonest antifreeze is *ethane-1,2-diol (ethylene glycol).

antifreeze molecule Any substance produced by an organism in order to prevent freezing of its tissues or body fluids when subject to subzero environmental temperatures. Many animals living in cold climates produce relatively inert molecules, notably glycerol and other polyhydric alcohols (polyols), such as sorbitol and ribitol, which accumulate in their blood, thereby raising the osmotic concentration and so depressing the *supercooling point. Some families of teleost fish inhabiting polar regions manufacture **antifreeze peptides** or **antifreeze glycopeptides**, which bind to the edges of ice crystal lattices and prevent the addition of further water molecules.

antigen Any substance that the body regards as foreign and that therefore elicits an *immune response, particularly the formation of specific antibodies capable of binding to it. Antigens may be formed in, or introduced into, the body. They are usually proteins. **Histocompatibility antigens** are associated with the tissues and are involved in the rejection of tissue or organ *grafts (*see* HISTOCOMPATIBILITY); an example is the group of antigens encoded by the *HLA system. A graft will be rejected if the recipient's body regards such antigens on the donor's tissues as foreign. *See also* ANTIBODY.

antigorite *See* SERPENTINE.

antihistamine Any drug that inhibits the effects of *histamine in the body and is therefore used to relieve and prevent the symptoms associated with allergic reactions, such as hay fever. Since one of the side-effects produced by antihistamines is sleepiness, some are used to prevent motion sickness and induce sleep.

***anti*-isomer** *See* ISOMERISM.

antiknock agent *See* KNOCKING.

antilogarithm *See* LOGARITHM.

antimatter *See* ANTIPARTICLE.

antimonic compounds Compounds of antimony in its +5 oxidation state; e.g. antimonic chloride is antimony(V) chloride ($SbCl_5$).

antimonous compounds Compounds of antimony in its +3 oxidation state; e.g. antimonous chloride is antimony(III) chloride ($SbCl_3$).

antimony Symbol Sb. An element belonging to *group 15 (formerly VB) of the periodic table; a.n. 51; r.a.m. 121.75; r.d. 6.68; m.p. 630.5°C; b.p. 1750°C. Antimony has several allotropes. The stable form is a bluish-white metal. Yellow antimony and black antimony are unstable nonmetallic allotropes made at low temperatures. The main source is stibnite (Sb_2S_3), from which antimony is extracted by reduction with iron metal or by roasting (to give the oxide) followed by reduction with carbon and sodium carbonate. The main use of the metal is as an alloying agent in lead-accumulator plates, type metals, bearing alloys, solders, Britannia metal, and pewter. It is also an agent for producing pearlitic cast iron. Its compounds are used in flame-proofing, paints, ceramics, enamels, glass dyestuffs, and rubber technology. The element will burn in air but is unaffected by water or dilute acids. It is attacked by oxidizing acids and by halogens. It was first reported by Tholden in 1450.

SEE WEB LINKS

- Information from the WebElements site

antinode *See* STATIONARY WAVE.

antioxidants Substances that slow the rate of oxidation reactions. Various antioxidants are used to preserve foodstuffs and to prevent the deterioration of rubber, synthetic plastics, and many other materials. Some antioxidants act as chelating agents to sequester the metal ions that catalyse oxidation reactions. Others inhibit the oxidation reaction by removing oxygen free radicals. Naturally occurring antioxidants include *vitamin E, β-*carotene, and *glutathione; they limit the cell and tissue damage caused by foreign substances, such as toxins and pollutants, in the body.

antiparallel spins Neighbouring spinning electrons in which the *spins, and hence the magnetic moments, of the electrons are aligned in the opposite direction. The interaction between the magnetic moments of electrons in atoms is dominated by exchange interactions. Under some circum-

stances the exchange interactions between magnetic moments favour *parallel spins, while under other conditions they favour antiparallel spins. The case of antiferromagnetism (*see* MAGNETISM) is an example of a system with antiparallel spins.

antiparallel vectors Vectors directed along the same line but in opposite directions.

antiparticle A subatomic particle that has the same mass as another particle and equal but opposite values of some other property or properties. For example, the antiparticle of the electron is the positron, which has a positive charge equal in magnitude to the electron's negative charge. The antiproton has a negative charge equal to the proton's positive charge. The neutron and the antineutron have *magnetic moments opposite in sign relative to their *spins. The existence of antiparticles is predicted by relativistic *quantum mechanics. When a particle and its corresponding antiparticle collide *annihilation takes place. **Antimatter** is postulated to consist of matter made up of antiparticles. For example, antihydrogen would consist of an antiproton with an orbiting positron. It appears that the universe consists overwhelmingly of (normal) matter, and explanations of the absence of large amounts of antimatter have been incorporated into cosmological models that involve the use of *grand unified theories of elementary particles.

antipyretic A drug that reduces fever by lowering body temperature. Certain *analgesic drugs, notably paracetamol, *aspirin, and phenylbutazone, also have antipyretic properties.

antisense DNA A single-stranded DNA molecule that can bind to a complementary base sequence in a particular messenger RNA (mRNA) molecule and so prevent synthesis of the protein encoded by the mRNA. Although antisense DNA has the potential to block the expression of a particular gene, this is achieved more effectively by short double-stranded RNA molecules (*see* RNA INTERFERENCE), which are not susceptible to degradation by DNase enzymes. *See also* ANTISENSE RNA.

antisense RNA A single-stranded RNA molecule whose base sequence is complementary to that of the RNA transcript of a gene, i.e. the 'sense' RNA, such as a messenger RNA (mRNA). Hence, an antisense RNA can undergo base pairing with its complementary mRNA sequence. This blocks gene expression, either by preventing access for ribosomes to translate the mRNA or by triggering degradation of the double-stranded RNA by ribonuclease enzymes. Like *antisense DNA, antisense RNA has therapeutic potential for modifying the activity of disease-causing genes. Also, genes encoding antisense RNAs can be used in genetic engineering to alter the makeup of organisms. For example, the FlavrSavr tomato was engineered with an artificial gene for antisense RNA that prevented expression of a gene for an enzyme involved in ripening, in order to retard spoilage.

antiseptic Any substance that kills or inhibits the growth of disease-causing microorganisms but is essentially nontoxic to cells of the body. Common antiseptics include hydrogen peroxide, the detergent cetrimide, and ethanol. They are used to treat minor wounds. *Compare* DISINFECTANT.

antiserum Serum containing antibodies, either raised against particular antigens, and hence of known specificity, or a broad mixture of antibodies. It is used to provide short-term passive immunity, e.g. against hepatitis A virus, and to treat an infection to which the patient has no immunity. Antisera may be obtained from large animals, such as horses, that have been inoculated with particular antigens, or from pooled donated human serum.

antitail A small tail on a *comet that points towards the sun, unlike the comet's main tail. It is thought to consist of large particles, which scatter sunlight, and is prominent only when observed from the plane of the comet's orbit.

antitoxin An antibody produced in response to a bacterial *toxin.

antiviral Describing a drug or other agent that kills or inhibits viruses and is used to treat viral infections. Several types of antiviral drug are now in use, such as *aciclovir, effective against herpesviruses, and **antiretroviral drugs** (e.g. *reverse transcriptase inhibitors and protease inhibitors); a combination of the latter, called **highly active antiretroviral therapy** (**HAART**), is used to treat HIV infection. The body's own natural antiviral agents, *interferons, can now be pro-

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duced by genetic engineering and are sometimes used therapeutically. However, many antiviral agents are extremely toxic, and viruses evolve rapidly so that a drug's effectiveness can soon be lost.

anti-Zeno effect *See* QUANTUM ZENO EFFECT.

anus The terminal opening of the *alimentary canal in most animals, through which indigestible material (*faeces) is expelled.

anyon *See* QUANTUM STATISTICS.

aorta The major blood vessel in higher vertebrates through which oxygenated blood leaves the *heart from the left ventricle. The aorta branches to form many smaller arteries, which in turn branch many times to supply oxygen and essential nutrients to all living cells in the body.

apastron The point at which the distance between the two components of a *binary star is greatest. The point of closest approach is called periastron.

apatite A highly complex mineral form of *calcium phosphate, $Ca_5(PO_4)_3(OH,F,Cl)$; the commonest of the phosphate minerals. It has a hexagonal structure and occurs widely as an accessory mineral in igneous rocks (e.g. pegmatite) and often in regional and contact metamorphic rocks, especially limestone. Large deposits occur in the Kola Peninsula, Russia. It is used in the production of fertilizers and is a major source of phosphorus. The enamel of teeth is composed chiefly of apatite.

aperture The effective diameter of a lens or mirror. The ratio of the effective diameter to the focal length is called the **relative aperture**, which is commonly known as the aperture, especially in photographic usage. The reciprocal of the relative aperture is called the **focal ratio**. The numerical value of the focal ratio is known as the **f-number** of a lens. For example, a camera lens with a 40 mm focal length and a 10 mm aperture has a relative aperture of 0.25 and a focal ratio of 4. Its f-number would be f/4, often written f4.

The light-gathering power of a telescope depends on the area of the lens, i.e. it is related to the square of the aperture. However, the larger the relative aperture the greater the *aberrations. In microscopy large-aperture objectives (corrected for aberrations) are preferred, since they reduce the blurring caused by *diffraction of light waves.

aperture synthesis *See* RADIO TELESCOPE.

aphelion The point in the solar orbit of a planet, comet, or other solar system object, natural or artificial, at which it is farthest from the sun. At the beginning of the 21st century, the earth is at aphelion on or about 4 July. Its distance from the sun at that point is 1.0167 astronomical units. *Compare* PERIHELION.

aphotic zone (bathypelagic zone) The region of a lake or sea where no light penetrates; it is situated beneath the *euphotic zone. The aphotic zone contains no algae or phytoplankton, and its inhabitants are exclusively carnivorous animals or organisms that feed on sediment or detritus, all reliant on energy inputs from the euphotic zone. It extends downwards from a depth of about 1000 m, or less in turbid waters, and includes the *abyssal zone.

apical dominance Inhibition of the growth of lateral buds in a plant by the presence of a growing apical bud. It is brought about by the action of auxins (produced by the apical bud) and abscisic acid.

apical meristem A region at the tip of each shoot and root of a plant in which cell divisions are continually occurring to produce new stem and root tissue, respectively. The new tissues produced are known collectively as the **primary tissues** of the plant. *See also* MERISTEM. *Compare* CAMBIUM.

aplanatic lens A lens that reduces both spherical *aberration and *coma.

apocarpy The condition in which the female reproductive organs (*carpels) of a flower are not joined to each other. It occurs, for example, in the buttercup. *Compare* SYNCARPY.

apochromatic lens *See* ACHROMATIC LENS.

apocrine secretion *See* SECRETION.

apocynthion The point in the orbit around the moon of a satellite launched from the earth that is furthest from the moon. For a satellite launched from the moon the equivalent point is the **apolune**. *Compare* PERICYNTHION.

apoenzyme An inactive enzyme that must associate with a specific *cofactor molecule

or ion in order to function. *Compare* HOLOENZYME.

apogee The point in the orbit of the moon, or an artificial earth satellite, at which it is furthest from the earth. At apogee the moon is 406 700 km from the earth, some 42 000 km further away than at *perigee.

apolune *See* APOCYNTHION.

apomixis (agamospermy) A reproductive process in plants that superficially resembles normal sexual reproduction but in which there is no fusion of gametes. In apomictic flowering plants there is no fertilization by pollen, and the embryos develop simply by division of a *diploid cell of the ovule. *See also* PARTHENOCARPY; PARTHENOGENESIS.

apoplast An interconnected system in plants that consists of all the cell walls and the water that exists in them (the cell wall is composed of cellulose fibres, between which are spaces filled with water). The movement of water (and dissolved ions and solutes) through the cell walls is known as the **apoplastic pathway**. This is the main route by which water taken up by a plant travels across the root cortex to the *endodermis. *Compare* SYMPLAST.

apoptosis (programmed cell death) The process of cell death that occurs naturally as part of the normal development, maintenance, and renewal of tissues within an organism. During embryonic development it plays a vital role in determining the final size and form of tissues and organs. For example, the fingers are 'sculpted' on the spadelike embryonic hand by apoptosis of the cells between them; the tubules of the embryonic kidney are hollowed out by a similar process. Apoptosis involves the action of enzymes called **caspases**, cellular proteins that – when activated (e.g. by cell damage) – initiate a series of events that results in digestion of the cytoskeleton, DNA, and other cell components. Apoptosis is normally suppressed as long as cells continue to receive extracellular survival signals in the form of trophic factors (e.g. nerve growth factor: *see* NEUROTROPHIN). In the absence of such signals, the cell embarks on a 'suicide' programme. Sometimes, other cells, for example immune cells, release specific 'murder' signals, which activate apoptosis in target cells. Cancer is associated with the suppression of apoptosis, which also occurs when viruses infect cells – in order to inhibit the activity of *natural killer cells. Apoptosis differs from cell necrosis, in which cell death may be stimulated by a toxic substance.

SEE WEB LINKS

- Brilliant introduction to apoptosis with clear graphics and intriguing animations

aposematic coloration *See* WARNING COLORATION.

apparent expansivity *See* EXPANSIVITY.

appeasement Behaviour that inhibits aggression from another animal of the same species, frequently taking the form of a special posture or *display emphasizing the weakness of the performer. Threatening structures (e.g. antlers) and markings are covered or turned away, and vulnerable parts of the body may be exposed. Appeasement is seen in *courtship, in greeting ceremonies, and often (from the loser) after a fight.

appendicular skeleton The components, collectively, of the vertebrate skeleton that are attached to the main supporting, or *axial, skeleton. The appendicular skeleton is made up of paired appendages (e.g. legs, wings, arms) together with the *pelvic girdle and *pectoral girdle.

appendix (vermiform appendix) An outgrowth of the *caecum in the alimentary canal. In humans it is a *vestigial organ containing lymphatic tissue and serves no function in normal digestive processes. Appendicitis is caused by inflammation of the appendix.

Appleton layer *See* EARTH'S ATMOSPHERE.

applications software Computer programs, or collections of programs, designed to meet the needs of the users of computer systems by directly contributing to the performance of specific roles. Examples include a word-processing or spreadsheet program, or a company's payroll package. In contrast, **systems software**, such as an operating system, are the group of programs required for effective use of a computer system.

approximation technique A method used to solve a problem in mathematics, or its physical applications, that does not give an exact solution but that enables an approximate solution to be found.

aprotic *See* SOLVENT.

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apsides The two points in an astronomical orbit that lie closest to (**periapsis**) and farthest from (**apoapsis**) the centre of gravitational attraction. The **line of apsides** is the straight line that joins the two apsides. If the orbit is elliptical the line of apsides is the major axis of the ellipse.

aqua acid A type of acid in which the acidic hydrogen is on a water molecule coordinated to a metal ion. For example,

$$Al(OH_2)_6^{3+} + H_2O \rightarrow Al(OH_2)_5(OH)^{2+} + H_3O^+$$

aquamarine A variety of the mineral *beryl that has a transparent blue-green colour, valued as a gemstone. It is found as an accessory mineral in pegmatite, sometimes as very large crystals.

aqua regia A mixture of concentrated nitric acid and concentrated hydrochloric acid in the ratio 1:3 respectively. It is a very powerful oxidizing mixture and will dissolve all metals (except silver, which forms an insoluble chloride) including such noble metals as gold and platinum, hence its name ('royal water'). Nitrosyl chloride (NOCl) is believed to be one of the active constituents.

aquation The process in which water molecules solvate or form coordination complexes with ions.

aqueous Describing a solution in water.

aqueous humour The fluid that fills the space between the cornea and the lens of the vertebrate eye. In addition to supplying the cornea and lens with nutrients, the aqueous humour helps to maintain the shape of the eye. It is produced and renewed every four hours by the *ciliary body.

aquifer A deposit of rock that yields economic supplies of water to wells or springs as a result of its porosity or permeability. It may be, for example, a zone of sandstone, unconsolidated gravels, or jointed limestone.

aquo ion A hydrated positive ion present in a crystal or in solution.

Arabidopsis A genus of flowering plants of the family Cruciferae (Brassicaceae). The species *A. thaliana* (thale cress) is widely used as a research tool in molecular genetics and developmental biology because it has a small and simple genome (five pairs of chromosomes), over half of which codes for protein, and it can be easily cultured, having a life cycle of only 6–8 weeks. Its full genome sequence was published in 2000.

arachidonic acid An unsaturated fatty acid, $CH_3(CH_2)_3(CH_2CH{=}CH)_4(CH_2)_3COOH$, that is essential for growth in mammals. It can be synthesized from *linoleic acid. Arachidonic acid acts as a precursor to several biologically active compounds, including *prostaglandins, and plays an important role in membrane production and fat metabolism. The release of arachidonic acid from membrane *phospholipids is triggered by certain hormones.

Arachnida A class of terrestrial *arthropods of the phylum Chelicerata, comprising about 65 000 species and including spiders, scorpions, harvestmen, ticks, and mites. An arachnid's body is divided into an anterior *cephalothorax (**prosoma**) and a posterior abdomen (**opisthosoma**). The prosoma bears a pair of grasping or piercing appendages (the **chelicerae**), a pair of **pedipalps** used for manipulation or as sensory structures, and four pairs of walking legs. The opisthosoma may bear various sensory or silk-spinning appendages (*see* SPINNERET). Arachnids are generally carnivorous, feeding on the body fluids of their prey or secreting enzymes to digest prey externally. Spiders immobilize their prey with poison injected by the fanglike chelicerae, while scorpions grasp their prey in large clawed pedipalps and may poison it using the posterior stinging organ. Ticks and some mites are parasitic but most arachnids are free-living. They breathe either via *tracheae (like insects) or by means of thin highly folded regions of the body wall called **lung books**.

SEE WEB LINKS

- Descriptions and pictures for all orders of arachnids, plus societies, special spider pages, and even arachnids in literature

arachnoid membrane One of the three membranes (*meninges) that surround the brain and spinal cord of vertebrates. It lies between the *pia mater and the *dura mater. The arachnoid membrane is very delicate and carries *cerebrospinal fluid, which sustains and cushions the nervous tissue.

arachno-structure *See* BORANE.

aragonite A rock-forming anhydrous mineral form of calcium carbonate, $CaCO_3$. It is much less stable than *calcite, the commoner form of calcium carbonate, from which it may be distinguished by its greater

hardness and specific gravity. Over time aragonite undergoes recrystallization to calcite. Aragonite occurs in cavities in limestone, as a deposit in limestone caverns, as a precipitate around hot springs and geysers, and in high-pressure low-temperature metamorphic rocks; it is also found in the shells of a number of molluscs and corals and is the main constituent of pearls. It is white or colourless when pure but the presence of impurities may tint it grey, blue, green, or pink.

arbovirus Obsolete name for any RNA-containing virus that is transmitted from animals to humans through the bite of mosquitoes and ticks (i.e. arthropods, hence *ar*thropod-*bo*rne viruses). They cause various forms of encephalitis (inflammation of the brain) and serious fevers, such as dengue and yellow fever.

arccos, arcsin, arctan *See* INVERSE FUNCTIONS.

Archaea A *domain of prokaryotic organisms containing the archaebacteria, including the *methanogens, which produce methane; the thermoacidophilic bacteria, which live in extremely hot and acidic environments (such as hot springs); and the halophilic bacteria, which can only function at high salt concentrations and are abundant in the world's oceans. The archaebacteria are grouped together principally on the basis of similarities in the base sequence of their ribosomal RNA. This molecular evidence shows them to be phylogenetically distinct and closer to the eukaryotes than the eubacteria. They are possibly descendants of the earliest forms of life, predating the earliest known microbial fossils.

Archaean The earliest eon of geological time, in which there is the first evidence of life on earth. It follows the *Hadean eon of pregeological time and extends from the time of the earliest known rocks, roughly 3900 million years ago, to the beginning of the *Proterozoic eon, about 2500 million years ago. Rock formations called *stromatolites, dated at 3500 million years old or older, are among the oldest of all fossil remains. They are thought to have been produced by the activities of microbial mats of filamentous purple and green bacteria. These prokaryotes performed photosynthesis anaerobically, perhaps using hydrogen sulphide as an electron donor instead of water. Some of their descendants evolved the ability to use water as an electron donor, producing oxygen as a by-product, and eventually brought about the change in atmospheric conditions necessary for aerobic life.

archaebacteria *See* ARCHAEA.

Archaeplastida *See* PLANT.

archegonium The multicellular flask-shaped female sex organ of bryophytes, clubmosses, horsetails, ferns, and many gymnosperms. Such plants are described as **archegoniate** to distinguish them from algae, which do not possess archegonia. The dilated base, the **venter**, contains the oosphere (female gamete). The cells of the narrow neck liquefy to allow the male gametes to swim towards the oosphere. The archegonium is thus an adaptation to the terrestrial environment as it provides a means for the male gametes to reach the female gamete. *Compare* ANTHERIDIUM.

archenteron (gastrocoel) A cavity within an animal embryo at the *gastrula stage of development. All or part of the archenteron eventually forms the cavity of the gut. It is connected to the outside by an opening (the **blastopore**), which becomes either the mouth, the mouth and anus, or the anal opening of the animal.

Archimedes of Syracuse (287–212 BC) Greek mathematician, who spent most of his life at his birthplace working on levers and other aspects of mechanics. In hydrostatics he devised a pump (the **Archimedian screw**) and formulated *Archimedes' principle. His method of successive approximation allowed him to determine the value of π to a good approximation and some of his work came close to anticipating integral calculus. He was killed by a soldier in the Roman siege of Syracuse.

Archimedes' principle The weight of the liquid displaced by a floating body is equal to the weight of the body. The principle was not in fact stated by Archimedes, though it has some connection with his discoveries. The principle is often stated in the form: when a body is (partially or totally) immersed in a fluid, the upthrust on the body is equal to the weight of fluid displaced.

arc lamp *See* ELECTRIC LIGHTING.

arcosh, arsinh, artanh *See* INVERSE FUNCTIONS.

a

area A measure of the size of a two-dimensional shape. The areas of common geometrical figures are given below, where l = length, h = altitude or height, r = radius, and s = slant height:

square	l^2
rectangle	lh
parallelogram	lh
triangle	$\frac{1}{2}lh$
circle	πr^2
sphere	$4\pi r^2$
cone	πrs (curved surface)
	$\pi rs + \pi r^2$ (total surface)
cylinder	$2\pi rh$ (curved surface)
	$2\pi rh + 2\pi r^2$ (total surface)

arene complex A complex in which an aromatic ring is bound to a metal atom by its pi-electrons. Examples of arene complexes are the *sandwich compounds $(C_6H_6)_2Cr$ and $(C_5H_5)_2Fe$.

arenes Aromatic hydrocarbons, such as benzene, toluene, and naphthalene.

Argand diagram *See* COMPLEX NUMBER.

argentic compounds Compounds of silver in its higher (+2) oxidation state; e.g. argentic oxide is silver(II) oxide (AgO).

argentite A sulphide ore of silver, Ag_2S. It crystallizes in the cubic system but most commonly occurs in massive form. It is dull grey-black in colour but bright when first cut and occurs in veins associated with other silver minerals. Important deposits occur in Mexico, Peru, Chile, Bolivia, and Norway.

argentous compounds Compounds of silver in its lower (+1) oxidation state; e.g. argentous chloride is silver(I) chloride.

arginine *See* AMINO ACID.

argon Symbol Ar. A monatomic noble gas present in air (0.93%); a.n. 18; r.a.m. 39.948; d. 0.00178 g cm^{-3}; m.p. –189°C; b.p. –185°C. Argon is separated from liquid air by fractional distillation. It is slightly soluble in water, colourless, and has no smell. Its uses include inert atmospheres in welding and special-metal manufacture (Ti and Zr), and (when mixed with 20% nitrogen) in gas-filled electric-light bulbs. The element is inert and has no true compounds. Lord Rayleigh and Sir William Ramsey identified argon in 1894.

SEE WEB LINKS

- Information from the WebElements site

argument **1.** A sequence of logical propositions based on a set of premisses and leading to a conclusion. **2.** *See* COMPLEX NUMBER.

aril An outgrowth that grows around and may completely enclose the testa (seed coat) of a seed. It develops from the placenta, funicle, or micropyle of an ovule. The aril surrounding the nutmeg seed forms the spice mace. *See also* CARUNCLE.

arithmetic/logic unit *See* ALU.

arithmetic mean *See* MEAN.

arithmetic series (arithmetic progression) A series or progression of numbers in which there is a common difference between terms, e.g. 3, 9, 15, 21,… is an arithmetic series with a common difference of 6. The general formula for the nth term is

$$[a + (n-1)d]$$

and the sum of n terms is

$$n[2a + (n-1)d]/2.$$

Compare GEOMETRIC SERIES.

armature Any moving part in an electrical machine in which a voltage is induced by a magnetic field, especially the rotating coils in an electric motor or generator and the ferromagnetic bar attracted by an electromagnet in a *relay.

Arndt–Eisert synthesis A method of converting a carboxylic acid into the next higher homologue acid (or one of its derivatives). Diazomethane is used to insert a CH_2 group.

aromatic compound An organic compound that contains a benzene ring in its molecules or that has chemical properties similar to benzene. Aromatic compounds are unsaturated compounds, yet they do not easily partake in addition reactions. Instead they undergo electrophilic substitution.

Benzene, the archetypal aromatic compound, has an hexagonal ring of carbon atoms and the classical formula (the Kekulé structure) would have alternating double and single bonds. In fact all the bonds in benzene are the same length intermediate between double and single C–C bonds. The properties arise because the electrons in the π-orbitals are delocalized over the ring, giving an extra stabilization energy of 150 kJ mol^{-1} over the energy of a Kekulé structure. The condition for such delocalization is that a compound should have a planar ring with $(4n + 2)$ pi electrons – this is known as the **Hückel rule**. Aromatic behav-

iour is also found in heterocyclic compounds such as pyridine. Aromatic character can be detected by the presence of a ring current using NMR. *See also* ANNULENES; NONBENZENOID AROMATICS; PSEUDOAROMATIC.

SEE WEB LINKS

- Information about IUPAC nomenclature

aromaticity The property characteristic of *aromatic compounds.

arousal A level of physiological and behavioural responsiveness in an animal, which tends to vary between sleep and full alertness. It is controlled by a particular part of the brain (the **reticular activating system**) and can be detected by changes in brain electrical activity, heart rate and muscle tone, responsiveness to new stimuli, and general activity.

ARPES *See* ANGLE-RESOLVED PHOTOELECTRON SPECTROSCOPY.

Arrhenius equation An equation of the form

$$k = A\exp(-E_a/RT)$$

where k is the rate constant of a given reaction and E_a the *activation energy. A is a constant for a given reaction, called the **pre-exponential factor**. Often the equation is written in logarithmic form

$$\ln k = \ln A - E_a/RT$$

A graph of $\ln k$ against $1/T$ is a straight line with a gradient $-E_a/R$ and an intercept on the $\ln k$ axis of $\ln A$. It is named after Svante Arrhenius (1859–1927).

Arrhenius theory *See* ACID.

arsenate(III) *See* ARSENIC(III) OXIDE.

arsenate(V) *See* ARSENIC(V) OXIDE.

arsenic Symbol As. A metalloid element of *group 15 (formerly VB) of the periodic table; a.n. 33; r.a.m. 74.92; r.d. 5.7; sublimes at 613°C. It has three allotropes – yellow, black, and grey. The grey metallic form is the stable and most common one. Over 150 minerals contain arsenic but the main sources are as impurities in sulphide ores and in the minerals orpiment (As_2S_3) and realgar (As_4S_4). Ores are roasted in air to form arsenic oxide and then reduced by hydrogen or carbon to metallic arsenic. Arsenic compounds are used in insecticides and as doping agents in semiconductors. The element is included in some lead-based alloys to promote hardening. Confusion can arise because As_4O_6 is often sold as white arsenic. Arsenic compounds are accumulative poisons. The element will react with halogens, concentrated oxidizing acids, and hot alkalis. Albertus Magnus is believed to have been the first to isolate the element in 1250.

SEE WEB LINKS

- Information from the WebElements site

arsenic acid *See* ARSENIC(V) OXIDE.

arsenic(III) acid *See* ARSENIC(III) OXIDE.

arsenic hydride *See* ARSINE.

arsenic(III) oxide (arsenic trioxide; arsenious oxide; white arsenic) A white or colourless compound, As_4O_6, existing in three solid forms. The commonest has cubic or octahedral crystals (r.d. 3.87; sublimes at 193°C) and is soluble in water, ethanol, and alkali solutions. It occurs naturally as **arsenolite**. A vitreous form can be prepared by slow condensation of the vapour (r.d. 3.74); its solubility in cold water is more than double that of the cubic form. The third modification, which occurs naturally as **claudetite**, has monoclinic crystals (r.d. 4.15). Arsenic(III) oxide is obtained commercially as a byproduct from the smelting of nonferrous sulphide ores; it may be produced in the laboratory by burning elemental arsenic in air. The structure of the molecule is similar to that of P_4O_6, with a tetrahedral arrangement of As atoms edge linked by oxygen bridges. Arsenic(III) oxide is acidic; its solutions were formerly called **arsenious acid** (technically, **arsenic(III) acid**) It forms **arsenate(III)** salts (formerly called **arsenites**). Arsenic(III) oxide is extremely toxic and is used as a poison for vermin; trace doses are used for a variety of medicinal purposes. It is also used for producing opalescent glasses and enamels.

arsenic(V) oxide (arsenic oxide) A white amorphous deliquescent solid, As_2O_5; r.d. 4.32; decomposes at 315°C. It is soluble in water and ethanol. Arsenic(V) oxide cannot be obtained by direct combination of arsenic and oxygen; it is usually prepared by the reaction of arsenic with nitric acid followed by dehydration of the arsenic acid thus formed. It readily loses oxygen on heating to give arsenic(III) oxide. Arsenic(V) oxide is acidic, dissolving in water to give arsenic(V) acid (formerly called **arsenic acid**), H_3AsO_4; the acid is tribasic and slightly weaker than phosphoric acid and should be visualized as

$(HO)_3AsO$. It gives **arsenate(V)** salts (formerly called **arsenates**).

arsenic trioxide *See* ARSENIC(III) OXIDE.

arsenious acid *See* ARSENIC(III) OXIDE.

arsenious oxide *See* ARSENIC(III) OXIDE.

arsenite *See* ARSENIC(III) OXIDE.

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

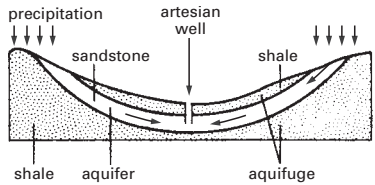
arsine (arsenic hydride) A colourless gas, AsH_3; m.p. –116.3°C; b.p. –55°C. It is soluble in water, chloroform, and benzene. Liquid arsine has a relative density of 1.69. Arsine is produced by the reaction of mineral acids with arsenides of electropositive metals or by the reduction of many arsenic compounds using nascent hydrogen. It is extremely poisonous and, like the hydrides of the heavier members of group 15 (formerly VB), is readily decomposed at elevated temperatures (around 260–300°C). Like ammonia and phosphine, arsine has a pyramidal structure.

Arsine gas has a very important commercial application in the production of modern microelectronic components. It is used in a dilute gas mixture with an inert gas and its ready thermal decomposition is exploited to enable other growing crystals to be doped with minute traces of arsenic to give *n*-type semiconductors.

arteriole A small muscular blood vessel that receives blood from the arteries and carries it to the capillaries.

artery A blood vessel that carries blood away from the heart towards the other body tissues. Most arteries carry oxygenated blood (the *pulmonary artery is an exception). The large arteries branch to form smaller ones, which in turn branch into *arterioles. All arteries have muscular walls, whose contraction aids in pumping blood around the body. The accumulation of fatty deposits in the walls of the arteries leads to **atherosclerosis**, which limits and may eventually block the flow of blood. *Compare* VEIN.

artesian basin A structural basin in the earth's crust in which a zone of permeable water-bearing rock (an *aquifer) is confined between impermeable beds. Water enters the aquifer where it reaches the surface and becomes trapped. As the point of intake of the water is above the level of the ground surface a well sunk into the aquifer through the overlying impermeable rock will result in water being forced up to the surface by hydrostatic pressure. However, the number of wells sunk into artesian basins often considerably lowers the level of water so that pumping is frequently required. Artesian wells were named after the region of Artois in France, where they were first observed. Other examples include the London Basin where chalk and Lower Eocene sandstones lie confined below the London clay and above the Gault clay.



Artesian basin.

Arthrophyta *See* SPHENOPHYTA.

arthropod Any invertebrate animal that characteristically possesses an outer body layer – the *cuticle – that functions as a rigid protective exoskeleton; growth is thus possible only by periodic moults (*see* ECDYSIS). There are over one million species of arthropods, inhabiting marine, freshwater, and terrestrial habitats worldwide. The arthropod body is composed of segments (*see* METAMERIC SEGMENTATION) usually forming distinct specialized body regions, e.g. head, thorax, and abdomen. These segments may possess hardened jointed appendages, modified variously as *mouthparts, limbs, wings, reproductive organs, or sense organs. The main body cavity, containing the internal organs, is a blood-filled *haemocoel, within which lies the heart. Although arthropods are generally placed in a single phylum, Arthropoda, the origins and relationships of the various groups of arthropods remain uncertain, and they are now usually assigned to several subphyla within the clade Ecdysozoa, notably *Crustacea (shrimps, barnacles, crabs, etc.); *Hexapoda (insects); Myriapoda (centipedes and millipedes); and Chelicerata, including the *Arachnida (spiders, scorpions, mites, and ticks).

articulation The attachment of two bones, usually by means of a *joint. The thigh bone (femur), for instance, articulates with the pelvic girdle.

artificial chromosome A type of cloning *vector that has some features of true chromosomes and is used to clone relatively large fragments of DNA. **Bacterial artificial chromosomes** (BACs) are based on the F (fertility) plasmid found naturally in *E. coli* bacteria with the addition of several bacterial genes necessary for replication of the plasmid by the host cell and a gene (usually for resistance to an antibiotic) that allows selection of BAC-containing cells. They can accommodate inserts of foreign DNA up to about 200 kilobase (kb) in length. Larger DNA fragments are cloned using **yeast artificial chromosomes** (YACs). These are linear vectors derived from a circular plasmid found naturally in baker's yeast (*Saccharomyces cerevisiae*) and capable of accommodating DNA inserts of up to 1000 kb. YACs have a *centromere, enabling them to undergo normal segregation in the yeast host during cell division, and *telomeres; thus they behave like mini-chromosomes. YACs are used for cloning eukaryotic genes or gene segments, for making *DNA libraries of organisms with large genomes (e.g. mammals), and for studying gene function.

artificial insemination (AI) The deposition of semen, using a syringe, at the mouth of the uterus to make conception possible. It is used in the selective *breeding of domestic animals and also in humans in some cases of impotence and infertility. It is timed to coincide with ovulation in the female.

artificial intelligence (AI) A field of computing concerned with the production of programs that perform tasks requiring intelligence when done by people. These tasks include playing games, such as chess or draughts, forming plans, understanding speech and natural languages, interpreting images, reasoning, and learning.

artificial selection The modification of species, traditionally by selective *breeding. Animals or plants with desirable characteristics are interbred with the aim of altering the *genotype and producing a new strain of the organism for a specific purpose. For example, sheep are bred by means of artificial selection in order to improve wool quality. Traditional breeding techniques have been supplemented, and in many cases supplanted, by genetic engineering, genetic testing, and embryo manipulation. Sequencing the genomes of commercially important animal and plant species has enabled the inheritance of desired genes to be monitored directly by molecular methods, instead of by phenotypic analysis. These methods have simultaneously opened up new approaches to selection and enabled it to become more refined and focused.

artinite A mineral form of basic *magnesium carbonate,

$MgCO_3.Mg(OH)_2.3H_2O$.

Artiodactyla An order of hooved mammals comprising the even-toed ungulates, in which the third and fourth digits are equally developed and bear the weight of the body. The order traditionally includes cattle and other ruminants (*see* RUMINANTIA), camels, hippopotamuses, and pigs. All except the latter are herbivorous, having an elongated gut and teeth with enamel ridges for grinding tough grasses. Evidence from molecular studies indicates that whales are closely related to hippos and represent a lineage that split off from ruminants about 55 million years ago. Hence whales and artiodactyls are now placed in a new superorder, **Cetartiodactyla**. *Compare* PERISSODACTYLA.

aryl group A group obtained by removing a hydrogen atom from an aromatic compound, e.g. phenyl group, C_6H_5–, derived from benzene.

aryne A compound that can be regarded as formed from an arene by removing two adjacent hydrogen atoms to convert a double bond into a triple bond. Arynes are transient intermediates in a number of reactions. The simplest example is *benzyne.

asbestos Any one of a group of fibrous amphibole minerals (amosite, crocidolite (blue asbestos), tremolite, anthophyllite, and actinolite) or the fibrous serpentine mineral chrysotile. Asbestos has widespread commercial uses because of its resistance to heat, chemical inertness, and high electrical resistance. The fibres may be spun and woven into fireproof cloth for use in protective clothing, curtains, brake linings, etc., or moulded into blocks. Since the 1970s short asbestos fibres have been recognized as a cause of asbestosis, a serious lung disorder, and mesothelioma, a fatal form of lung cancer. These concerns have limited its use and imposed many safety procedures when it is used. Canada is the largest producer of asbestos; others include Russia, South Africa, Zimbabwe, and China.

a

ASCII (pronounced askey) American standard code for information interchange: a standard scheme for encoding the letters A–Z, a–z, digits 0–9, punctuation marks, and other special and control characters in binary form. Originally developed in the US, it is widely used in many computers and for interchanging information between computers. Characters are encoded as strings of seven *bits, providing 2^7 or 128 different bit patterns. International 8-bit codes that are extensions of ASCII have been published by the International Standards Organization; these allow the accented Roman letters used in European languages, as well as Cyrillic, Arabic, Greek, and Hebrew characters, to be encoded. *See also* UNICODE.

Ascomycota A phylum of fungi, formerly classified as a class (Ascomycetes) or a subdivision (Ascomycotina). It includes the *yeasts, some species of edible fungi, and *Claviceps purpurea*, which causes ergot in rye. Many are fungal partners of *lichens. Sexual reproduction is by means of **ascospores**, eight of which are characteristically produced within a spherical or cylindrical cell, the **ascus**. The asci are usually grouped together in an **ascocarp**.

ascorbic acid *See* VITAMIN C.

asexual reproduction Reproduction in which new individuals are produced from a single parent without the formation of gametes. It occurs chiefly in lower animals, microorganisms, and plants. In microorganisms and lower animals the chief methods are *fission (e.g. in protists), *fragmentation (e.g. in some aquatic annelid worms), and *budding (e.g. in cnidarians and yeasts). The principal methods of asexual reproduction in plants are by *vegetative propagation (e.g. bulbs, corms, tubers) and by the formation of *spores. Spore formation occurs in mosses, ferns, and other plants showing alternation of generations, as a dormant stage between sporophyte and gametophyte, and in some algae and fungi, to produce replicas of the organism. *Compare* SEXUAL REPRODUCTION.

asparagine *See* AMINO ACID.

aspartic acid *See* AMINO ACID.

Aspect experiment An experiment conducted by the French physicist Alain Aspect (1947–) and his colleagues in the early 1980s to test Bell's inequality (*see* BELL'S THEOREM). The experiment involves producing pairs of photons from a source of excited calcium ions. The photons have different wavelengths and filters are used to ensure that the photons in a pair travel to different detectors in different directions. The photons are circularly polarized and the net angular momentum of the pair is zero. Two polarizing filters are used, each placed at an angle in the path of the photons. These filters either reflect or transmit photons of different linear polarization to one of four detectors (two for each polarizing filter). Coincidence measurements are made using these detectors and the experiment is organized so that the measurements apply only to photons separated to a point at which they cannot communicate by sending a signal at the speed of light. The results are generally believed to show that there are no local *hidden variables in quantum mechanics.

SEE WEB LINKS

- The original 1982 paper in *Physical Review Letters*

aspirin (acetylsalicylic acid) an acetylated form of *salicylic acid (1-hydroxybenzoic acid), used extensively as a medicinal drug to alleviate pain, combat fever, and reduce inflammation; r.d. 1.4; m.p. 138–140°C; b.p. 140°C (with decomposition). It was first marketed in 1899 as an analgesic. The acid can be obtained from willow bark and it has long been known that the bark could be used for pain relief and for the reduction of fever. The name salicylic acid comes from the botanical name of the willow (*Salix alba*). Aspirin acts by suppressing the production of *prostaglandins, which are major factors in the inflammation process, by inhibiting the enzyme cyclooxygenase (COX). Consequently, it is known as a 'COX inhibitor'. It also reduces the aggregation of blood platelets and small doses are taken regularly to reduce the risk of heart attack. A common side effect of high doses is stomach bleeding and stomach ulcers. Aspirin is made industrially from phenol, which with concentrated sodium hydroxide and carbon dioxide gives sodium phenoxide:

$$C_6H_5OH + NaOH \rightarrow C_6H_5O^- Na^+ + H_2O.$$

The phenoxide ion undergoes electrophilic substitution to give sodium salicylate:

$$C_6H_5O^- + CO_2 + Na^+ \rightarrow C_6H_4\,(OH)COO^- Na^+$$

With acid, this forms salicylic acid, which can be acetylated in the ortho position with ethanoic anhydride.

assimilation The utilization by a living organism of absorbed food materials in the processes of growth, reproduction, or repair.

association **1.** (in ecology) An ecological unit in which two or more species occur in closer proximity to one another than would be expected on the basis of chance. Early plant ecologists recognized associations of fixed composition on the basis of the *dominant species present (e.g. a coniferous forest association). Associations now tend to be detected by using more objective statistical sampling methods. *See also* CONSOCIATION. **2.** (in chemistry) The combination of molecules of one substance with those of another to form chemical species that are held together by forces weaker than normal chemical bonds. For example, ethanol and water form a mixture (an **associated liquid**) in which hydrogen bonding holds the different molecules together.

association centre The part of the brain that links a primary sensory area (the part of the cerebral cortex that receives primary sensory impulses) with other parts of the brain, such as memory and motor areas, and deals with the interpretation and meaning of the primary sensory input. For example, the auditory association area interprets a 'moo' sound as that coming from a cow.

associative law The mathematical law stating that the value of an expression is independent of the grouping of the numbers, symbols, or terms in the expression. The **associative law for addition** states that numbers may be added in any order, e.g. $(x + y) + z = (x + (y) + z$. The **associative law for multiplication** states that numbers can be multiplied in any order, e.g. $x(yz) = (xy)z$. Subtraction and division are not associative. *Compare* COMMUTATIVE LAW; DISTRIBUTIVE LAW.

astatic galvanometer A sensitive form of moving-magnet *galvanometer in which any effects of the earth's magnetic field are cancelled out. Two small oppositely directed magnets are suspended at the centres of two oppositely wound coils. As its resultant moment on the magnets is zero, the earth's field has no effect and the only restoring torque on the magnets is that provided by the suspending fibre. This makes a sensitive but delicate instrument.

astatine Symbol At. A radioactive *halogen element; a.n. 85; r.a.m. 211; m.p. 302°C; b.p. 337°C. It occurs naturally by radioactive decay from uranium and thorium isotopes. Astatine forms at least 20 isotopes, the most stable astatine–210 has a half-life of 8.3 hours. It can also be produced by alpha bombardment of bismuth–200. Astatine is stated to be more metallic than iodine; at least 5 oxidation states are known in aqueous solutions. It will form interhalogen compounds, such as AtI and AtCl. The existence of At_2 has not yet been established. The element was synthesized by nuclear bombardment in 1940 by D. R. Corson, K. R. MacKenzie, and E. Segrè at the University of California.

SEE WEB LINKS

- Information from the WebElements site

aster A starlike arrangement of microtubules radiating from a *centrosome. Asters become conspicuous in animal cells at the ends of the *spindle when cell division starts. They are believed to help locate the spindle in relation to the cell's boundaries and to trigger cleavage of the cytoplasm when nuclear division is completed.

asterism A pattern of stars that forms a separate entity within a larger constellation. For example, the Plough forms an asterism within the constellation Ursa Major (Great Bear).

asteroids (planetoids) A number of *small solar system bodies that mostly revolve around the sun between the orbits of Mars and Jupiter in a zone extending from 1.7 to 4.0 astronomical units from the sun (the **asteroid belt** or **main belt**). The term 'asteroid' has also been used to describe many similar small objects whose orbits bring them close to the earth (**near-earth asteroids**) or cross the orbits of Jupiter and Saturn (the *centaurs). The **Trojans** are two groups of asteroids trapped in Jupiter's orbit at its *Lagrangian points. The size of asteroids varies from the largest, (1) Ceres (a spherical body now classed as a *dwarf planet, with a diameter of 933 km), to irregularly shaped objects less than 1 km in diameter. It is estimated that there are about 10 asteroids with diameters in excess of 250 km and some 120 bodies with diameters over 130 km.

asthenosphere A layer of the earth's mantle (*see* EARTH) that underlies the lithosphere at a depth of about 70 km. The velocity of *seismic waves is considerably reduced in

the asthenosphere and it is thought to be a zone of partial melting. It extends to a depth of about 250 km where rocks are solid.

astigmatism A lens defect in which rays in one plane are in focus when those in another plane are not. In lenses and mirrors it occurs with objects not on the axis and is best controlled by reducing the *aperture to restrict the use of the lens or mirror to its central portion. The eye can also suffer from astigmatism, usually when the cornea is not spherical. It is corrected by using an *anastigmatic lens.

Aston, Francis William (1877–1945) British chemist and physicist, who until 1910 worked at Mason College (later Birmingham University) and then with J. J. *Thomson at Cambridge University. In 1919 Aston designed the mass spectrograph (*see* MASS SPECTROMETRY), for which he was awarded the Nobel Prize for chemistry in 1922. With it he discovered the *isotopes of neon, and was thus able to explain nonintegral atomic weights.

astrobleme A fairly ancient circular crater in the earth's crust formed by the impact of a meteorite. It is caused by the explosion of the meteorite on impact and characteristically gives rise to shatter cones in the adjacent rocks. The largest astroblemes range in size from 6 to 40 kilometres across.

astrochemistry The study of molecules in interstellar space. **Interstellar molecules** are usually detected by their spectra in the radio, microwave, or infrared regions of the electromagnetic spectrum. To date, over 140 different molecules have been detected. Of special interest in astrochemistry is the way in which these molecules are formed and the way in which they interact with clouds of interstellar dust.

SEE WEB LINKS

- The website of the astrochemistry work group of the International Astronomical Union

astrometry The branch of astronomy concerned with the measurement of the positions of the celestial bodies on the *celestial sphere.

astronomical observatory An earth-based building or complex or a spacecraft or artificial satellite housing the equipment required for observing celestial objects and phenomena, including optical, infrared, and/or radio telescopes, as well as instruments for making spectrographic, photometric, or other similar measurements. On earth, most optical observatories are located away from city lights on high mountain tops, where the atmosphere is thin, or in dry high-altitude deserts, where observing conditions are stable. Radio telescopes must be isolated from earth-based radio and electrical interference. *See* TELESCOPE.

astronomical telescope *See* TELESCOPE.

astronomical unit (AU) The mean distance between the sun and the earth. It is equal to 149 597 870 km (499 light seconds).

astronomy The study of the universe beyond the earth's atmosphere. The main branches are *astrometry, *celestial mechanics, and *astrophysics.

astrophysics The study of the physical and chemical processes involving astronomical phenomena. Astrophysics deals with stellar structure and evolution (including the generation and transport of energy within stars), the properties of the interstellar medium and its interactions with stellar systems, and the structure and dynamics of systems of stars (such as clusters and galaxies), and of systems of galaxies. *See also* COSMOLOGY.

asymmetric atom *See* OPTICAL ACTIVITY.

asymptote A line that a curve approaches but only touches at infinity.

asymptotic freedom The consequence of certain *gauge theories, particularly *quantum chromodynamics, that the forces between such particles as quarks become weaker at shorter distances (i.e. higher energies) and vanish as the distance between particles tends to zero. Only non-Abelian gauge theories with unbroken gauge symmetries can have asymptotic freedom (*see* GROUP). In contrast, *quantum electrodynamics implies that the interaction between particles decreases as a result of dielectric screening; asymptotic freedom for quarks implies that antiscreening occurs. Physically, asymptotic freedom postulates that the *vacuum state for gluons is a medium that has colour paramagnetism, i.e. the vacuum antiscreen colour charges.

Asymptotic freedom explains the successes of the *parton model of pointlike objects inside hadrons and enables systematic corrections to the parton model to be calculated using perturbation theory. That the in-

teraction between quarks increases as the distance between them increases has given rise to the hypothesis of *quark confinement. It appears that if a theory requires the presence of Higgs bosons, asymptotic freedom is destroyed. Thus, *electroweak theory does not have asymptotic freedom.

asymptotic series A series formed by the expansion of a function in the form $a_0 + a_1/x + a_2/x^2 + \ldots + a_n/x^n + \ldots$, such that the error resulting from terminating the series at the term a_n/x^n tends to zero more rapidly than $1/x^n$ as x tends to infinity. An asymptotic series expansion is not necessarily a *convergent series.

atactic polymer *See* POLYMER.

atlas The first *cervical vertebra, a ringlike bone that joins the skull to the vertebral column in terrestrial vertebrates. In advanced vertebrates articulation between the skull and atlas permits nodding movements of the head. *See also* AXIS.

atm. *See* ATMOSPHERE.

atmolysis The separation of a mixture of gases by means of their different rates of diffusion. Usually, separation is effected by allowing the gases to diffuse through the walls of a porous partition or membrane.

atmosphere **1.** Symbol atm. A unit of pressure equal to 101 325 pascals. This is equal to 760.0 mmHg. The actual *atmospheric pressure fluctuates around this value. The unit is usually used for expressing pressures well in excess of standard atmospheric pressure, e.g. in high-pressure chemical or physical processes. **2.** *See* EARTH'S ATMOSPHERE.

atmospheric pressure The pressure exerted by the weight of the air above it at any point on the earth's surface. At sea level the atmosphere will support a column of mercury about 760 mm high. This decreases with increasing altitude. The standard value for the atmospheric pressure at sea level in SI units is 101 325 pascals.

atoll A circular or elliptical coral reef that encloses a shallow central lagoon. It may be continuous or, more often, broken into closely spaced islets. The water outside the reef is deep. Atolls range in size from a few kilometres to more than 100 km across and are most often found in the Pacific Ocean. They represent the craters of volcanic islands that have sunk as coral grew on or around the rim.

atom The smallest part of an element that can exist. Atoms consist of a small dense nucleus of protons and neutrons surrounded by moving electrons. The number of electrons equals the number of protons so the overall charge is zero. The electrons may be thought of as moving in circular or elliptical orbits (*see* BOHR THEORY) or, more accurately, in regions of space around the nucleus (*see* ORBITAL).

The **electronic structure** of an atom refers to the way in which the electrons are arranged about the nucleus, and in particular the *energy levels that they occupy. Each electron can be characterized by a set of four quantum numbers, as follows:
(1) The **principal quantum number** n gives the main energy level and has values 1, 2, 3, etc. (the higher the number, the further the electron from the nucleus). Traditionally, these levels, or the orbits corresponding to them, are referred to as **shells** and given letters K, L, M, etc. The K-shell is the one nearest the nucleus. The maximum number of electrons in a given shell is $2n^2$.
(2) The **orbital quantum number** l, which governs the angular momentum of the electron. The possible values of l are $(n-1)$, $(n-2)$, …, 1, 0. Thus, in the first shell ($n = 1$) the electrons can only have angular momentum zero ($l = 0$). In the second shell ($n = 2$), the values of l can be 1 or 0, giving rise to two **subshells** of slightly different energy. In the third shell ($n = 3$) there are three subshells, with $l = 2$, 1, or 0. The subshells are denoted by letters s ($l = 0$), p ($l = 1$), d ($l = 2$), f ($l = 3$). The number of electrons in each subshell is written as a superscript numeral to the subshell symbol, and the maximum number of electrons in each subshell is s^2, p^6, d^{10}, and f^{14}. The orbital quantum number is sometimes called the **azimuthal quantum number**.
(3) The **magnetic quantum number** m, which governs the energies of electrons in an external magnetic field. This can take values of $+l$, $+(l-1)$, …, 1, 0, –1, …, $-(l-1)$, $-l$. In an s-subshell (i.e. $l = 0$) the value of $m = 0$. In a p-subshell ($l = 1$), m can have values +1, 0, and –1; i.e. there are three p-orbitals in the p-subshell, usually designated p_x, p_y, and p_z. Under normal circumstances, these all have the same energy level.
(4) The **spin quantum number** m_s, which

gives the spin of the individual electrons and can have the values +½ or –½.

According to the *Pauli exclusion principle, no two electrons in the atom can have the same set of quantum numbers. The numbers define the **quantum state** of the electron, and explain how the electronic structures of atoms occur. See Chronology: Atomic Theory.

atomic absorption spectroscopy (AAS) An analytical technique in which a sample is vaporized and the nonexcited atoms absorb electromagnetic radiation at characteristic wavelengths.

atomic bomb *See* NUCLEAR WEAPONS.

atomic clock An apparatus for measuring or standardizing time that is based on periodic phenomena within atoms or molecules. *See* AMMONIA CLOCK; CAESIUM CLOCK.

atomic emission spectroscopy An analytical technique in which a sample is vaporized and the atoms present are detected by their emission of electromagnetic radiation at characteristic wavelengths.

atomic energy *See* NUCLEAR ENERGY.

atomic force microscopy (AFM) A variation of *scanning probe microscopy that measures the force of interaction between a fine-tipped probe and the surface of a sample. Capable of nanometre-scale resolution, it is suitable for imaging the topography of biomolecules such as DNA and proteins, cell surfaces, and cell organelles. Essentially the apparatus consists of a silicon-tipped probe, mounted on a flexible cantilever, which is moved across the sample surface. Deflections of the probe are detected by a laser beam focused onto the back of the cantilever and reflected to a photosensor position detector.

SEE WEB LINKS

- An account of the technique from Nanoscience Instruments Inc

atomicity The number of atoms in a given molecule. For example, oxygen (O_2) has an atomicity of 2, ozone (O_3) an atomicity of 3, benzene (C_6H_6) an atomicity of 12, etc.

atomic mass unit (a.m.u.) A unit of mass used to express *relative atomic masses. It is 1/12 of the mass of an atom of the isotope carbon–12 and is equal to $1.660\,33 \times 10^{-27}$ kg. This unit superseded both the physical and chemical mass units based on oxygen–16 and is sometimes called the **unified mass unit** or the **dalton**.

atomic number (proton number) Symbol *Z*. The number of protons in the nucleus of an atom. The atomic number is equal to the number of electrons orbiting the nucleus in a neutral atom.

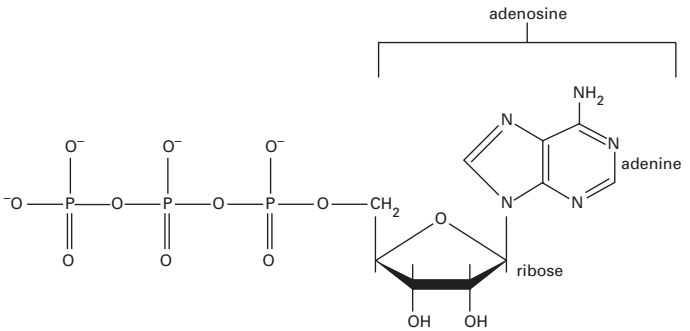
atomic orbital *See* ORBITAL.

atomic pile An early form of *nuclear reactor using graphite as a *moderator.

atomic volume The relative atomic mass of an element divided by its density.

atomic weight *See* RELATIVE ATOMIC MASS.

ATP (adenosine triphosphate) A nucleotide that is of fundamental importance as a carrier of chemical energy in all living organisms. It consists of adenine linked to D-ribose (i.e. adenosine); the D-ribose com-



ATP.

ATOMIC THEORY

c.430 BC	Greek natural philosopher Empedocles (d. c. 430 BC) proposes that all matter consists of four elements: earth, air, fire, and water.
c.400 BC	Greek natural philosopher Democritus of Abdera (c. 460–370 BC) proposes that all matter consists of atoms.
c.306 BC	Greek philosopher Epicurus (c. 342–270 BC) champions Democritus' atomic theory.
1649	French philosopher Pierre Gassendi (1592–1655) proposes an atomic theory (having read Epicurus).
1803	John Dalton proposes Dalton's atomic theory.
1897	J. J. Thomson discovers the electron.
1904	J. J. Thomson proposes his 'plum pudding' model of the atom, with electrons embedded in a nucleus of positive charges. Japanese physicist Hantaro Nagaoka (1865–1950) proposes a 'Saturn' model of the atom with a central nucleus having a ring of many electrons.
1911	Ernest Rutherford discovers the atomic nucleus.
1913	Niels Bohr proposes model of the atom with a central nucleus surrounded by orbiting electrons and the orbits characterized by quantum numbers. British physicist Henry Moseley (1887–1915) equates the positive charge on the nucleus with its atomic number. Frederick Soddy discovers isotopes.
1916	German physicist Arnold Sommerfield (1868–1951) modifies Bohr's model of the atom specifying elliptical orbits for the electrons; introduces azimuthal and magnetic quantum numbers in addition to the principal quantum number.
1919	Ernest Rutherford discovers the proton.
1920	Ernest Rutherford postulates the existence of the neutron.
1925	Wolfgang Pauli proposes a fourth quantum number, subsequently identified as spin, and proposes his exclusion principle.
1926	Erwin Schrödinger proposes a wave-mechanical model of the atom (with electrons represented as wave trains).
1932	James Chadwick discovers the neutron. Werner Heisenberg proposes a model of the atomic nucleus in which protons and neutrons exchange electrons to achieve stability.
1936	Niels Bohr proposes a 'liquid drop' model of the atomic nucleus.
1948	German-born US physicist Maria Goeppert-Mayer (1906–72) and German physicist Hans Jensen (1907–73) independently propose the 'shell' structure of the nucleus.
1950	Danish physicist Aage Bohr (1922–) and US physicists Benjamin Mottelson (1926–) and Leo Rainwater (1917–86) combine the 'liquid-drop' and 'shell' models of the nucleus into a single theory.

ponent bears three phosphate groups, linearly linked together by covalent bonds (see formula). These bonds can undergo hydrolysis to yield either a molecule of ADP (**adenosine diphosphate**) and inorganic phosphate or a molecule of AMP (**adenosine monophosphate**) and pyrophosphate (*see* ATPASE). Both these reactions yield a large amount of energy (about 30.6 kJ mol^{-1}) that is used to bring about such biological processes as muscle *contraction, the *active transport of ions and molecules across cell membranes, and the synthesis of biomolecules. The reactions bringing about these processes often involve the enzyme-catalysed transfer of the phosphate group to intermediate substrates. Most ATP-mediated reactions require Mg^{2+} ions as *cofactors.

ATP is regenerated by the rephosphorylation of AMP and ADP using the chemical energy obtained from the oxidation of food. This takes place during *glycolysis and the *Krebs cycle but, most significantly, is also a result of the reduction–oxidation reactions of the *electron transport chain, which ultimately reduces molecular oxygen to water (*oxidative phosphorylation). ATP is also formed by the light-dependent reactions of *photosynthesis.

ATPase Any enzyme that brings about the hydrolysis of ATP. This results in the cleavage of either one phosphate group, with the formation of ADP and inorganic phosphate (P_i), or of two phosphate groups, with the formation of AMP and pyrophosphate (PP_i); the second reaction yields twice as much energy as the first. ATPase activity is associated with many energy-consuming processes; for example, in muscle contraction it is associated with *myosin when activated by actin.

atrioventricular node (AVN) A specialized group of *cardiac muscle fibres situated in the fibrous ring between the right atrium and ventricle of the heart. The AVN is the only pathway between the atria and the ventricles through which electrical impulses can pass. Thus, following the contraction of the atria, the AVN initiates a wave of contraction in the ventricles via the *bundle of His.

atrium **1. (auricle)** A chamber of the *heart that receives blood from the veins and forces it by powerful muscular contraction into the *ventricle(s). Fish have a single atrium but all other vertebrates have two. **2.** Any of various cavities or chambers in animals, such as the chamber surrounding the gill slits of the lancelet and other invertebrate chordates.

atrophy The degeneration or withering of an organ or part of the body.

atropine A poisonous crystalline alkaloid, $C_{17}H_{23}NO_3$; m.p. 118–119°C. It can be extracted from deadly nightshade and other solanaceous plants and is used in medicine to treat colic, to reduce secretions, and to dilate the pupil of the eye.

ATRS *See* ATTENUATED TOTAL REFLECTANCE SPECTROSCOPY.

attenuated total reflectance spectroscopy (ATRS) A variation of infrared spectroscopy in which the IR source is reflected from the sample and absorption occurs only in the surface layer. ATRS is used in forensic science for analysis of thin layers (e.g. paint).

attenuation **1.** (in physics) **a.** A loss of intensity suffered by sound, radiation, etc., as it passes through a medium. It may be caused by absorption or scattering. **b.** The drop in voltage or current experienced by a signal as it passes through a circuit. **2.** (in medicine) A process of reducing the disease-producing ability of a microorganism. It can be achieved by chemical treatment, heating, drying, irradiation, by growing the organism under adverse conditions, or by serial passage through another organism. Attenuated bacteria or viruses are used for some *vaccines. **3.** (in mycology) The conversion by yeasts of carbohydrates to alcohol, as in brewing and wine and spirit production.

atto- Symbol a. A prefix used in the metric system to denote 10^{-18}. For example, 10^{-18} second = 1 attosecond (as).

attractor The set of points in *phase space to which the representative point of a dissipative system (i.e. one with internal friction) tends as the system evolves. The attractor can be: a single point; a closed curve (a **limit cycle**), which describes a system with periodic behaviour; or a *fractal (or **strange attractor**), in which case the system exhibits *chaos. *See also* BRUSSELATOR.

AU *See* ASTRONOMICAL UNIT.

audibility The state of being perceptible to hearing. The limits of audibility of the human ear are between about 20 hertz (a low rumble) and 20 000 hertz (a shrill whis-

tle). With increased age the upper limit falls quite considerably.

audiofrequency A frequency that is audible to the human ear. *See* AUDIBILITY.

audiometer An instrument that generates a sound of known frequency and intensity in order to measure an individual's hearing ability.

auditory Of or relating to the *ear. For example, the **auditory meatus** is the canal leading from the pinna to the tympanum (eardrum).

auditory nerve The nerve that transmits sensory information from the ear to the brain.

Aufbau principle A principle that gives the order in which orbitals are filled in successive elements in the periodic table. The order of filling is 1*s*, 2*s*, 2*p*, 3*s*, 3*p*, 4*s*, 3*d*, 4*p*, 5*s*, 4*d*, 5*p*, 6*s*, 4*f*, 5*d*, 6*p*, 7*s*, 5*f*, 6*d*. *See* ATOM.

Auger effect The ejection of an electron from an atom without the emission of an X- or gamma-ray photon, as a result of the de-excitation of an excited electron within the atom. This type of transition occurs in the X-ray region of the emission spectrum. The kinetic energy of the ejected electron, called an **Auger electron**, is equal to the energy of the corresponding X-ray photon minus the binding energy of the Auger electron. The effect was discovered by Pierre Auger (1899–1994) in 1925.

auric compounds Compounds of gold in its higher (+3) oxidation state; e.g. auric chloride is gold(III) chloride ($AuCl_3$).

auricle **1.** *See* ATRIUM. **2.** *See* PINNA.

aurora The luminous phenomena seen in the night sky in high latitudes, occurring most frequently near the earth's geomagnetic poles. The displays of aurora appear as coloured arcs, rays, bands, streamers, and curtains, usually green or red. The aurora is caused by the interaction of the atoms (mainly atomic oxygen) and molecules in the upper atmosphere (above about 100 km) with charged particles streaming from the sun, attracted to the auroral regions by the earth's magnetic field. The aurora is known as the **aurora borealis** (or northern lights) in the northern hemisphere and as the **aurora australis** (or southern lights) in the southern hemisphere.

aurous compounds Compounds of gold in its lower (+1) oxidation state; e.g. aurous chloride is gold(I) chloride (AuCl).

austenite *See* STEEL.

Australopithecus A genus of fossil primates that lived 4–2 million years ago, coexisting for some of this time with early forms of humans (*see* HOMO). They walked erect and had teeth resembling those of modern humans, but the brain capacity was less than one-third that of a modern human. Various finds have been made, chiefly in East and South Africa (hence the name, which means 'southern ape'). The earliest belong to the species *A. afarensis*, which includes the specimen of a female, dubbed 'Lucy', found at Laetoli in Tanzania. *Australopithecus* and related genera are known as **australopithecines**.

autecology The study of ecology at the level of the species. An autecological study aims to investigate the ecology of *populations or individuals of a particular species, including habitat, distribution, life cycle, etc. This should enable a full description of the *ecological niche of the organism to be made. *Compare* SYNECOLOGY.

autocatalysis *Catalysis in which one of the products of the reaction is a catalyst for the reaction. Reactions in which autocatalysis occurs have a characteristic S-shaped curve for reaction rate against time – the reaction starts slowly and increases as the amount of catalyst builds up, falling off again as the products are used up.

autoclave A strong steel vessel used for carrying out chemical reactions, sterilizations, etc., at high temperature and pressure.

autogamy **1.** A type of reproduction that occurs in single isolated individuals of ciliate protozoans of the genus *Paramecium*. The nucleus divides into two genetically identical haploid nuclei, which then fuse to form a diploid zygote. The onset of autogamy is associated with changing environmental conditions and may be necessary to maintain cell vitality. **2.** Self-fertilization in plants. *See* FERTILIZATION.

autograft *See* GRAFT.

autoimmunity A disorder of the body's defence mechanisms in which an *immune response is elicited against its own tissues, which are thereby damaged or destroyed. Rheumatoid arthritis, systemic lupus erythematosus, myasthenia gravis, and several

forms of thyroid dysfunction are examples of autoimmune diseases.

autolysis The process of self-destruction of a cell, cell organelle, or tissue. It occurs by the action of enzymes within or released by *lysosomes. *See also* LYSIS.

autonomic nervous system (ANS) The part of the vertebrate *peripheral nervous system that supplies stimulation via motor nerves to the smooth and cardiac muscles (the involuntary muscles) and to the glands of the body. It is divided into the *parasympathetic and the *sympathetic nervous systems, which tend to work antagonistically on the same organs. The activity of the ANS is controlled principally by the *medulla oblongata and *hypothalamus of the brain.

autopolyploid A *polyploid organism in which the multiple sets of chromosomes are all derived from the same species. For example, doubling of the chromosome number during mitotic cell division, possibly induced by *colchicine, gives rise to a tetraploid known as an **autotetraploid**. *Compare* ALLOPOLYPLOID.

autoradiography An experimental technique in which a radioactive specimen is placed in contact with (or close to) a photographic plate, so as to produce a record of the distribution of radioactivity in the specimen. The film is darkened by the ionizing radiation from radioactive parts of the sample. Autoradiography has a number of applications, being used particularly to study the distribution of particular substances in living tissues, cells, and cultures. A radioactive isotope of the substance is introduced into the organism or tissue, which is killed, sectioned, and examined after enough time has elapsed for the isotope to be incorporated into the substance. Autoradiography is also used to locate radioactively labelled DNA probes or antibodies in such techniques as *Southern blotting and *Western blotting.

autosome Any of the chromosomes in a cell other than the *sex chromosomes.

autotomy The shedding by an animal of part of its body followed by the regeneration of the lost part. Autotomy is achieved by the contraction of muscles at specialized regions in the body. It serves as a protective mechanism if the animal is damaged or attacked (e.g. tail loss in certain reptiles) and is common as a method of asexual reproduction in polychaete worms, in which both new head and tail regions may be regenerated.

autotrophic nutrition A type of nutrition in which organisms synthesize the organic materials they require from inorganic sources. Chief sources of carbon and nitrogen are carbon dioxide and nitrates, respectively. All green plants are autotrophic and use light as a source of energy for the synthesis, i.e. they are **photoautotrophic** (*see* PHOTOSYNTHESIS). Some bacteria are also photoautotrophic; others are **chemoautotrophic**, using energy derived from chemical processes (*see* CHEMOSYNTHESIS). *Compare* HETEROTROPHIC NUTRITION.

auxanometer Any mechanical instrument or measuring device used to study the growth or movement of plant organs. One type of auxanometer consists of a recording device that translates any increase in stem height into movement of a needle across a scale.

auxin Any of a group of plant hormones responsible for such processes as the promotion of growth by cell enlargement, the maintenance of *apical dominance, and the initiation of root formation in cuttings. Auxins are also involved in suppressing the *abscission of leaves, fruits, or other plant organs and in the development of flowers and fruits. Naturally occurring auxins, principally **indoleacetic acid** (**IAA**), are synthesized in actively growing regions of the plant, from where they are transported to other parts. Synthetic auxins include **2,4-D**, which is used as a weedkiller, and **indolebutyric acid** and **naphthaleneacetic acid**, which are sold in preparations of 'rooting hormones'.

auxochrome A group in a dye molecule that influences the colour due to the *chromophore. Auxochromes are groups, such as –OH and $–NH_2$, containing lone pairs of electrons that can be delocalized along with the delocalized electrons of the chromophore. The auxochrome intensifies the colour of the dye. Formerly, the term was also used of such groups as $–SO_2O^-$, which make the molecule soluble and affect its application.

avalanche A shower of ionized particles created by a single *ionization as a result of secondary ionizations caused by the original electron and ion being accelerated in an electric field. Each ionization leads to the formation of more electrons and ions, which

themselves cause further ionizations. Such avalanches occur in a *Geiger counter.

average *See* MEAN. *See also* ROOT-MEAN-SQUARE VALUE.

Aves The birds: a class of bipedal vertebrate chordates (*see* CHORDATA) with *feathers, wings, and a beak. They evolved from reptilian ancestors, probably in the Jurassic period (190–136 million years ago), and modern birds still have scaly legs, like reptiles. Birds are warm-blooded (*see* HOMOIOTHERMY). The skin is dry and loose and has no sweat glands, so cooling is effected by panting. Their efficient lungs and four-chambered heart (which completely separates oxygenated and deoxygenated blood) ensure a good supply of oxygen to the tissues. Birds can therefore sustain a high body temperature and level of activity ncessary for *flight. The breastbone bears a keel for the attachment of flight muscles. The skeleton is very light; many of the bones are tubular, having internal struts to provide strength and air sacs to reduce weight and provide extra oxygen in flight. Their feathers are vital for flight, streamlining the body, and insulation against heat loss.

Many birds show a high degree of social behaviour in forming large flocks and pair bonding for nesting, egg incubation, and rearing young. Fertilization is internal and the female lays hard-shelled eggs. *See also* RATITAE.

SEE WEB LINKS

- Global partnership of organizations involved in bird conservation

AVN *See* ATRIOVENTRICULAR NODE.

Avogadro, Amedeo (1776–1856) Italian chemist and physicist. In 1811 he published his hypothesis (*see* AVOGADRO'S LAW), which provided a method of calculating molecular weights from vapour densities. The importance of the work remained unrecognized, however, until championed by Stanislao Cannizzaro (1826–1910) in 1860.

Avogadro constant Symbol N_A or L. The number of atoms or molecules in one *mole of substance. It has the value 6.022 1367(36) $\times 10^{23}$. Formerly it was called **Avogadro's number**.

Avogadro's law Equal volumes of all gases contain equal numbers of molecules at the same pressure and temperature. The law, often called **Avogadro's hypothesis**, is true only for ideal gases. It was first proposed in 1811 by Amedeo Avogadro.

axenic culture A *culture medium in which only one type of microorganism is growing. Such cultures are widely used in microbiology to determine the basic growth requirements or degree of inhibition by antibiotics or other chemicals of a particular species.

axial period The time taken for a celestial object to rotate once on its axis. For a planet, measured with respect to the direction of a fixed star, it is equal to a sidereal *day.

axial skeleton The main longitudinal section of the vertebrate *skeleton, including the *skull, the *vertebral column, and the rib cage. *Compare* APPENDICULAR SKELETON.

axial tilt (obliquity) The inclination angle of the axis of rotation of a celestial body, such as a planet or satellite, relative to the plane that is perpendicular to the plane of its orbit. In the case of the earth, this angle is currently (epoch 2000) 23° 26′ 21.448″. The earth's axial tilt, which results from the gravitational influences of the other planets, is responsible for the seasons, as first one hemisphere and then the other is turned to face the sun, causing annual variations in the amount of solar radiation falling on the earth and the angle at which it strikes the planet. The earth's axial tilt oscillates between 22.1° and 24.5° over a period of about 41 000 years and is currently decreasing.

axial vector (pseudo-vector) A *vector that does not reverse its sign when the coordinate system is changed to a new system by a reflection in the origin (i.e. $x'_i = -x_i$). An example of an axial vector is the *vector product of two *polar vectors, such as $\boldsymbol{L} = \boldsymbol{r} \times \boldsymbol{p}$, where $\boldsymbol{L}$ is the *angular momentum of a particle, $\boldsymbol{r}$ is its position vector, and $\boldsymbol{p}$ is its momentum vector. *Compare* PSEUDO-SCALAR.

axil The angle between a branch or leaf and the stem it grows from. **Axillary** (or **lateral**) **buds** develop in the axil of a leaf. The presence of axillary buds distinguishes a leaf from a leaflet.

axillary bud *See* AXIL.

axion A hypothetical elementary particle postulated to explain why there is no observed CP violation (*see* CP INVARIANCE) in the strong interaction (*see* FUNDAMENTAL INTERACTIONS). Axions have not been detected experimentally, although it has been possi-

ble to put limits on their mass and other properties from the effects that they would have on some astrophysical phenomena (e.g. the cooling of stars). It has also been suggested that they may account for some or all of the *missing mass in the universe.

axis **1.** (in mathematics) **a.** One of a set of reference lines used to locate points on a graph or in a coordinate system. *See* CARTESIAN COORDINATES; POLAR COORDINATES. **b.** A line about which a figure, curve, or body is symmetrical (**axis of symmetry**) or about which it rotates (**axis of rotation**). **2.** (in anatomy) The second *cervical vertebra, which articulates with the *atlas (the first cervical vertebra, which articulates with the skull). The articulation between the axis and atlas in reptiles, birds, and mammals permits side-to-side movement of the head. The body of the axis is elongated to form a peg (the **odontoid process**), which extends into the ring of the atlas and acts as a pivot on which the atlas (and skull) can turn.

axon The long threadlike part of a nerve cell (*neuron). It carries the nerve impulse (in the form of an *action potential) away from the *cell body of a neuron towards either an effector organ or the brain. *See also* NERVE FIBRE.

azeotrope (azeotropic mixture; constant-boiling mixture) A mixture of two liquids that boils at constant composition; i.e. the composition of the vapour is the same as that of the liquid. Azeotropes occur because of deviations in Raoult's law leading to a maximum or minimum in the *boiling-point–composition diagram. When the mixture is boiled, the vapour initially has a higher proportion of one component than is present in the liquid, so the proportion of this in the liquid falls with time. Eventually, the maximum and minimum point is reached, at which the two liquids distil together without change in composition. The composition of an azeotrope depends on the pressure.

azeotropic distillation A technique for separating components of an azeotrope by adding a third liquid to form a new azeotrope with one of the original components. It is most commonly used to separate ethanol from water, adding benzene to associate with the ethanol.

azides Compounds containing the ion N_3^- or the group $-N_3$.

azimuth **1.** In horizontal coordinate systems used in astronomy, the angular distance measured eastwards along the observer's horizon from the south point or sometimes the north point to the intersection of the vertical circle through a celestial body. **2.** *See* POLAR COORDINATES.

azimuthal quantum number *See* ATOM.

azine An organic heterocyclic compound containing a six-membered ring formed from carbon and nitrogen atoms. Pyridine is an example containing one nitrogen atom (C_5H_5N). **Diazines** have two nitrogen atoms in the ring (e.g. $C_4H_4N_2$), and isomers exist depending on the relative positions of the nitrogen atoms. **Triazines** contain three nitrogen atoms.

SEE WEB LINKS

- Information about IUPAC nomenclature

azo compounds Organic compounds containing the group –N=N– linking two other groups. They can be formed by reaction of a diazonium ion with a benzene ring.

SEE WEB LINKS

- Information about IUPAC nomenclature

azo dye *See* DYES.

azoimide *See* HYDROGEN AZIDE.

azurite A secondary mineral consisting of hydrated basic copper carbonate, $Cu_3(OH)_2(CO_3)_2$, in monoclinic crystalline form. It is generally formed in the upper zone of copper ore deposits and often occurs with *malachite. Its intense azure-blue colour made it formerly important as a pigment. It is a minor ore of copper and is used as a gemstone.