S

Sabatier–Senderens process A method of organic synthesis employing hydrogenation and a heated nickel catalyst. It is employed commercially for hydrogenating unsaturated vegetable oils to make margarine. It is named after Paul Sabatier (1854–1941) and Jean-Baptiste Senderens (1856–1937).

saccharide *See* SUGAR.

saccharin A white crystalline solid, $C_7H_5NO_3S$, m.p. 224°C. It is made from a compound of toluene, derived from petroleum or coal tar. It is a well-known artificial sweetener, being some 500 times as sweet as sugar (sucrose), and is usually marketed as its sodium salt. Because of an association with cancer in laboratory animals, its use is restricted in some countries.

Saccharomyces An industrially important genus of yeasts. *S. cerevisiae*, of which there are at least 1000 strains, is used in baking (*see* BAKER'S YEAST), brewing, and wine making; it is also used in the production of various proteins and other compounds in biotechnology, including industrial alcohol. Other yeasts used in the production of beer include *S. uvarum* (or *carlsbergensis*); it is distinguished from *S. cerevisiae* by its ability to ferment the disaccharide melibose using α-galactosidase, an enzyme not produced by *S. cerevisiae*.

saccharose *See* SUCROSE.

sacculus (saccule) A chamber of the *inner ear from which the *cochlea arises in reptiles, birds, and mammals. It bears patches of sensory epithelium concerned with balance (*see* MACULA).

Sachse reaction A reaction of methane at high temperature to produce ethyne:

$$2CH_4 \rightarrow C_2H_2 + 3H_2$$

The reaction occurs at about 1500°C, the high temperature being obtained by burning part of the methane in air.

Sachs–Wolfe effect A phenomenon, predicted in 1967 by Rainer Kurt Sachs (1932–) and Arthur Michael Wolfe (1932–), in which density fluctuations associated with quantum-mechanical effects in the early universe caused 'ripples' in the cosmic microwave background radiation. It was first observed by the *COBE satellite and analysed in detail by *WMAP.

Sackur–Tetrode equation An equation for the entropy of a perfect monatomic gas. The entropy S is given by:

$$S = nR \ln(e^{5/2}\, V/nN_A\Lambda^3),$$

where $\Lambda = h/(2\pi mkT)^{1/2}$, where n is the amount of the gas, R is the gas constant, e is the base of natural logarithms, V is the volume of the system, N_A is the Avogadro constant, h is the Planck constant, m is the mass of each atom, k is the Boltzmann constant, and T is the thermodynamic temperature. To calculate the **molar entropy** of the gas both sides are divided by n. The Sackur–Tetrode equation can be used to show that the entropy change ΔS, when a perfect gas expands isothermally from V_i to V_f, is given by:

$$\Delta S = nR \ln(aV_f) - nR \ln(aV_i) = nR \ln(V_f/V_i),$$

where aV is the quantity inside the logarithm bracket in the Sackur–Tetrode equation. The equation was produced independently in 1912 by Hugo Tetrode (1895–1931) and Otto Sackur (1880–1914).

sacral vertebrae The vertebrae that lie between the lumbar and the caudal vertebrae in the *vertebral column. The function of the sacral vertebrae is to articulate securely with the *pelvic girdle, and they are usually fused to form a single bone (the **sacrum**) to provide a firm support. The number of sacral vertebrae varies from animal to animal. Amphibians have a single sacral vertebra, reptiles have two, and mammals have three or more.

sacrificial protection (cathodic protection) The protection of iron or steel against corrosion (*see* RUSTING) by using a more reactive metal. A common form is galvanizing (*see* GALVANIZED IRON), in which the iron surface is coated with a layer of zinc. Even if the zinc layer is scratched, the iron does not rust because zinc ions are formed in solution in

preference to iron ions. Pieces of magnesium alloy are similarly used in protecting pipelines, etc.

saddle point For a three-dimensional surface, a point that is a minimum in one planar cross-section and a maximum in another plane. At this point, the surface is saddle-shaped.

safranin A stain used in optical microscopy that colours lignified tissues, cutinized tissues, and nuclei red and chloroplasts pink. It is used mainly for plant tissues, in conjunction with a green or blue counterstain.

sal ammoniac *See* AMMONIUM CHLORIDE.

salicylic acid (1-hydroxybenzoic acid) A naturally occurring carboxylic acid, HOC_6H_4COOH, found in certain plants; r.d. 1.44; m.p. 159°C; sublimes at 211°C. It is used in making *aspirin and in the foodstuffs and dyestuffs industries.

saline Describing a chemical compound that is a salt, or a solution containing a salt. *See also* PHYSIOLOGICAL SALINE.

salinometer An instrument for measuring the salinity of a solution. There are two main types: one is a type of *hydrometer to measure density; the other is an apparatus for measuring the electrical conductivity of the solution.

saliva A watery fluid secreted by the *salivary glands in the mouth. Production of saliva is stimulated by the presence of food in the mouth and also by the smell or thought of food. Saliva contains mucin, which lubricates food and eases its passage into the oesophagus, and in some animals salivary *amylase (or ptyalin), which begins the digestion of starch. The saliva of insects is rich in digestive enzymes, and that of bloodsucking animals contains an anticoagulant.

salivary glands Glands in many terrestrial animals that secrete *saliva into the mouth. In humans there are three pairs: the sublingual, submandibular, and the submaxillary glands. The salivary gland cells of some insect larvae produce giant (**polytene**) chromosomes, which are widely used in the study of genetics and protein synthesis.

Salmonella A genus of rod-shaped Gram-negative bacteria that inhabit the intestine and cause disease (**salmonellosis**) in humans and animals. They are aerobic or facultatively anaerobic, and most are motile. Salmonellae can exist for long periods outside their host, and may be found, for example, in sewage and surface water. Humans may become infected by consuming contaminated water or food, especially animal products, such as eggs, meat, and milk, or vegetables that have been fertilized with contaminated manure. The bacteria can also be transmitted from human or animal carriers by unhygienic food preparation. Various species of *Salmonella* cause gastroenteritis and septicaemia; typhoid fever and paratyphoid fever are caused by *S. typhi* and *S. paratyphi*, respectively.

sal soda Anhydrous *sodium carbonate, Na_2CO_3.

salt A compound formed by reaction of an acid with a base, in which the hydrogen of the acid has been replaced by metal or other positive ions. Typically, salts are crystalline ionic compounds such as Na^+Cl^- and $NH_4^+NO_3^-$. Covalent metal compounds, such as $TiCl_4$, are also often regarded as salts.

saltation A mechanism by which the moving water in a river carries sedimentary material. The particles bound along the river bed in a series of small leaps. A similar process occurs on land, when wind acts on grains of material.

salt bridge An electrical connection made between two half cells. It usually consists of a glass U-tube filled with agar jelly containing a salt, such as potassium chloride. A strip of filter paper soaked in the salt solution can also be used.

salt cake Industrial *sodium sulphate.

salting in *See* SALTING OUT.

salting out The effect in which the solubility of a substance in a certain solvent is reduced by the presence of a second solute dissolved in the solvent. For example, certain substances dissolved in water can be precipitated (or evolved as a gas) by addition of an ionic salt. The substance is more soluble in pure water than in the salt solution. The opposite effect involving an increase in solubility may occur. This is known as **salting in**.

saltpetre *See* NITRE.

samara A dry single-seeded indehiscent fruit in which the fruit wall hardens and extends to form a long membranous winglike structure that aids dispersal. Examples are ash and elm fruits. The sycamore fruit is a

double samara and technically a *schizocarp. *See also* ACHENE.

samarium Symbol Sm. A soft silvery metallic element belonging to the *lanthanoids; a.n. 62; r.a.m. 150.35; r.d. 7.52 (20°C); m.p. 1077°C; b.p. 1791°C. It occurs in monazite and bastnatite. There are seven naturally occurring isotopes, all of which are stable except samarium–147, which is weakly radioactive (half-life 2.5×10^{11} years). The metal is used in special alloys for making nuclear-reactor parts as it is a neutron absorber. Samarium oxide (Sm_2O_3) is used in small quantities in special optical glasses. The largest use of the element is in the ferromagnetic alloy $SmCo_5$, which produces permanent magnets five times stronger than any other material. The element was discovered by François Lecoq de Boisbaudran in 1879.

SEE WEB LINKS

- Information from the WebElements site

sampling The selection of small groups of entities to represent a large number of entities in *statistics. In **random sampling** each individual of a population has an equal chance of being selected as part of the sample. In **stratified random sampling**, the population is divided into strata, each of which is randomly sampled and the samples from the different strata are pooled. In **systematic sampling**, individuals are chosen at fixed intervals; for example, every tenth animal in a population. In **sampling with replacement**, each individual chosen is replaced before the next selection is made.

sand Particles of rock with diameters in the range 0.06–2.00 mm. Most sands are composed chiefly of particles of quartz, which are derived from the weathering of quartz-bearing rocks.

Sandmeyer reaction A reaction of diazonium salts used to prepare chloro- or bromo-substituted aromatic compounds. The method is to diazotize an aromatic amide at low temperature and add an equimolar solution of the halogen acid and copper(I) halide. A complex of the diazonium salt and copper halide forms, which decomposes when the temperature is raised. The copper halide acts as a catalyst in the reaction of the halide ions from the acid, for example

$$C_6H_5N_2^+(aq) + Cl^-(aq) + CuCl(aq) \rightarrow C_6H_5Cl(l) + N_2(g) + CuCl(aq)$$

The reaction was discovered in 1884 by the German chemist Traugott Sandmeyer (1854–1922). *See also* GATTERMANN REACTION.

sandstone A common sedimentary rock composed of grains of sand. The sand accumulated originally underwater in shallow seas or lakes, or on the ground along shorelines or in desert regions. The rounded quartz grains are 0.06–2 mm across. They may be consolidated by pressure, but more often they are cemented together by calcite (calcareous sandstone), clay, or iron oxide (ferruginous sandstone), which determines the colour of the rock.

sandwich compound A transition-metal complex in which a metal atom or ion is 'sandwiched' between two rings of atoms. *Ferrocene was the first such compound to be prepared, having two parallel cyclopentadienyl rings with an iron ion between them. In such compounds (also known as **metallocenes**) the metal coordinates to the pi electron system of the ring, rather than to individual atoms. A wide variety of these compounds are known, having five-, six-, seven-, or eight-membered rings and involving such metals as Cr, Mn, Co, Ni, and Fe. Other similar compounds are known. A **multidecker sandwich** has three or more parallel rings with metal atoms between them. In a **bent sandwich**, the rings are not parallel. A **half sandwich** (or **piano stool**) has one ring, with single ligands on the other side of the metal.

Sanger's reagent 2,4-dinitrofluorobenzene, $C_6H_3F(NO_2)_2$, used to identify the end *amino acid in a protein chain. It is named after Frederick Sanger (1918–).

sap **1.** The sugary fluid that is found in the phloem tissue of plants. Sap is the medium in which carbohydrates, produced in photosynthesis, and other organic molecules are transported and stored in plants. **2. (cell sap)** The fluid that is contained in the *vacuoles of plant cells. It is a solution of organic and inorganic compounds, including sugars, amino acids, salts, pigments, and waste products.

saponification The reaction of esters with alkalis to give alcohols and salts of carboxylic acids:

$$RCOOR' + OH^- \rightarrow RCOO^- + R'OH$$

See ESTERIFICATION; SOAP.

sapphire Any of the gem varieties of

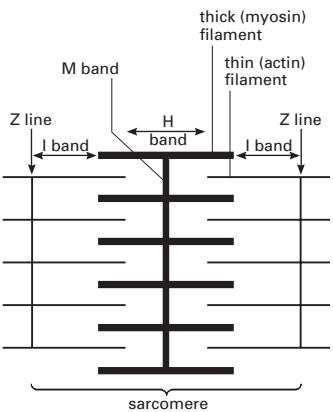
*corundum except ruby, especially the blue variety, but other colours of sapphire include yellow, brown, green, pink, orange, and purple. Sapphires are obtained from igneous and metamorphic rocks and from alluvial deposits. The chief sources are Sri Lanka, Kashmir, Burma, Thailand, East Africa, the USA, and Australia. Sapphires are used as gemstones and in record-player styluses and some types of laser. They are synthesized by the Verneuil flame-fusion process.

saprotroph (saprobe; saprobiont) Any organism that feeds by absorbing dead organic matter. Most saprotrophs are bacteria and fungi. Saprotrophs are important in *food chains as they bring about decay and release nutrients for plant growth. *Compare* PARASITISM.

sapwood (alburnum) The outer wood of a tree trunk or branch. It consists of living *xylem cells, which both conduct water and provide structural support. *Compare* HEARTWOOD.

sarcoma *See* CANCER.

sarcomere Any of the functional units that make up the myofibrils of *voluntary muscle. Each sarcomere is bounded by two membranes (**Z lines**), which provide the points of attachment of *actin filaments; another membrane (the **M band** or **line**) is the point of attachment of the *myosin filaments. The sarcomere is divided into various bands reflecting the arrangement of the filaments (see illustration). During muscle contraction the actin and myosin filaments slide over each other and the length of the sarcomere shortens: the Z lines are drawn closer together and the I and H bands become narrower.



A sarcomere.

sarin A highly toxic colourless liquid, $C_4H_{10}FO_2P$; r.d. 1.09; m.p. –56°C; b.p. 158°C. It is an organophosphorus compound, O-isopropyl methylphosphonofluoridate. Sarin was discovered in 1938 and belongs to the G-series of *nerve agents (GB). It was used by Iraq in the Iran–Iraq war (1980–88). In 1988, sarin was also used by Iraq in a poison gas attack on the Kurd city of Halabja in the north of Iraq. About 5000 people died. In 1994, a Japanese religious sect released sarin in Matsumoto and in 1995 released it in the Tokyo subway.

saros A cycle of 6586.32 days (almost exactly 18 years) that governs the order and recurrence of solar and lunar eclipses. At the end of each saros the earth, moon, and sun return to approximately the same positions relative to each other, and the eclipses are repeated in the same sequence and separated by approximately the same intervals.

satellite **1. (natural satellite)** A relatively small natural body that orbits a planet. For example, the earth's only natural satellite is the moon. **2. (artificial satellite)** A man-made spacecraft that orbits the earth, moon, sun, or a planet. Artificial satellites are used for a variety of purposes. **Communication satellites** are used for relaying telephone, radio, and television signals round the curved surface of the earth (*see* SYNCHRONOUS ORBIT). They are of two types: **passive satellites** reflect signals from one point on the earth's surface to another; **active satellites** are able to amplify and retransmit the signals that they pick up. **Astronomical satellites** are equipped to gather and transmit to earth astronomical information from space, including conditions in the earth's atmosphere, which is of great value in weather forecasting.

satellite DNA *See* REPETITIVE DNA.

saturated **1.** (of a solution) Containing the maximum equilibrium amount of solute at a given temperature. In a saturated solution the dissolved substance is in equilibrium with undissolved substance; i.e. the rate at which solute particles leave the solution is exactly balanced by the rate at which they dissolve. A solution containing less than the

equilibrium amount is said to be **unsaturated**. One containing more than the equilibrium amount is **supersaturated**. Supersaturated solutions can be made by slowly cooling a saturated solution. Such solutions are metastable; if a small crystal seed is added the excess solute crystallizes out of solution. **2.** (of a vapour) *See* VAPOUR PRESSURE. **3.** (of a ferromagnetic material) Unable to be magnetized more strongly as all the domains are orientated in the direction of the field. **4.** (of a compound) Consisting of molecules that have only single bonds (i.e. no double or triple bonds). Saturated compounds can undergo substitution reactions but not addition reactions. *Compare* UNSATURATED.

saturation **1.** *See* COLOUR. **2.** *See* SUPERSATURATION.

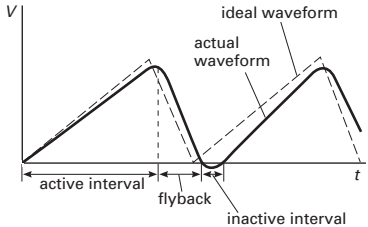
Saturn The second largest planet in the *solar system and the sixth in order from the sun (1433.45×10^6 km distant). Its equatorial diameter is 120 536 km and its *sidereal period is 29.46 years. Saturn is a *gas giant. Its mass is 5.685×10^{26} kg or 95 times that of the earth. Although it is the second largest planet, its mean density is lower than any other and is less than that of water, its relative density being 0.7. It has at least 61 satellites, of which the largest, *Titan, is the only planetary satellite to have a dense atmosphere. Like Jupiter, Saturn is believed to consist of a dense rocky core, surrounded by hydrogen compressed to such an extent that it behaves like a metal; this layer merges with an atmosphere of mostly hydrogen. Saturn is best known for the spectacular and complex system of rings that surrounds it in its equatorial plane; the rings have an overall diameter of about 273 000 km. They are believed to consist of millions of particles of ice (possibly with a rock core) with diameters between <1 mm and 10 m. Saturn was given a preliminary examination by the spacecraft Pioneer II in 1979, more detailed studies by Voyager I in 1980 and Voyager II in 1981, and a comprehensive survey (including its rings and satellites) by the Cassini-Huygens space probe in 2004.

SEE WEB LINKS

- NASA's profile to the planet and its moons

savanna *See* GRASSLAND.

sawtooth waveform A waveform in which the variable increases uniformly with time for a fixed period, drops sharply to its initial value, and then repeats the sequence periodically. The illustration shows the ideal waveform and the waveform generated by practical electrical circuits. Sawtooth generators are frequently used to provide a time base for electronic circuits, as in the *cathode-ray oscilloscope.



Sawtooth waveform.

SAX Simple API for XML: a specification for an event-driven XML parser. SAX parsers read XML files and raise appropriate events for each type of XML object encountered (start of element, end of element, character-data block, etc.). Unlike DOM parsers, SAX parsers do not create a representation of the document in RAM, which makes them faster and less memory-hungry. It is the application's responsibility to use the SAX events to extract and maintain whatever information it requires. The current version is 2.0 (**SAX2**), with Java implementation generally regarded as normative in the absence of a formal specification.

SEE WEB LINKS

- The SAX home page

***s*-block elements** The elements of the first two groups of the *periodic table; i.e. groups 1 (Li, Na, K, Rb, Cs, Fr) and 2 (Be, Mg, Ca, Sr, Ba, Ra). The outer electronic configurations of these elements all have inert-gas structures plus outer ns^1 (group 1) or ns^2 (group 2) electrons. The term thus excludes elements with incomplete inner *d*-levels (transition metals) or with incomplete inner *f*-levels (lanthanoids and actinoids) even though these often have outer ns^2 or occasionally ns^1 configurations. Typically, the *s*-block elements are reactive metals forming stable ionic compounds containing M^+ or M^{2+} ions. *See* ALKALI METALS; ALKALINE-EARTH METALS.

scalar product (dot product) The product of two vectors ***U*** and ***V***, with components

U_1, U_2, U_3 and V_1, V_2, V_3, respectively, given by:

$$\boldsymbol{U}.\boldsymbol{V} = U_1V_1 + U_2V_2 + U_3V_3.$$

It can also be written as $UV\cos\theta$, where U and V are the lengths of $\boldsymbol{U}$ and $\boldsymbol{V}$, respectively, and θ is the angle between them. *Compare* VECTOR PRODUCT.

scalar quantity A quantity in which direction is either not applicable (as in temperature) or not specified (as in speed). *Compare* VECTOR.

scalar triple product *See* TRIPLE PRODUCT.

scalene Denoting a triangle having three unequal sides.

scaler (scaling circuit) An electronic counting circuit that provides an output when it has been activated by a prescribed number of input pulses. A **decade scaler** produces an output pulse when it has received ten or a multiple of ten input pulses; a **binary scaler** produces its output after two input pulses.

scales The small bony or horny plates forming the body covering of fish and reptiles. The wings of some insects, notably the Lepidoptera (butterflies and moths), are covered with tiny scales that are modified cuticular hairs.

In fish there are three types of scales. **Placoid scales** (**denticles**), characteristic of cartilaginous fish, are small and toothlike, with a projecting spine and a flattened base embedded in the skin. They are made of *dentine, have a pulp cavity, and the spine is covered with a layer of enamel. Teeth are probably modified placoid scales. **Cosmoid scales**, characteristic of lungfish and coelacanths, have an outer layer of hard **cosmin** (similar to dentine) covered by modified enamel (**ganoine**) and inner layers of bone. The scale grows by adding to the inner layer only. In modern lungfish the scales are reduced to large bony plates. **Ganoid scales** are characteristic of primitive ray-finned fishes, such as sturgeons. They are similar to cosmoid scales but have a much thicker layer of ganoine and grow by the addition of material all round. The scales of modern teleost fish are reduced to thin bony plates.

In reptiles there are two types of scales: horny epidermal **corneoscutes** sometimes fused with underlying bony dermal **osteoscutes**.

scandium Symbol Sc. A rare soft silvery metallic element belonging to group 3 (formerly IIIA) of the periodic table; a.n. 21; r.a.m. 44.956; r.d. 2.989 (alpha form), 3.19 (beta form); m.p. 1541°C; b.p. 2831°C. Scandium often occurs in *lanthanoid ores, from which it can be separated on account of the greater solubility of its thiocyanate in ether. The only natural isotope, which is not radioactive, is scandium–45, and there are nine radioactive isotopes, all with relatively short half-lives. Because of the metal's high reactivity and high cost no substantial uses have been found for either the metal or its compounds. Predicted in 1869 by Dmitri Mendeleev, and then called **ekaboron**, the oxide (called **scandia**) was isolated by Lars Nilson (1840–99) in 1879.

SEE WEB LINKS

- Information from the WebElements site

scanning The process of repeatedly crossing a surface or volume with a beam, aerial, or moving detector in order to bring about some change to the surface or volume, to measure some activity, or to detect some object. The fluorescent screen of a television picture tube is scanned by an electron beam in order to produce the picture; an area of the sky may be scanned by the movable dish aerial of a radio telescope in order to detect celestial bodies, etc.

scanning electron microscope *See* ELECTRON MICROSCOPE.

scanning probe microscopy (SPM) Any of several microscopic techniques that are based on measuring the interaction between a very sharp-tipped probe and the surface of the sample. The probe scans the sample surface and records the surface topography, which can be processed by a computer to produce images. Widely used in chemistry, such techniques are now increasingly used in biology to study biomolecules and cell surfaces at the nanometre scale. *See* ATOMIC FORCE MICROSCOPY; SCANNING TUNNELLING MICROSCOPY.

SEE WEB LINKS

- Overview of scanning probe microscopy techniques produced by Nanoscience Instruments Inc

scanning tunnelling microscopy (STM) A variation of *scanning probe microscopy in which electrons tunnel between the sample and the probe, producing an electrical signal. The probe is slowly moved across the surface and raised and lowered so as to keep

the signal constant. A profile of the surface is produced, and a computer-generated contour map of the surface is produced. Although most suitable for imaging substances that are electrical conductors, STM is now used for studying biological materials at the nanometre scale.

SEE WEB LINKS

- An account of the technique produced by Nanoscience Instruments Inc

scapula (shoulder blade) The largest of the bones that make up each half of the *pectoral (shoulder) girdle. It is a flat triangular bone, providing anchorage for the muscles of the forelimb and an articulation for the *humerus at the *glenoid cavity. It is joined to the *clavicle (collar bone) in front.

scattered disc A remote region of the outer *solar system that is home to a sparse population of *trans-Neptunian objects following extremely erratic orbits around the sun. The scattered disc appears to overlap the *Kuiper belt but extends far beyond its outer limits. Scattered disc objects (SDOs) are thought by some astronomers to be former members of the Kuiper belt that were ejected into their present orbits by the gravitational influence of the gas giants. The scattered disc may also be the present home of short-period *comets and possibly the original home of the *centaurs.

scattering of electromagnetic radiation The process in which electromagnetic radiation is deflected by particles in the matter through which it passes. In **elastic scattering** the photons of the radiation are reflected; i.e. they bounce off the atoms and molecules without any change of energy. In this type of scattering, known as **Rayleigh scattering** (after Lord Rayleigh; 1842–1919), there is a change of phase but no frequency change. In **inelastic scattering** and **superelastic scattering**, there is interchange of energy between the photons and the particles. Consequently, the scattered photons have a different wavelength as well as a different phase. Examples include the *Raman effect and the *Compton effect. *See also* TYNDALL EFFECT.

scavenger An animal that feeds on dead organic matter. Scavengers (such as hyenas) may feed on animals killed by predators or they may be *detritivores.

Scheele, Karl Wilhelm (1742–86) Swedish chemist, who became an apothecary and in 1775 set up his own pharmacy at Köping. He made many chemical discoveries. In 1772 he prepared oxygen (*see also* LAVOISIER, ANTOINE LAURENT; PRIESTLEY, JOSEPH) and in 1774 he isolated chlorine. He also discovered manganese, glycerol, hydrocyanic (prussic) acid, citric acid, and many other substances.

scheelite A mineral form of calcium tungstate, $CaWO_4$, used as an ore of tungsten. It occurs in contact metamorphosed deposits and vein deposits as colourless or white tetragonal crystals.

Schiaparelli, Giovanni Virginio (1835–1910) Italian astronomer, who became director of the Milan Observatory in 1860. There he studied asteroids, meteors, and planets. In 1877 he described *canali* among the surface features of *Mars. The Italian word (which means 'channels') was mistranslated as 'canals', establishing a long controversy about the possibility of intelligent life on Mars.

Schiff base A compound formed by a condensation reaction between an aromatic amine and an aldehyde or ketone, for example

$$RNH_2 + R'CHO \rightarrow RN{:}CHR' + H_2O$$

The compounds are often crystalline and are used in organic chemistry for characterizing aromatic amines (by preparing the Schiff base and measuring the melting point). They are named after the German chemist Hugo Schiff (1834–1915).

Schiff reagent A reagent used for testing for aldehydes and ketones; it consists of a solution of fuchsin dye that has been decolorized by sulphur dioxide. Aliphatic aldehydes restore the pink immediately, whereas aromatic ketones have no effect on the reagent. Aromatic aldehydes and aliphatic ketones restore the colour slowly.

schist A group of coarse-grained metamorphic rocks characterized by the presence of platy minerals (e.g. micas, chlorite, talc, hornblende, and graphite) that show parallel alignment at right angles to the direction of stress. The original bedding of the rock is absent. Schists readily split into layers along schistosity planes, parallel to the alignment of the minerals.

schizocarp A dry indehiscent fruit formed from carpels that develop into separate one-seeded fragments called **mericarps**, which

may be dehiscent, as in the *regma, or indehiscent, as in the *cremocarp and *carcerulus.

schizogeny The localized separation of plant cells to form a cavity (surrounded by the intact cells) in which secretions accumulate. Examples are the resin canals of some conifers and the oil ducts of caraway and aniseed fruits. *Compare* LYSIGENY.

Schleiden, Matthias Jakob *See* CELL THEORY; SCHWANN, THEODOR.

schlieren photography A technique that enables density differences in a moving fluid to be photographed. In the turbulent flow of a fluid, for example, short-lived localized differences in density create differences of refractive index, which show up on photographs taken by short flashes of light as streaks (German: *Schliere*). Schlieren photography is used in wind-tunnel studies to show the density gradients created by turbulence and the shock waves around a stationary model.

Schmidt camera *See* TELESCOPE.

Schoenflies system A system for categorizing symmetries of molecules. C_n groups contain only an n-fold rotation axis. C_{nv} groups, in addition to the n-fold rotation axis, have a mirror plane that contains the axis of rotation (and mirror planes associated with the existence of the n-fold axis). C_{nh} groups, in addition to the n-fold rotation axis, have a mirror plane perpendicular to the axis. S_n groups have an n-fold rotation–reflection axis. D_n groups have an n-fold rotation axis and a two-fold axis perpendicular to the n-fold axis (and two-fold axes associated with the existence of the n-fold axis). D_{nh} groups have all the symmetry operations of D_n and also a mirror plane perpendicular to the n-fold axis. D_{nd} groups contain all the symmetry operations of D_n and also mirror planes that contain the n-fold axis and bisect the angles between the two-fold axes. In the Schoenflies notation C stands for 'cyclic', S stands for 'spiegel' (mirror), and D stands for 'dihedral'. The subscripts h, v, and d stand for horizontal, vertical, and diagonal respectively, where these words refer to the position of the mirror planes with respect to the n-fold axis (considered to be vertical). In addition to the noncubic groups referred to so far, there are cubic groups, which have several rotation axes with the same value of n. These are the tetrahedral groups T, T_h, and T_d, the octahedral groups O and O_h, and the icosahedral group I. The Schoenflies system is commonly used for isolated molecules, while the *Hermann–Mauguin system is commonly used in crystallography.

schönite A mineral form of potassium sulphate, K_2SO_4.

Schottky defect *See* CRYSTAL DEFECT.

Schottky effect A reduction in the *work function of a substance when an external accelerating electric field is applied to its surface in a vacuum. The field reduces the potential energy of electrons outside the substance, distorting the potential barrier at the surface and causing *field emission. A similar effect occurs when a metal surface is in contact with a *semiconductor rather than a vacuum, when it is known as a **Schottky barrier**. The effect was discovered by the German physicist Walter Schottky (1886–1976).

Schrieffer, John *See* BARDEEN, JOHN.

Schrödinger, Erwin (1887–1961) Austrian physicist, who became professor of physics at Berlin University in 1927. He left for Oxford to escape the Nazis in 1933, returned to Graz in Austria in 1936, and then left again in 1938 for Dublin's Institute of Advanced Studies. He finally returned to Austria in 1956. He is best known for the development of *wave mechanics and the *Schrödinger equation, work that earned him a share of the 1933 Nobel Prize for physics with Paul Dirac (1902–84).

Schrödinger equation An equation used in wave mechanics (*see* QUANTUM MECHANICS) for the wave function of a particle. The time-independent Schrödinger equation is:

$$\nabla^2\psi + 8\pi^2 m(E - U)\psi/h^2 = 0$$

where ψ is the wave function, ∇^2 the Laplace operator (*see* LAPLACE EQUATION), h the Planck constant, m the particle's mass, E its total energy, and U its potential energy. The equation can be solved exactly for simple systems, such as the harmonic oscillator and the hydrogen atom. It was devised by Erwin Schrödinger, who was mainly responsible for wave mechanics.

Schrödinger's cat A thought experiment introduced by Erwin Schrïdinger in 1935 to illustrate the paradox in *quantum mechanics regarding the probability of finding, say, a

subatomic particle at a specific point in space. According to Niels Bohr, the position of such a particle remains indeterminate until it has been observed. Schrödinger postulated a sealed vessel containing a live cat and a device triggered by a quantum event, such as the radioactive decay of a nucleus. If the quantum event occurs, cyanide is released and the cat dies; if the event does not occur the cat lives. Schrödinger argued that Bohr's interpretation of events in quantum mechanics means that the cat could only be said to be alive or dead when the vessel has been opened and the situation inside it had been observed.

Wigner's friend is a variation of the Schrödinger's cat paradox in which a friend of the physicist Eugene Wigner is the first to look inside the vessel. The friend will either find a live or dead cat. However, if Professor Wigner has both the vessel with the cat and the friend in a closed room, the state of mind of the friend (happy if there is a live cat but sad if there is a dead cat) cannot be determined in Bohr's interpretation of quantum mechanics until the professor has looked into the room although the friend has looked at the cat. This paradox has been extensively discussed since its introduction with many proposals made to resolve it. It is thought that the explanation depends on *decoherence.

Schwann, Theodor (1810–82) German physiologist, who trained in medicine. After working in Berlin, he moved to Belgium. In 1838 the German botanist Matthias Schleiden (1804–81) had stated that plant tissues were composed of cells. Schwann demonstrated the same fact for animal tissues, and in 1839 concluded that all tissues are made up of cells: this laid the foundations for the *cell theory. Schwann also worked on fermentation and discovered the enzyme *pepsin. *Schwann cells are named after him.

Schwann cell A cell that forms the *myelin sheath of nerve fibres (axons). Each cell is responsible for a given length of a particular axon (called an **internode**); adjacent internodes are separated by small gaps (**nodes of Ranvier**) where the axon is bare. During its development the cell wraps itself around the fibre, so the sheath consists of concentric layers of Schwann cell membrane. These cells are named after Theodor Schwann.

Schwarzschild radius A critical radius of a body of given mass that must be exceeded if light is to escape from that body. It equals $2GM/c^2$, where G is the gravitational constant, c is the speed of light, and M is the mass of the body. If the body collapses to such an extent that its radius is less than the Schwarzschild radius the escape velocity becomes equal to the speed of light and the object becomes a *black hole. The Schwarzschild radius is then the radius of the hole's event horizon. It is named after Karl Schwarzschild (1873–1916).

Schweizer's reagent A solution made by dissolving copper(II) hydroxide in concentrated ammonia solution. It has a deep blue colour and is used as a solvent for cellulose in the cuprammonium process for making rayon. When the cellulose solution is forced through spinnarets into an acid bath, fibres of cellulose are reformed.

scientific notation *See* STANDARD FORM.

scintillation (twinkling) The rapid intermittent changes in brightness in the light from a celestial object, especially a star, caused by the earth's atmosphere.

scintillation counter A type of particle or radiation counter that makes use of the flash of light (scintillation) emitted by an excited atom falling back to its ground state after having been excited by a passing photon or particle. The scintillating medium is usually either solid or liquid and is used in connection with a *photomultiplier, which produces a pulse of current for each scintillation. The pulses are counted with a *scaler. In certain cases, a pulse-height analyser can be used to give an energy spectrum of the incident radiation.

scintillator *See* PHOSPHOR.

scion *See* GRAFT.

sclera *See* SCLEROTIC.

sclerenchyma A plant tissue whose cell walls have become impregnated with lignin. Due to the added strength that this confers, sclerenchyma plays an important role in support; it is found in the stems and also in the midribs of leaves. Mature sclerenchyma cells are dead, since the lignin makes the cell wall impermeable to water and gases. The presence of *plasmodesmata prevents lignin being deposited in areas of the cell wall called **pits**; these form shallow depressions enabling the exchange of substances be-

tween adjacent cells. *Compare* COLLENCHYMA (*see* GROUND TISSUES); PARENCHYMA.

sclerometer A device for measuring the hardness of a material by determining the pressure on a standard point that is required to scratch it or by determining the height to which a standard ball will rebound from it when dropped from a fixed height. The rebound type is sometimes called a **scleroscope**.

scleroprotein Any of a group of proteins found in the exoskeletons of some invertebrates, notably insects. Scleroproteins are formed by conversion of the relatively soft elastic larval protein by a natural tanning process (**sclerotization**) involving orthoquinones. These are secreted and form cross linkages between polypeptides of the proteins, producing a hard rigid covering.

sclerotic (sclera) The tough external layer of the vertebrate eye. At the front of the eye, the sclera is modified to form the *cornea.

scorpions *See* ARACHNIDA.

scotopic vision The type of vision that occurs when the *rods in the eye are the principal receptors, i.e. when the level of illumination is low. With scotopic vision colours cannot be identified. *Compare* PHOTOPIC VISION.

Scott's test (cobalt thiocyanate test; Ruybal test) A *presumptive test for cocaine. **Scott's reagent** has an initial solution of 2% cobalt thiocyanate ($Co(SCN)_2$) in glycerine and water. This is followed by concentrated hydrochloric acid, and then chloroform. A positive test is indicated by a blue colour in the chloroform layer.

SCP *See* SINGLE-CELL PROTEIN.

screen grid A wire grid in a tetrode or pentode *thermionic valve, placed between the anode and the *control grid to reduce the grid–anode capacitance. *See also* SUPPRESSOR GRID.

screw **1.** A simple *machine effectively consisting of an inclined plane wrapped around a cylinder. The mechanical advantage of a screw is $2\pi r/p$, where r is the radius of the thread and p is the **pitch**, i.e. the distance between adjacent threads of the screw measured parallel to its axis. **2.** A symmetry element in a crystal lattice that consists of a combination of a rotation and a translation. *See also* GLIDE.

scrotum The sac of skin and tissue that contains and supports the *testes in most mammals. It is situated outside the body cavity and allows sperm to develop at the optimum temperature, which is slightly lower than body temperature.

scurvy A disease caused by deficiency of *vitamin C, which results in poor collagen formation. Symptoms include anaemia, skin discoloration, and tooth loss. Scurvy was a common disease among sailors in the 16th–18th centuries, when no fresh food was available on long sea voyages.

S-drop *See* STRANGE MATTER.

seaborgium Symbol Sg. A radioactive *transactinide element; a.n. 106. It was first detected in 1974 by Albert Ghiorso and a team in California. It can be produced by bombarding californium–249 nuclei with oxygen–18 nuclei. It is named after the US physicist Glenn Seaborg (1912–99).

SEE WEB LINKS

- Information from the WebElements site

seamount An isolated steep-sided hill up to 1000 m tall on the sea floor. Most are conical in shape and volcanic in origin, with summits 1000–2000 m below the sea surface. *See also* GUYOT.

search coil A small coil in which a current can be induced to detect and measure a magnetic field. It is used in conjunction with a *fluxmeter.

Searle's bar An apparatus for determining the thermal conductivity of a bar of material. The bar is lagged and one end is heated while the other end is cooled, by steam and cold water respectively. At two points d apart along the length of the bar the temperature is measured using a thermometer or thermocouple. The conductivity can then be calculated from the measured temperature gradient.

seaweeds Large multicellular *algae living in the sea or in the intertidal zone. They are commonly species of the *Chlorophyta, *Phaeophyta, and *Rhodophyta.

sebaceous gland A small gland occurring in mammalian *skin. Its duct opens into a hair follicle, through which it discharges *sebum onto the skin surface.

sebacic acid *See* DECANEDIOIC ACID.

sebum The substance secreted by *seba-

ceous glands onto the surface of the *skin. It is a fatty mildly antiseptic material that protects, lubricates, and waterproofs the skin and hair and helps prevent desiccation.

secant **1.** *See* TRIGONOMETRIC FUNCTIONS. **2.** A line that cuts a circle or other curve.

sech *See* HYPERBOLIC FUNCTIONS.

second **1.** Symbol s. The SI unit of time equal to the duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the caesium–133 atom. **2.** Symbol ″. A unit of angle equal to 1/3600 of a degree or 1/60 of a minute.

secondary alcohol *See* ALCOHOLS.

secondary amine *See* AMINES.

secondary cell A *voltaic cell in which the chemical reaction producing the e.m.f. is reversible and the cell can therefore be charged by passing a current through it. *See* ACCUMULATOR; INTERCALATION CELL. *Compare* PRIMARY CELL.

secondary colour Any colour that can be obtained by mixing two *primary colours. For example, if beams of red light and green light are made to overlap, the secondary colour, yellow, will be formed. Secondary colours of light are sometimes referred to as the pigmentary primary colours. For example, if transparent yellow and magenta pigments are overlapped in white light, red will be observed. In this case the red is a pigmentary secondary although it is a primary colour of light.

secondary consumer *See* CONSUMER.

secondary emission The emission of electrons from a surface as a result of the impact of other charged particles, especially as a result of bombardment with (primary) electrons. As the number of secondary electrons can exceed the number of primary electrons, the process is important in *photomultipliers. *See also* AUGER EFFECT.

secondary growth (secondary thickening) The increase in thickness of plant shoots and roots through the activities of the vascular *cambium and *cork cambium. It is seen in most dicotyledons and gymnosperms but not in monocotyledons. The tissues produced by secondary growth are called **secondary tissues** and the resultant plant or plant part is the **secondary plant body**. *Compare* PRIMARY GROWTH.

secondary sexual characteristics External features of a sexually mature animal that, although not directly involved in copulation, are significant in reproductive behaviour. The development of such features is controlled by sex hormones (androgens or oestrogens); they may be seasonal (e.g. the antlers of male deer or the body colour of male sticklebacks) or permanent (e.g. breasts in women or facial hair in men). In humans they develop during *adolescence.

secondary structure *See* PROTEIN.

secondary thickening *See* SECONDARY GROWTH.

secondary winding The winding on the output side of a *transformer or *induction coil. *Compare* PRIMARY WINDING.

second convoluted tubule *See* DISTAL CONVOLUTED TUBULE.

second messenger A chemical within a cell that is responsible for initiating the response to a signal from a chemical messenger (such as a hormone, neurotransmitter, or growth factor) that cannot enter the target cell itself, for example because it is not lipid-soluble and is therefore unable to cross the plasma membrane. A common second messenger is *cyclic AMP; the signal for its formation within the cell by *adenylate cyclase is transmitted from hormone receptors on the cell surface by a *G protein.

second-order reaction *See* ORDER.

secretin A hormone produced by the anterior part of the small intestine (the *duodenum and *jejunum) in response to the presence of hydrochloric acid from the stomach. It causes the pancreas to secrete alkaline pancreatic juice and stimulates bile production in the liver. Secretin, whose function was first demonstrated in 1902, was the first substance to be described as a hormone.

secretion **1.** The manufacture and discharge of specific substances into the external medium by cells in living organisms. (The substance secreted is also called the secretion.) Secretory cells are often specialized and organized in groups to form *glands. The substances produced may be released directly into the blood (**endocrine secretion**; *see* ENDOCRINE GLAND) or through a duct (**exocrine secretion**; *see* EXOCRINE GLAND). Secretions can be classified according to the manner of their discharge. **Merocrine** (**ec-**

crine) **secretion** occurs without the secretory cells sustaining any permanent change; in **apocrine secretion** the cells release a secretory vesicle incorporating part of the secretory cell membrane; and **holocrine secretion** involves the disruption of the entire cell to release its accumulated secretory vesicles. **2.** The process by which a substance is pumped out of a cell against a concentration gradient. Secretion has an important role in adjusting the composition of urine as it passes through the *nephrons of the kidney.

secular magnetic variation *See* GEOMAGNETISM.

sedimentary rocks A group of rocks formed as a result of the accumulation and consolidation of sediments. Sedimentary rocks are one of the three major rock groups forming the earth's crust (*see also* IGNEOUS ROCKS; METAMORPHIC ROCKS). Most sedimentary rocks are formed from pre-existing rocks that have been broken down through mechanical processes into small particles, which have then been transported and redeposited; these form the clastic sedimentary rocks. The clastic rocks are subdivided according to the size of the dominant constituent particles: arenaceous being composed largely of sand-grade particles (e.g. sandstone, grit), argillaceous of silt- or clay-grade (e.g. mud, mudstone, clay, shale), and rudaceous of gravel-grade or larger particles (e.g. conglomerate). Chemical sedimentary rocks form the second large division of sedimentary rocks and originate as chemical precipitates at the site of deposition. These include the evaporites and sedimentary iron ores, and the organic sedimentary rocks, which are derived largely from the remains of plants and animals and include coal and many limestones.

sedimentation The settling of the solid particles through a liquid either to produce a concentrated slurry from a dilute suspension or to clarify a liquid containing solid particles. Usually this relies on the force of gravity, but if the particles are too small or the difference in density between the solid and liquid phases is too small, a *centrifuge may be used. In the simplest case the rate of sedimentation is determined by *Stokes' law, but in practice the predicted rate is rarely reached. Measurement of the rate of sedimentation in an *ultracentrifuge can be used to estimate the size of macromolecules.

Seebeck effect (thermoelectric effect) The generation of an e.m.f. in a circuit containing two different metals or semiconductors, when the junctions between the two are maintained at different temperatures. The magnitude of the e.m.f. depends on the nature of the metals and the difference in temperature. The Seebeck effect is the basis of the *thermocouple. It was named after Thomas Seebeck (1770–1831), who actually found that a magnetic field surrounded a circuit consisting of two metal conductors only if the junctions between the metals were maintained at different temperatures. He wrongly assumed that the conductors were magnetized directly by the temperature difference. *Compare* PELTIER EFFECT.

seed **1.** (in botany) The structure in angiosperms and gymnosperms that develops from the ovule after fertilization. Occasionally seeds may develop without fertilization taking place (*see* APOMIXIS). The seed contains the *embryo and nutritive tissue, either as *endosperm or food stored in the *cotyledons. Angiosperm seeds are contained within a *fruit that develops from the ovary wall. Gymnosperm seeds lack an enclosing fruit and are thus termed **naked**. The seed is covered by a protective layer, the *testa. During development of the testa the seed dries out and enters a resting phase (dormancy) until conditions are suitable for germination.

Annual plants survive the winter or dry season as seeds. The evolution of the seed habit enabled plants to colonize the land, since seed plants do not depend on water for fertilization (unlike the lower plants). **2.** (in chemistry) A crystal used to induce other crystals to form from a gas, liquid, or solution.

seed coat *See* TESTA.

seed ferns *See* CYCADOFILICALES.

seed leaf *See* COTYLEDON.

seed plant Any plant that produces seeds. Most seed plants belong to the phyla *Anthophyta (flowering plants) or *Coniferophyta (conifers).

Seger cones (pyrometric cones) A series of cones used to indicate the temperature inside a furnace or kiln. The cones are made from different mixtures of clay, limestone, feldspars, etc., and each one softens at a different temperature. The drooping of the vertex is an indication that the known softening

temperature has been reached and thus the furnace temperature can be estimated.

segmentation **1.** *See* METAMERIC SEGMENTATION. **2.** *See* CLEAVAGE.

Segrè chart A diagram in which the number of protons in a nucleus is plotted against the number of neutrons. This chart, named after the Italian–American physicist Emilio Segrè (1905–89), enables the narrow range of stable nuclei to be seen clearly and also illustrates that for more than 20 protons more neutrons than protons are required for stable nuclei.

segregation The separation of pairs of *alleles during the formation of reproductive cells so that they contain one allele only of each pair. Segregation is the result of the separation of *homologous chromosomes during *meiosis. *See also* MENDEL'S LAWS.

Segrè plot A plot of *neutron number (N) against *atomic number (Z) for all stable nuclides. The stability of nuclei can be understood qualitatively on the basis of the nature of the strong interaction (*see* FUNDAMENTAL INTERACTIONS) and the competition between this attractive force and the repulsive electrical force. The strong interaction is independent of electric charge, i.e. at any given separation the strong force between two neutrons is the same as that between two protons or between a proton or a neutron. Therefore, in the absence of the electrical repulsion between protons, the most stable nuclei would be those having equal numbers of neutrons and protons. The electrical repulsion shifts the balance to favour a greater number of neutrons, but a nucleus with too many neutrons is unstable, because not enough of them are paired with protons.

As the number of nucleons increases, the total energy of the electrical interaction increases faster than that of the nuclear interaction. The (positive, repulsive) electric potential energy of the nucleus increases approximately as Z^2, while the (negative, attractive) nuclear potential energy increases approximately as $N + Z$ with corrections for pairing effects. For large $N + Z$ values, the electrical potential energy per nucleon grows much faster than the nuclear potential energy per nucleon, until a point is reached where the formation of a stable nucleus is impossible. The competition between the electric and nuclear forces therefore accounts for the increase with Z of the neutron–proton ratio in stable nuclei as well as the existence of maximum values for $N + Z$ for stability. The plot is named after Emilio Segrè (1905–89). *See* BINDING ENERGY; LIQUID-DROP MODEL; DECAY.

seif dune *See* DUNE.

seismic waves A vibration propagated within the earth or along its surface as a result of an *earthquake or explosion. Earthquakes generate two types of body waves that travel within the earth and two types of surface wave. The body waves consist of primary (or longitudinal) waves that impart a back-and-forth motion to rock particles along their path. They travel at speeds between 6 km per second in surface rock and 10.4 km per second near the earth's core. Secondary (or transverse or shear) waves cause rock particles to move back and forth perpendicularly to their direction of propagation. They travel at between 3.4 km per second in surface rock and 7.2 km per second near the core.

The surface waves consist of Rayleigh waves (after Lord Rayleigh, who predicted them) and Love waves (after A. E. Love). The Love waves displace particles perpendicularly to the direction of propagation and have no longitudinal or vertical components. They travel in the surface layer above a solid layer of rock with different elastic characteristics. Rayleigh waves travel over the surface of an elastic solid giving an elliptical motion to rock particles. It is these Rayleigh waves that have the strongest effect on distant seismographs.

seismograph An instrument that records ground oscillations, e.g. those caused by earthquakes, volcanic activity, and explosions. Most modern seismographs are based on the inertia of a delicately suspended mass and depend on the measurement of the displacement between the mass and a point fixed to the earth. Others measure the relative displacement between two points on earth. The record made by a seismograph is known as a **seismogram**.

seismology The branch of geology concerned with the study of earthquakes.

SEE WEB LINKS

- The British Geological Survey seismology home page

Selachii The major subclass of the Chondrichthyes (cartilaginous fishes), containing the sharks, rays, skates, and similar

but extinct forms. Their sharp teeth develop from the toothlike placoid *scales (denticles) and are rapidly replaced as they wear out.

selection (in biology) The process by which one or more factors acting on a population produce differential mortality and favour the transmission of specific characteristics to subsequent generations. *See* ARTIFICIAL SELECTION; NATURAL SELECTION; SEXUAL SELECTION.

selection pressure The extent to which organisms possessing a particular characteristic are either eliminated or favoured by environmental demands. It indicates the degree of intensity of *natural selection.

selection rules Rules that determine which transitions between different energy levels are possible in a system, such as an elementary particle, nucleus, atom, molecule, or crystal, described by quantum mechanics. Transitions cannot take place between any two energy levels. *Group theory, associated with the *symmetry of the system, determines which transitions, called **allowed transitions**, can take place and which transitions, called *forbidden transitions, cannot take place. Selection rules determined in this way are very useful in analysing the *spectra of quantum-mechanical systems.

selective breeding *See* BREEDING.

selectron *See* SUPERSYMMETRY.

selenides Binary compounds of selenium with other more electropositive elements. Selenides of nonmetals are covalent (e.g. H_2Se). Most metal selenides can be prepared by direct combination of the elements. Some are well-defined ionic compounds (containing Se^{2-}), while others are non-stoichiometric interstitial compounds (e.g. Pd_4Se, $PdSe_2$).

selenium Symbol Se. A metalloid element belonging to group 16 (formerly VIB) of the periodic table; a.n. 34; r.a.m. 78.96; r.d. 4.81 (grey); m.p. 217°C (grey); b.p. 684.9°C. There are a number of allotropic forms, including grey, red, and black selenium. It occurs in sulphide ores of other metals and is obtained as a by-product (e.g. from the anode sludge in electrolytic refining). The element is a semiconductor; the grey allotrope is light-sensitive and is used in photocells, xerography, and similar applications. Chemically, it resembles sulphur, and forms compounds with selenium in the +2, +4, and +6 oxidation states. Selenium was discovered in 1817 by Jöns Berzelius.

SEE WEB LINKS

- Information from the WebElements site

selenium cell Either of two types of *photoelectric cell; one type relies on the photoconductive effect, the other on the photovoltaic effect (*see* PHOTOELECTRIC EFFECT). In the photoconductive selenium cell an external e.m.f. must be applied; as the selenium changes its resistance on exposure to light, the current produced is a measure of the light energy falling on the selenium. In the photovoltaic selenium cell, the e.m.f. is generated within the cell. In this type of cell, a thin film of vitreous or metallic selenium is applied to a metal surface, a transparent film of another metal, usually gold or platinum, being placed over the selenium. Both types of cell are used as light meters in photography.

selenology The branch of astronomy concerned with the scientific study of the *moon.

self-assembly *See* SELF-ORGANIZATION.

self-exciting generator A type of electrical generator in which the field electromagnets are excited by current from the generator output.

self-fertilization *See* FERTILIZATION.

self-inductance *See* INDUCTANCE.

selfish DNA Regions of DNA that apparently have no function (they are also known as 'junk' DNA) and exist between those regions of DNA that represent the genes. *Transposons are good examples. Certain types of *repetitive DNA also have 'selfish' characteristics. This DNA is said to be 'selfish' as it seemingly exists only to pass copies of itself from one generation to another; it does so by using the organism in which it is contained as a survival machine. This is known as the **selfish DNA theory**. The greatest amounts of selfish DNA are found in vertebrates and higher plants. The presence of selfish DNA may be due to an unrecognizable function that it performs or because the cell has no way of halting its increase in the genome.

self-organization The spontaneous order arising in a system when certain parameters of the system reach critical values. Self-

organization occurs in many systems in physics, chemistry, and biology. An example in physics is the *Bénard cell. In chemistry, **self-assembly** is one of the features of *supramolecular chemistry. Self-organization can occur when a system is driven far from thermal *equilibrium. Since a self-organizing system is open to its environment, the second law of *thermodynamics is not violated by the formation of an ordered phase, as entropy can be transferred to the environment. Self-organization is related to the concepts of *broken symmetry, *complexity, nonlinearity, and *non-equilibrium statistical mechanics. Many systems that undergo transitions to self-organization can also undergo transitions to *chaos.

self-pollination *See* POLLINATION.

self-sterility The condition found in many hermaphrodite organisms in which male and female reproductive cells produced by the same individual will not fuse to form a zygote, or if they do, the zygote is unable to develop into an embryo. In plants this is usually termed **self-incompatibility** (*see* INCOMPATIBILITY).

Seliwanoff's test A biochemical test to identify the presence of ketonic sugars, such as fructose, in solution. It was devised by the Russian chemist F. F. Seliwanoff. A few drops of the reagent, consisting of resorcinol crystals dissolved in equal amounts of water and hydrochloric acid, are heated with the test solution and the formation of a red precipitate indicates a positive result.

semaphorin One of a class of proteins that act as guidance molecules during the development of nerve cells, immune cells, blood vessels, bone, and other tissues. There are several classes, some occurring in invertebrates and others in vertebrates; some semaphorins are secreted by cells, whereas others remain bound to the plasma membrane. However, all semaphorin molecules have a characteristic region called a sema domain. Class 3 semaphorins act as short-range cues to guide the *growth cone at the tip of elongating nerve fibres along appropriate pathways through tissue. They may either attract the growth cone or repel it, depending on the particular semaphorin and the type of nerve cell. The action of semaphorins is effected by binding to any of various cell surface receptors.

semen A slightly alkaline fluid (pH 7.2–7.6) containing sperm and various secretions that is produced by a male mammal during copulation and is introduced into the body of the female by *ejaculation. Spermatozoa are produced by the *testes and the secretions by the *prostate gland, *seminal vesicles, and *Cowper's glands. Semen also contains enzymes that activate the sperm after ejaculation.

semicarbazones Organic compounds containing the unsaturated group $=C:N.NH.CO.NH_2$. They are formed when aldehydes or ketones react with a semicarbazide ($H_2N.NH.CO.NH_2$). Semicarbazones are crystalline compounds with relatively high melting points. They are used to identify aldehydes and ketones in quantitative analysis: the semicarbazone derivative is made and identified by its melting point. Semicarbazones are also used in separating ketones from reaction mixtures: the derivative is crystallized out and hydrolysed to give the ketone.

SEE WEB LINKS

- Information about IUPAC nomenclature

semicircular canals The sense organ in vertebrates that is concerned with the maintenance of physical equilibrium (sense of balance). It occurs in the *inner ear and consists of three looped canals set at right angles to each other and attached to the *utriculus. The canals contain a fluid (**endolymph**) that flows in response to movements of the head and body. A swelling (*ampulla) at one attachment point of each canal contains sensory cells that respond to movement of the endolymph in any of the three planes. These sensory cells initiate nervous impulses to the brain.

semiclassical approximation An approximation technique used to calculate quantities in quantum mechanics. This technique is called the semiclassical approximation because the *wave function is written as an asymptotic series with ascending powers of the Planck constant h, with the first term being purely classical. The semiclassical approximation is also known as the **Wentzel– Kramers–Brillouin** (**WKB**) **approximation**, named after its inventors Gregor Wentzel (1898–1978), Hendrik Anton Kramers (1894– 1952), and Léon Brillouin (1889–1969), who invented it independently in 1926. The semiclassical approximation is particularly successful for calculations in-

volving the *tunnel effect, such as *field emission and radioactive decay producing *alpha particles.

semiconductor A crystalline solid with an electrical conductivity (typically 10^5–10^{-7} siemens per metre) intermediate between that of a conductor (up to 10^9 S m^{-1}) and an insulator (as low as 10^{-15} S m^{-1}). Semiconducting properties are a feature of *metalloid elements, such as silicon and germanium. As the atoms in a crystalline solid are close together, the orbitals of their electrons overlap and their individual *energy levels are spread out into *energy bands. Conduction occurs in semiconductors as the result of a net movement, under the influence of an electric field, of electrons in the conduction band and empty states, called **holes**, in the valence band. A hole behaves as if it was an electron with a positive charge. Electrons and holes are known as the **charge carriers** in a semiconductor. The type of charge carrier that predominates in a particular region or material is called the **majority carrier** and that with the lower concentration is the **minority carrier**. An **intrinsic semiconductor** is one in which the concentration of charge carriers is a characteristic of the material itself; electrons jump to the conduction band from the valence band as a result of thermal excitation, each electron that makes the jump leaving behind a hole in the valence band. Therefore, in an intrinsic semiconductor the charge carriers are equally divided between electrons and holes. In **extrinsic semiconductors** the type of conduction that predominates depends on the number and valence of the impurity atoms present. Germanium and silicon atoms have a valence of four. If impurity atoms with a valence of five, such as arsenic, antimony, or phosphorus, are added to the lattice, there will be an extra electron per atom available for conduction, i.e. one that is not required to pair with the four valence electrons of the germanium or silicon. Thus extrinsic semiconductors doped with atoms of valence five give rise to crystals with electrons as majority carriers, the so-called **n-type conductors**. Similarly, if the impurity atoms have a valence of three, such as boron, aluminium, indium, or gallium, one hole per atom is created by an unsatisfied bond. The majority carriers are therefore holes, i.e. **p-type conductors**.

Semiconductor devices have virtually replaced thermionic devices, because they are several orders of magnitude smaller, cheaper in energy consumption, and more reliable. The basic structure for electronic semiconductor devices is the **semiconductor diode** (*see also* TRANSISTOR). This consists of a silicon crystal doped in such a way that half is *p*-type and half is *n*-type. At the junction between the two halves there is a depletion layer in which electrons from the *n*-type have filled holes from the *p*-type. This sets up a potential barrier, which tends to keep the remaining electrons in the *n*-region and the remaining holes in the *p*-region. However, if the *p*-region is biased with a positive potential, the height of the barrier is reduced; the diode is said to be forward biased, because the majority holes in the *p*-region can then flow to the *n*-region and majority electrons in the *n*-region flow to the *p*-region. When forward biased there is a good current flow across the barrier. On the other hand if the *p*-region is negatively biased, the height of the potential barrier is increased and there is only a small leakage current of minority electrons from the *p*-region able to flow to the *n*-region. Thus the *p*–*n* junction acts as an efficient rectifier, for which purpose it is widely used.

semiconductor diode *See* DIODE; SEMICONDUCTOR.

semiconservative replication The generally accepted method of *DNA replication, in which the two strands of the DNA helix separate and free nucleotides pair with the exposed bases on the single chains to form two new DNA molecules, each containing one original and one newly synthesized strand of DNA.

semimetal *See* METALLOID.

seminal receptacle semimetal *See* SPERMATHECA.

seminal vesicle **1.** A pouch or sac in many male invertebrates and lower vertebrates that is used for storing sperm. **2.** One of a pair of glands in male mammals that secrete a liquid component of *semen into the vas deferens. This secretion is alkaline, which neutralizes the acidic conditions in the female genital tract, and contains fructose, used by the sperm as a source of energy.

seminiferous tubules *See* TESTIS.

semipermeable membrane A membrane that is permeable to molecules of the solvent but not the solute in *osmosis. Semi-

permeable membranes can be made by supporting a film of material (e.g. cellulose) on a wire gauze or porous pot.

semipolar bond *See* CHEMICAL BOND.

Semtex A nitrogen-based stable odourless plastic *explosive.

senescence The changes that occur in an organism (or a part of an organism) between maturity and death, i.e. ageing. Characteristically there is a deterioration in functioning as the cells become less efficient in maintaining and replacing vital cell components. In animals this results in a decline in physical ability and, in humans, there is also often a reduction in mental ability. Not all the parts of the body necessarily become senescent at the same time or age at the same rate. For example, in deciduous trees the shedding of senescent leaves in the autumn is a normal physiological process.

sense organ A part of the body of an animal that contains or consists of a concentration of *receptors that are sensitive to specific stimuli (e.g. sound, light, pressure, heat). Stimulation of these receptors initiates the transmission of nervous impulses to the brain, where sensory information is analysed and interpreted. Examples of sense organs are the *eye, *ear, *nose, and *taste bud.

senses The faculties that enable animals to perceive information about their external environment or about the state of their bodies in relation to this environment (*see* SENSE ORGAN; VISION; HEARING; BALANCE; OLFACTION (SMELL); TASTE; TOUCH). Specific *receptors are sensitive to pain, temperature, chemicals, etc.

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sensitivity (irritability) One of the fundamental properties of all organisms: the capacity to detect, interpret, and respond to changes in the environment (e.g. the stimuli of light, touch, chemicals, etc.). Multicellular animals have specialized *sense organs and *effector organs for this purpose; in unicellular organisms, which lack a nervous system, the reception of, and response to, a stimulus occur in the same cell.

sensitization **1.** (of a cell) The alteration of the integrity of a plasma membrane resulting from the reaction of specific *antibodies with *antigens on the surface of the cell. In the presence of *complement, the cell ruptures. **2.** (of an individual) Initial exposure to a specific antigen such that re-exposure to the same antigen causes a severe immune response (*see* ANAPHYLAXIS).

sensory cell *See* RECEPTOR.

sensory neuron A nerve cell (*see* NEURON) that transmits information about changes in the internal and external environment to the central nervous system. Sensory neurons are of two types. **Somatic sensory neurons** occur in peripheral nerves in the skin, skeletal muscle, joints, and bones. **Visceral sensory neurons** are located in sympathetic and parasympathetic nerves in the heart, lungs, and other organs.

sepal One of the parts of a flower making up the *calyx. Sepals are considered to be modified leaves with a simpler structure. They are usually green and often hairy but in some plants, e.g. monk's hood, they may be brightly coloured.

septivalent (heptavalent) Having a valency of seven.

septum Any dividing wall in a plant or animal. Examples are the septa that separate the chambers of the heart.

sequence analysis The process of characterizing sequences of biomolecules, particularly the nucleotides of nucleic acids (DNA or RNA) or the amino acids of proteins. Once the order of nucleotides of, say, a genome fragment has been established by *DNA sequencing, the sequence data can be analysed using computer software. The unknown sequence is compared with existing sequence data held on any of numerous databases. Likely homology is revealed by its degree of *alignment with other DNA sequences, which will provide clues about its evolutionary relationships with other biomolecules (*see* PHYLOGENOMICS). *See also* BIOINFORMATICS.

sequence database A database containing the sequences of biomolecules, which may be the sequences of nucleotides for nucleic acids (DNA or RNA) or of amino acids for proteins. *See* INTERNATIONAL NUCLEOTIDE SEQUENCE DATABASE COLLABORATION.

sequestration The process of forming coordination complexes of an ion in solution. Sequestration often involves the formation of chelate complexes, and is used to prevent the chemical effect of an ion without removing it from the solution (e.g. the sequestration of Ca^{2+} ions in water softening). It is also a way of supplying ions in a protected form,

e.g. sequestered iron solutions for plants in regions having alkaline soil.

sere A complete *succession of plant communities, which results in the climax community. A sere is composed of a series of different plant communities that change with time. These communities are known as **seral stages** or **seral communities**.

series A sequence of terms each of which can be written in a form that is an algebraic function of its position in the series. For example, the *exponential series $1 + x + x^2/2! + x^3/3!$ has an nth term $x^n/n!$. The sum of all the terms from $n = 0$ to $n = \infty$ is written:

$$\sum_{n=0}^{\infty} x^n/n!$$

This series has an infinite number of terms and is therefore called an **infinite series**. A **finite series** has a fixed number of terms. *See also* ASYMPTOTIC SERIES; CONVERGENT SERIES.

series circuits Circuits in which the circuit elements are arranged in sequence so that the same current flows through each of them in turn. For resistances in series, the total resistance is the sum of the individual resistances. For capacitors in series, the total capacitance, C, is given by $1/C = 1/C_1 + 1/C_2 + 1/C_3 \ldots$.

series-wound machine *See* SHUNT.

serine *See* AMINO ACID.

seroconversion The stage in an immune response when antibodies to the infecting agent are first detected in the bloodstream. For example, people infected with HIV typically seroconvert about 4–6 weeks following the initial infection, when antibodies against viral proteins are first produced.

serology The laboratory study of blood serum and its constituents, particularly *antibodies and *complement, which play a part in the *immune response.

serotonin (5-hydroxytryptamine; 5-HT) A compound, synthesized from the amino acid tryptophan, that (among other actions) affects the diameter of blood vessels and also functions as a *neurotransmitter. Serotonin plays a key role in arousal, mood, aggression, and the sleep–wake cycle; reduced levels are associated with various disorders, including depression and migraine. Several types of antidepressant drugs act by enhancing serotonin levels in the brain, including the **SSRIs** (selective serotonin reuptake inhibitors), which slow the rate of uptake of serotonin by neurons.

serous membrane (serosa) A tissue consisting of a layer of *mesothelium attached to a surface by a thin layer of connective tissue. Serous membrane lines body cavities that do not open to the exterior; the *peritoneum, *pleura, and serous *pericardium are examples.

serpentine Any of a group of hydrous magnesium silicate minerals with the general composition $Mg_3Si_2O_5(OH)_4$. Serpentine is monoclinic and occurs in two main forms: **chrysotile**, which is fibrous and the chief source of *asbestos; and **antigorite**, which occurs as platy masses. It is generally green or white with a mottled appearance, sometimes resembling a snakeskin – hence the name. It is formed through the metamorphic alteration of ultrabasic rocks rich in olivine, pyroxene, and amphibole. **Serpentinite** is a rock consisting mainly of serpentine; it is used as an ornamental stone.

Sertoli cells (sustentacular cells) Cells that line the seminiferous tubules in the *testis, named after the Italian histologist Enrico Sertoli (1842–1910). Sertoli cells protect the spermatids (developing germ cells) and convey nutrients to both the developing and mature spermatozoa. They also produce a hormone, **inhibin**, which can inhibit *follicle-stimulating hormone and thereby regulate production of spermatozoa.

serum *See* BLOOD SERUM.

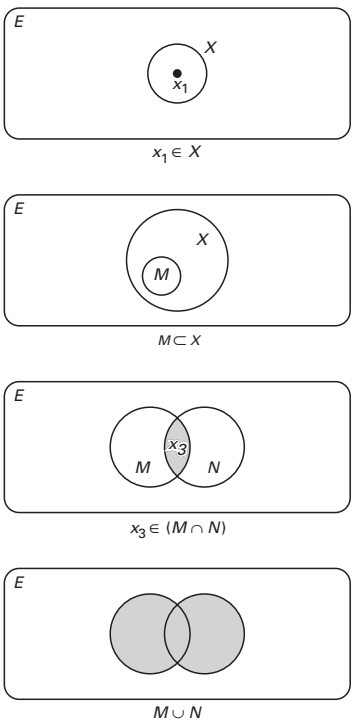
sesqui- Prefix indicating a ratio of 2:3 in a chemical compound. For example, a sesquioxide has the formula M_2O_3.

sesquiterpene *See* TERPENES.

sessile **1.** Describing animals that live permanently attached to a surface, i.e. sedentary animals. Many marine animals, e.g. sea anemones and limpets, are sessile. **2.** Describing any organ that does not possess a stalk where one might be expected. For example, the leaves of the oak (*Quercus robur*) are attached directly to the twigs.

seta **1.** A bristle or hair in many invertebrates. Setae are produced by the epidermis and consist either of a hollow projection of cuticle containing all or part of an epidermal cell (as in insects) or are composed of chitin (as in the *chaetae of annelid worms). **2.** *See* SPOROGONIUM.

sets Collections of objects or elements that have at least one characteristic in common. For example, the set X may consist of all the elements x_1, x_2, x_3, etc. This is written $\{x_1, x_2, x_3, \ldots\} = X$. A specific element in a set is characterized by $x_1 \in X$, meaning x_1 is a member of set X. A **subset** of set X, say M, would be written $M \subset X$, i.e. M is contained in X. If x_3 is a member of both subsets M and N, then $x_3 \in (M \cap N)$, i.e. x_3 belongs to the **intersection** of M and N. $M \cup N$ means the **union** of M and N. For example, if M consists of {1, 4, 5, 8} and N consists of {2, 3, 4, 5} then $M \cap N =$ {4, 5} and $M \cup N =$ {1, 2, 3, 4, 5, 8}. In the diagram, the rectangle represents the universal set E, circles represent sets or subsets. These diagrams are called **Venn diagrams**, after John Venn (1834–1923), who invented them.



Sets.

sewage Waste matter from industrial and domestic sources that is dissolved or suspended in water. Raw (untreated) sewage is a pollutant. It has a high content of organic matter (notably faeces and nitrogenous waste) and therefore provides a rich source of food for many decomposers (bacteria, fungi) and *detritivores, some of which are pathogenic to humans. The release of raw (untreated) sewage into a river causes eutrophication (*see* EUTROPHIC); there is a sudden increase in the *biochemical oxygen demand (BOD), as the organisms that feed on sewage proliferate and use up the available dissolved oxygen in the river. Oxygen-sensitive organisms, such as fish, will die. Certain organisms can proliferate in particular concentrations of sewage, depending on their tolerance, and can be used as markers of the extent to which a river is polluted by sewage. For example, *Tubifex* worms are able to tolerate high concentrations of sewage.

Sewage can be treated before release. This involves a number of stages, including filtration, sedimentation, and microbial degradation (notably by *methanogens). When most of the solid waste has been removed, the remaining liquid (**effluent**) is discharged into rivers, etc. During sedimentation, particulate organic matter accumulates at the bottom of large tanks. This material, known as **sludge**, is periodically removed, further decomposed by microorganisms, and then sold as fertilizer or dumped.

sex chromosome A chromosome that operates in the sex-determining mechanism of a species. In many animals there are two kinds of sex chromosomes; for example, in mammals there is a large **X chromosome** and a much smaller **Y chromosome**. A combination of two X chromosomes occurs in a female while one X and one Y chromosome is found in males. Sex chromosomes carry genes governing the development of sex organs and secondary sexual characteristics (*see* TESTIS-DETERMINING FACTOR). They also carry other genes unrelated to sex (*see* SEX LINKAGE). *See also* SEX DETERMINATION.

sex determination The method by which the distinction between males and females is established in a species. It is usually under genetic control. Equal numbers of males and females are produced when sex is determined by *sex chromosomes or by a contrasting pair of alleles. In some species (e.g. bees) females develop from fertilized

eggs and males from unfertilized eggs. This does not produce equal numbers. Environmental factors (e.g. temperature) can also play a role in determining the sex of developing individuals.

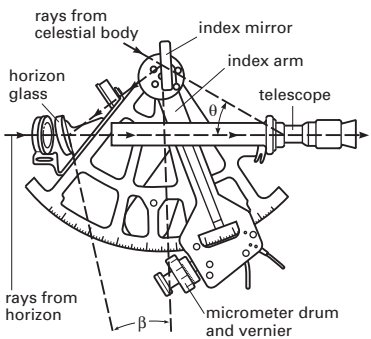
sex hormones Steroid hormones that control sexual development. The most important are the *androgens and *oestrogens.

sexivalent (hexavalent) Having a valency of six.

sex linkage The tendency for certain inherited characteristics to occur far more frequently in one sex than the other. For example, red–green colour blindness and *haemophilia affect men more often than women. This is because the genes governing normal colour vision and blood clotting occur on the X *sex chromosome. Women have two X chromosomes. If one carries an abnormal allele it is likely that its effects will be masked by a normal allele on the other X chromosome. However, men only have one X chromosome and any abnormal alleles therefore will not be masked. *See also* CARRIER.

sex ratio The ratio of the number of females to the number of males in a *population. Because the mortality rates in the two sexes may be different, the sex ratios in different age classes may differ.

sextant An instrument used in navigation to measure the altitude of a celestial body. Originally it had an arc of 60° (one sixth of a circle, hence its name) but modern instruments have various angles. The sextant uses two mirrors: the horizon glass, in which only the lower half is silvered, and the index mirror, which can be rotated about an axis perpendicular to the plane of the instrument (see illustration). An arm attached to the index glass sweeps round the calibrated arc, from which angles are read. The instrument is aimed at the horizon and the index mirror rotated until the celestial object can also be seen through the telescope. After careful adjustment to make the image of the celestial body just touch the horizon, the angle is read off the graduated scale.



Sextant.

sexual intercourse (coitus; copulation; mating) The process by which spermatozoa from a male are deposited in the body of a female during *sexual reproduction. In mammals the penis of the male becomes erect and stiff as its tissues become filled with blood, enabling it to be inserted into the vagina of the female. Thrusting movements of the penis result in *ejaculation, in which *semen, containing spermatozoa, is deposited in the vagina.

sexually transmitted disease (STD) Any disease that is passed from one individual to another during sexual intercourse or other types of sexual activity. These diseases have been traditionally referred to as **venereal diseases**. They include gonorrhoea, caused by the bacterium *Neisseria gonorrhoeae*; syphilis, due to infection by the bacterium *Treponema pallidum*; genital herpes, which is caused by a herpesvirus; and *AIDS, resulting from infection with *HIV, a retrovirus. The transmission of sexually transmitted diseases can be reduced by limiting the number of sexual partners and by the use of condoms (*see* BIRTH CONTROL), which reduces the risk of contact with body fluids that harbour the microorganisms that cause these diseases.

sexual reproduction A form of reproduction that involves the fusion of two reproductive cells (*gametes) in the process of *fertilization. Normally, especially in animals, it requires two parents, one male and the other female. However, most plants bear both male and female reproductive organs and self-fertilization may occur, as it does in hermaphrodite animals. Gametes are formed by *meiosis, a special kind of cell division in the parent reproductive organs that both reassorts the genetic material and halves the chromosome number. Meiosis thus ensures genetic variability in the gametes and therefore in the offspring result-

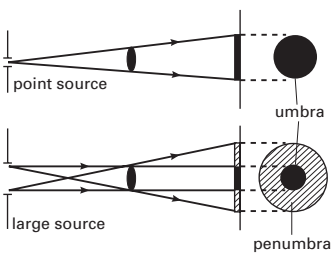
ing from their subsequent fusion. Sexual reproduction, unlike *asexual reproduction, therefore generates variability within a species. However, it depends on there being reliable means of bringing together male and female gametes, and many elaborate mechanisms have evolved to ensure this.

sexual selection The means by which it is assumed that certain *secondary sexual characteristics, particularly of male animals, have evolved. Females presumably choose to mate with the male that gives the best courtship display and therefore has the brightest coloration, etc.: these features would be inherited by its male offspring and would thus tend to become exaggerated down the generations.

Seyfert galaxy A type of galaxy, typically a spiral or barred spiral, with an active *galactic nucleus. The nucleus is brighter than the spiral arms, too bright to derive its radiation only from stars. It is thought that there is probably a low-power *quasar-like object at the centre or possibly an extremely massive black hole. It is named after the American astronomer Carl Keenan Seyfert (1911–60), who identified this category in 1943.

SGML Standard generalized mark-up language: an international standard metalanguage (ISO 8859) used for defining the syntax of textual mark-up languages. This enables both sender and receiver of the text to identify its structure (e.g. title, author, header, paragraph, etc.). *See also* XML, DTD, HTML.

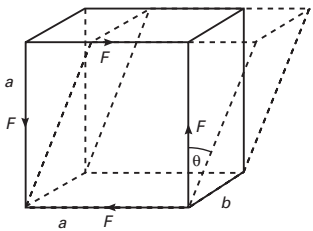
shadow An area of darkness formed on a surface when an object intercepts the light falling on the surface from a source. In the case of a point source the shadow has a sharply defined outline. If the source has an appreciable size the shadow has two distinct regions; one of full-shadow, called the **umbra**, the other of half-shadow, called the **penumbra** (see illustration).



Shadow.

shale A form of *clay that occurs in thin layers. Shales are very common *sedimentary rocks. *See also* OIL SHALE.

shearing force A force that acts parallel to a plane rather than perpendicularly, as with a tensile or compressive force. A **shear stress** requires a combination of four forces acting over (most simply) four sides of a plane and produces two equal and opposite couples. It is measured as the ratio of one shearing force to the area over which it acts, $F/(ab)$ in the diagram. The shear strain is the angular deformation, θ, in circular measure. The **shear modulus** is the ratio of the shear stress to the shear strain (*see also* ELASTIC MODULUS).



Shearing force.

shear modulus *See* ELASTIC MODULUS; SHEARING FORCE.

shell *See* ATOM.

shell model **1.** *See* ATOM. **2.** A model of the atomic nucleus in which nucleons are assumed to move under the influence of a central field in shells that are analogous to atomic electron shells. The model provides a good explanation of the stability of nuclei that have *magic numbers and is successful in predicting other properties of many nuclei.

sherardizing The process of coating iron or steel with a zinc corrosion-resistant layer by heating the iron or steel in contact with zinc dust to a temperature slightly below the melting point of zinc. At a temperature of about 371°C the two metals amalgamate to form internal layers of zinc–iron alloys and an external layer of pure zinc. The process

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was invented by Sherard Cowper-Coles (1867–1935).

Sherrington, Sir Charles Scott (1857–1952) British physiologist, who became professor of physiology at Oxford University in 1913. After early work on antitoxins he began studying human reflex reactions. Like *Pavlov in Russia, he discovered conditioned reflexes. His subsequent research concerned the functioning of neurons, for which he shared the 1932 Nobel Prize for physiology or medicine with Sir Edgar *Adrian.

shielding **1.** A barrier surrounding a region to exclude it from the influence of an energy field. For example, to protect a region from an electric field an earthed barrier is required; to protect it from a magnetic field a shield of high magnetic permeability is needed. **2.** A barrier used to surround a source of harmful or unwanted radiations. For example, the core of a *nuclear reactor is surrounded by a cement or lead shield to absorb neutrons and other dangerous radiation. **3.** (in atoms) the barrier provided by inner electron shells to the influence of nuclear charge on outer electrons. Shielding has an effect on ionic radius, as in the *lanthanoids.

shivering *See* THERMOGENESIS.

SHM *See* SIMPLE HARMONIC MOTION.

Shockley, William *See* BARDEEN, JOHN.

shock wave A very narrow region of high pressure and temperature formed in a fluid when the fluid flows supersonically over a stationary object or a projectile flying supersonically passes through a stationary fluid. A shock wave may also be generated by violent disturbances in a fluid, such as a lightning stroke or a bomb blast.

shoot The aerial part of a vascular plant. It develops from the *plumule and consists of a stem supporting leaves, buds, and flowers.

Shor's algorithm An algorithm in quantum computing that enables large numbers to be factorized into prime numbers in a way which is much quicker than using traditional computers. This algorithm, which was proposed by the American computer scientist Peter Shor (1959–) in 1994, has major implications for the security of Internet information transfer.

short-day plant A plant in which flowering can be induced or enhanced by short days, usually of less than 12 hours of daylight. Examples are strawberry and chrysanthemum. *See* PHOTOPERIODISM. *Compare* DAY-NEUTRAL PLANT; LONG-DAY PLANT.

short period *See* PERIODIC TABLE.

short-sightedness *See* MYOPIA.

shoulder girdle *See* PECTORAL GIRDLE.

shower *See* COSMIC RADIATION.

shunt An electrical resistor or other element connected in parallel with some other circuit or device, to take part of the current passing through it. For example, a shunt is used across the terminals of a galvanometer to increase the current that can pass through the system. A **shunt-wound** electric generator or motor is one in which the field winding is in parallel with the armature circuit. In a **series-wound** electrical machine the field coils and the armature circuit are in series.

sial The rocks that form the earth's continental crust. These are granite rock types rich in *si*lica (SiO_2) and *al*uminium (Al), hence the name. *Compare* SIMA.

siblings Individuals that have both parents in common.

sickle-cell disease *See* POLYMORPHISM.

sideband The band of frequencies above or below the frequency of the carrier wave in a telecommunications system within which the frequency components of the wave produced by *modulation fall. For example, if a carrier wave of frequency f is modulated by a signal of frequency x, the **upper sideband** will have a frequency $f + x$ and the **lower sideband** a frequency $f - x$.

side chain *See* CHAIN.

side reaction A chemical reaction that occurs at the same time as a main reaction but to a lesser extent, thus leading to other products mixed with the main products.

sidereal day *See* DAY.

sidereal period The time taken for a planet or satellite to complete one revolution of its orbit measured with reference to the background of the stars. *See also* DAY; SYNODIC PERIOD; YEAR.

siderite A brown or grey-green mineral form of iron(II) carbonate, $FeCO_3$, often with

magnesium and manganese substituting for the iron. It occurs in sedimentary deposits or in hydrothermal veins and is an important iron ore. It is found in England, Greenland, Spain, N Africa, and the USA.

siemens Symbol S. The SI unit of electrical conductance equal to the conductance of a circuit or element that has a resistance of 1 ohm. 1 S = 10^{-1} Ω. The unit was formerly called the mho or reciprocal ohm. It is named after Ernst Werner von Siemens (1816–92).

sieve element A type of plant cell occurring within the *phloem. Sieve elements combine to form a series of tubes (**sieve tubes**) connecting the leaves, shoots, and roots in a fine network. Food materials are transported from one element to another via perforations termed **sieve areas** or **sieve plates**. Sieve elements contain little cytoplasm and no nucleus. Their metabolic activities are supplemented by *companion cells in angiosperms and by albuminous cells in gymnosperms.

sievert The SI unit of dose equivalent (*see* RADIATION UNITS). It is named after the Swedish physicist Rolf Sievert (1896–1966).

sieve tube A tube within the *phloem tissue of a plant, composed of joined *sieve elements.

sigma bond *See* ORBITAL.

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

sigma particle A type of spin ½ *baryon. There are three types of sigma particles, denoted Σ^-, Σ^0, Σ^+, for the negatively charged, electrically neutral, and positively charged forms, respectively. The quark content of the sigma particles are Σ^- (dds), Σ^0 (dus), Σ^+ (uus), where d, u, and s denote down, up, and strange, respectively. The masses of the sigma particles are 1189.36 MeV (Σ^+), 1192.46 MeV (Σ^0), 1197.34 MeV (Σ^-); their average lifetimes are 0.8×10^{-10} s (Σ^+), 5.8×10^{-20} s (Σ^0), and 1.5×10^{-10} s (Σ^-).

sigmatropic reaction A type of rearrangement in which a sigma bond is formed between two nonlinked atoms at the same time as an existing sigma bond is broken.

signal The variable parameter that contains information and by which information is transmitted in an electronic system or circuit. The signal is often a voltage source in which the amplitude, frequency, and waveform can be varied.

signal molecule A molecule of a hormone, neurotransmitter, growth factor, or other chemical that binds specifically with a cell-surface *receptor and thereby initiates a sequence of activities that triggers a response inside the cell. *See also* SECOND MESSENGER; G PROTEIN.

signature of space–time The division of space–time into space dimensions and time dimensions. It has been claimed that the combination of duality and *supersymmetry can explain why there only appears to be one time dimension, with there being duality relations between theories with one time dimension and any other possible theories that can have more than one time dimension.

sign convention A set of rules determined by convention for giving plus or minus signs to distances in the formulae involving lenses and mirrors. The *real-is-positive is the convention now usually adopted. The **New Cartesian convention** is now not widely used. In this convention distances to the right of the pole are treated as positive, those to the left as negative. This system has the advantage of conforming to the sign convention used with Cartesian coordinates in mathematics and is therefore preferred by some for the more complicated calculations.

significant figures The number of digits used in a number to specify its accuracy. The number 6.532 is a value taken to be accurate to four significant figures. The number 7.3×10^3 is accurate only to three significant figures. Similarly 0.0732 is also only accurate to three significant figures. In these cases the zeros only indicate the order of magnitude of the number, whereas 7.065 is accurate to four significant figures as the zero in this case is significant in expressing the value of the number.

sign stimulus (releaser) The essential feature of a stimulus, which is necessary to elicit a response. For example, a red belly (characteristic of courting male sticklebacks) is the sign stimulus necessary to provoke an attack from a rival male; even a very crude model fish is attacked if it has a red undersurface.

silane (silicane) **1.** A colourless gas, SiH_4,

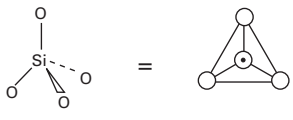
which is insoluble in water; d. 1.44 g dm^{-3}; r.d. 0.68 (liquid); m.p. –185°C; b.p. –112°C. Silane is produced by reduction of silicon with lithium tetrahydridoaluminate(III). It is also formed by the reaction of magnesium silicide (Mg_2Si) with acids, although other silicon hydrides are also produced at the same time. Silane itself is stable in the absence of air but is spontaneously flammable, even at low temperatures. It is a reducing agent and has been used for the removal of corrosion in inaccessible plants (e.g. pipes in nuclear reactors). **2. (silicon hydride)** Any of a class of compounds of silicon and hydrogen. They have the general formula Si_nH_{2n+2}. The first three in the series are silane itself (SiH_4), **disilane** (Si_2H_6), and **trisilane** (Si_3H_8). The compounds are analogous to the alkanes but are much less stable and only the lower members of the series can be prepared in any quantity (up to Si_6H_{14}). No silicon hydrides containing double or triple bonds exist (i.e. there are no analogues of the alkenes and alkynes).

silica *See* SILICON(IV) OXIDE.

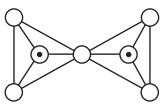
silica gel A rigid gel made by coagulating a sol of sodium silicate and heating to drive off water. It is used as a support for catalysts and also as a drying agent because it readily absorbs moisture from the air. The gel itself is colourless but, when used in desiccators, etc., a blue cobalt salt is added. As moisture is taken up, the salt turns pink, indicating that the gel needs to be regenerated (by heating).

silicane *See* SILANE.

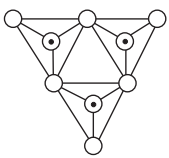
silicate Any of a group of substances containing negative ions composed of silicon and oxygen. The silicates are a very extensive group and natural silicates form the major component of most rocks (*see* SILICATE MINERALS). The basic structural unit is the tetrahedral SiO_4 group. This may occur as a simple discrete SiO_4^{4-} anion as in the **orthosilicates**, e.g. **phenacite** (Be_2SiO_4) and **willemite** (Zn_2SiO_4). Many larger silicate species are also found (see illustration). These are composed of SiO_4 tetrahedra linked by sharing oxygen atoms as in the **pyrosilicates**, $Si_2O_7^{6-}$, e.g. $Sc_2Si_2O_7$. The linking can extend to such forms as bentonite, $BaTiSi_3O_9$, or alternatively infinite chain anions, which are single strand (*pyroxenes) or double strand (*amphiboles). Spodumene, $LiAl(SiO_3)_2$, is a pyroxene and the asbestos minerals are amphiboles. Large two-dimensional sheets are also possible, as in the various *micas (see illustration overleaf), and the linking can extend to full three-dimensional framework structures, often with substituted trivalent atoms in the lattice. The *zeolites are examples of this.



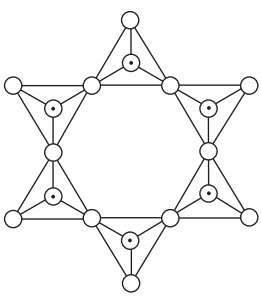
SiO_4^{4-} as in Be_2SiO_4 (phenacite)



$Si_2O_5^{2-}$ as in $Sc_2Si_2O_7$ (thortveitite)



$Si_3O_9^{6-}$ as in $BaTiSi_3O_9$ (bentonite)

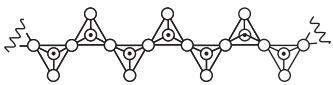


$Si_6O_{18}^{12-}$ as in $Be_3Al_2Si_6O_{18}$ (beryl)

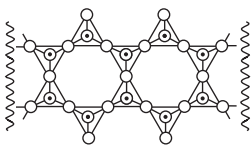
Silicate. Structure of some discrete silicate ions.

silicate minerals A group of rock-forming minerals that make up the bulk of the earth's outer crust (about 90%) and constitute one-third of all minerals. All silicate minerals are

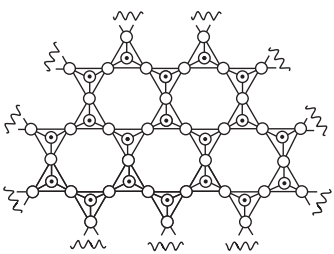
based on a fundamental structural unit – the SiO_4 tetrahedron (*see* SILICATE). They consist of a metal (e.g. calcium, magnesium, aluminium) combined with silicon and oxygen. The silicate minerals are classified on a structural basis according to how the tetrahedra are linked together. The six groups are: nesosilicates (e.g. olivine and *garnet); sorosilicates (e.g. hemimorphite); cyclosilicates (e.g. axinite, *beryl, and *tourmaline); inosilicates (e.g. *amphiboles and *pyroxenes); phyllosilicates (e.g. *micas, *clay minerals, and *talc); and tektosilicates (e.g. *feldspars and *feldspathoids). Many silicate minerals are of economic importance.



single chain : pyroxenes



double chain : amphiboles



sheet : micas

Silicate. Structure of some polymeric silicate ions.

silicide A compound of silicon with a more electropositive element. The silicides are structurally similar to the interstitial carbides but the range encountered is more diverse. They react with mineral acids to form a range of *silanes.

silicon Symbol Si. A metalloid element belonging to *group 14 (formerly IVB) of the periodic table; a.n. 14; r.a.m. 28.086; r.d. 2.33; m.p. 1410°C; b.p. 2355°C. Silicon is the second most abundant element in the earth's crust (25.7% by weight) occurring in various forms of silicon(IV) oxide (e.g. *quartz) and in *silicate minerals. The element is extracted by reducing the oxide with carbon in an electric furnace and is used extensively for its semiconductor properties. It has a diamond-like crystal structure; an amorphous form also exists. Chemically, silicon is less reactive than carbon. The element combines with oxygen at red heat and is also dissolved by molten alkali. There is a large number of organosilicon compounds (e.g. *siloxanes) although silicon does not form the range of silicon–hydrogen compounds and derivatives that carbon does (*see* SILANE). The element was identified by Antoine Lavoisier in 1787 and first isolated in 1823 by Jöns Berzelius.

SEE WEB LINKS

- Information from the WebElements site

silicon carbide (carborundum) A black solid compound, SiC, insoluble in water and soluble in molten alkali; r.d. 3.217; m.p. *c.* 2700°C. Silicon carbide is made by heating silicon(IV) oxide with carbon in an electric furnace (depending on the grade required sand and coke may be used). It is extremely hard and is widely used as an abrasive. The solid exists in both zinc blende and wurtzite structures. There is a clear form known as moissanite, used as a diamond substitute.

silicon chip A single crystal of a semiconducting silicon material, typically having millimetre dimensions, fabricated in such a way that it can perform a large number of independent electronic functions (*see* INTEGRATED CIRCUIT).

silicon dioxide *See* SILICON(IV) OXIDE.

silicones Polymeric compounds containing chains of silicon atoms alternating with oxygen atoms, with the silicon atoms linked to organic groups. A variety of silicone materials exist, including oils, waxes, and rubbers. They tend to be more resistant to temperature and chemical attack than their carbon analogues.

silicon hydride *See* SILANE.

silicon(IV) oxide (silicon dioxide; silica)

A colourless or white vitreous solid, SiO_2, insoluble in water and soluble (by reaction) in hydrofluoric acid and in strong alkali; m.p. 1713°C; b.p. 2230°C. The following forms occur naturally: **cristobalite** (cubic or tetragonal crystals; r.d. 2.32); **tridymite** (rhombic; r.d. 2.26); *quartz (hexagonal; r.d. 2.63–2.66); **lechatelierite** (r.d. 2.19). Quartz has two modifications: α-quartz below 575°C and β-quartz above 575°C; above 870°C β-quartz is slowly transformed to tridymite and above 1470°C this is slowly converted to cristobalite. Various forms of silicon(IV) oxide occur widely in the earth's crust; yellow sand for example is quartz with iron(III) oxide impurities and flint is essentially amorphous silica. The gemstones amethyst, opal, and rock crystal are also forms of quartz.

Silica is an important commercial material in the form of **silica brick**, a highly refractive furnace lining, which is also resistant to abrasion and to corrosion. Silicon(IV) oxide is also the basis of both clear and opaque silica glass, which is used on account of its transparency to ultraviolet radiation and its resistance to both thermal and mechanical shock. A certain proportion of silicon(IV) oxide is also used in ordinary glass and in some glazes and enamels. It also finds many applications as a drying agent in the form of *silica gel.

silicula A type of *capsule formed from a bicarpellary ovary. It is longitudinally flattened and divided lengthwise into two cavities (**loculi**). It is broader than a *siliqua. Examples include the fruits of *Alyssum* and candytuft.

siliqua A type of *capsule formed from a bicarpellary ovary. It resembles a *silicula but is longer than it is broad; an example is the fruit of the wallflower. *See also* LOMENTUM.

siloxanes A group of compounds containing silicon atoms bound to oxygen atoms, with organic groups linked to the silicon atoms, e.g. $R_3SiOSiR_3$, where R is an organic group. *Silicones are polymers of siloxanes.

Silurian A geological period of the Palaeozoic era following the Ordovician period and extending until the beginning of the Devonian period. It began about 444 million years ago and lasted for about 28 million years. The Silurian was named by Roderick Murchison (1792–1871) after an ancient British tribe that inhabited South Wales, where he observed rocks of this period. The majority of Silurian life was marine but during the later part of the period primitive plants began to make their appearance on land. Trilobites and graptolites became less common, brachiopods were numerous and varied, crinoids became common for the first time, and corals also increased. The only known vertebrates during the Silurian were primitive fish; the first jawed fish appeared later in the period. The Caledonian orogeny (mountain-building period) reached its peak towards the end of the Silurian.

silver Symbol Ag. A white lustrous soft metallic *transition element; a.n. 47; r.a.m. 107.87; r.d. 10.5; m.p. 961.93°C; b.p. 2212°C. It occurs as the element and as the minerals argentite (Ag_2S) and horn silver (AgCl). It is also present in ores of lead and copper, and is extracted as a by-product of smelting and refining these metals. The element is used in jewellery, tableware, etc., and silver compounds are used in photography. Chemically, silver is less reactive than copper. A dark silver sulphide forms when silver tarnishes in air because of the presence of sulphur compounds. Silver(I) ionic salts exist (e.g. $AgNO_3$, AgCl) and there are a number of silver(II) complexes.

SEE WEB LINKS

- Information from the WebElements site

silver(I) bromide A yellowish solid compound, AgBr; r.d. 6.5; m.p. 432°C. It can be precipitated from silver(I) nitrate solution by adding a solution containing bromide ions. It dissolves in concentrated ammonia solutions (but, unlike the chloride, does not dissolve in dilute ammonia). The compound is used in photographic emulsions.

silver(I) chloride A white solid compound, AgCl; r.d. 5.6; m.p. 455°C; b.p. 1550°C. It can be precipitated from silver(I) nitrate solution by adding a solution of chloride ions. It dissolves in ammonia solution (due to formation of the complex ion $[Ag(NH_3)_2]^+$). The compound is used in photographic emulsions.

silver(I) iodide A yellow solid compound, AgI; r.d. 6.01; m.p. 558°C; b.p. 1506°C. It can be precipitated from silver(I) nitrate solutions by adding a solution of iodide ions. Unlike the chloride and bromide, it does not dissolve in ammonia solutions.

silver-mirror test *See* TOLLENS REAGENT.

S

silver(I) nitrate A colourless solid, $AgNO_3$; r.d. 4.3; m.p. 212°C. It is an important silver salt because it is water-soluble. It is used in photography. In the laboratory, it is used as a test for chloride, bromide, and iodide ions and in volumetric analysis of chlorides using an absorption indicator (*see* ADSORPTION INDICATOR).

silver(I) oxide A brown slightly water-soluble amorphous powder, Ag_2O; r.d. 7.14. It can be made by adding sodium hydroxide solution to silver(I) nitrate solution. Silver(I) oxide is strongly basic and is also an oxidizing agent. It is used in certain reactions in preparative organic chemistry; for example, moist silver(I) oxide converts haloalkanes into alcohols; dry silver oxide converts haloalkanes into ethers. The compound decomposes to the elements at 300°C and can be reduced by hydrogen to silver. With ozone it gives the oxide AgO (which is diamagnetic and probably $Ag^{I}Ag^{III}O_2$).

sima The rocks that form the earth's oceanic crust and underlie the upper crust. These are basaltic rock types rich in *si*lica (SiO_2) and *ma*gnesium (Mg), hence the name. The sima is denser and more plastic than the *sial that forms the continental crust.

Simmons–Smith reaction A reaction in which a cyclopropane ring is produced from an alkene. It uses the **Simmons–Smith reagent**, which was originally diiodomethane (CH_2I_2) with a Zn/Cu couple. Usually, diethyl zinc is used rather than Zn/Cu. The mechanism involves the formation of $H_2C(I)(ZnI)$ and *carbene transfer from the zinc to the double bond of the alkene.

simple harmonic motion (SHM) A form of periodic motion in which a point or body oscillates along a line about a central point in such a way that it ranges an equal distance on either side of the central point and that its acceleration towards the central point is always proportional to its distance from it. One way of visualizing SHM is to imagine a point rotating around a circle of radius r at a constant angular velocity ω. If the distance from the centre of the circle to the projection of this point on a vertical diameter is y at time t, this projection of the point will move about the centre of the circle with simple harmonic motion. A graph of y against t will be a sine wave, whose equation is $y = r\sin\omega t$ (see diagram). *See also* PENDULUM.

simulation *See* MONTE CARLO SIMULATION.

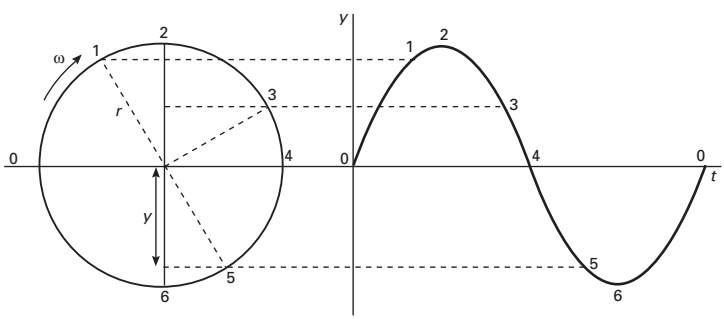
simultaneous equations A set of equations that jointly specify the values of the variables they contain. If the number of variables is equal to the number of equations, each variable has a unique value, i.e. the equations can be solved.

sine *See* TRIGONOMETRIC FUNCTIONS.

sine wave (sinusoidal wave) Any waveform that has an equation in which one variable is proportional to the sine of the other. Such a waveform can be generated by an oscillator that executes *simple harmonic motion.

single bond *See* CHEMICAL BOND.

single-cell protein (SCP) Protein produced by microorganisms, such as bacteria, yeasts, and unicellular algae, that is extracted for use as a component of human and animal foods.



Simple harmonic motion.

single circulation The type of circulatory system that occurs in fishes, in which the blood passes only once through the heart in each complete circuit of the body *Compare* DOUBLE CIRCULATION.

single nucleotide polymorphism (SNP) A variation in the base sequence occurring at any given single position in the genome (for example A instead of C) that is found in more than 1% of the population. It thus differs from a *point mutation only in its greater frequency. SNPs can be found in all parts of the genome, including structural genes, regulatory regions, and noncoding 'junk' DNA. In the human genome overall, about 10 million SNPs are thought to occur, making them exceptionally useful as *molecular markers. Some are known to be linked to disease-causing alleles.

singularity An infinitely dense point located at the centre of a *black hole, where the laws of physics no longer apply. It is surrounded by the event horizon and so cannot be seen (because no light can escape from it).

sinh *See* HYPERBOLIC FUNCTIONS.

sink hole (pot-hole) A saucer-shaped or funnel-shaped depression in a limestone landscape formed when the rock is dissolved away by standing water. If a stream or river flows into the depression and disappears underground, it is called a swallow hole. Some sink holes are formed when the roof of a cave collapses.

sinoatrial node *See* PACEMAKER.

sintered glass Porous glass made by sintering powdered glass, used for filtration of precipitates in gravimetric analysis.

sintering The process of heating and compacting a powdered material at a temperature below its melting point in order to weld the particles together into a single rigid shape. Materials commonly sintered include metals and alloys, glass, and ceramic oxides. Sintered magnetic materials, cooled in a magnetic field, make especially retentive permanent magnets.

sinus A saclike cavity or organ in an animal, e.g. the **sinus venosus** in the heart of lower vertebrates.

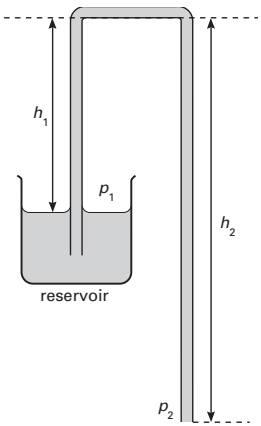
sinusoid A tiny blood vessel or blood-filled space in an organ. Sinusoids replace capillaries in certain organs, notably the liver; they allow more direct contact between the blood and the tissue it is supplying.

sinusoidal oscillator *See* OSCILLATOR.

sinusoidal wave *See* SINE WAVE.

siphon An inverted U-tube with one limb longer than the other. Liquid will be transferred from a reservoir at the base of the shorter limb to the end of the longer limb, provided that the U-tube is filled with liquid (see illustration). The device is useful for emptying an inaccessible container, such as a car's petrol tank.

The pressure (p_1) on the liquid at the base of the short limb (length h_1) is $p - h_1k$, where p is the atmospheric pressure and k is a constant equal to the product of the density of the liquid and the acceleration of free fall. The pressure (p_2) on the liquid at the base of the long limb (length h_2) is $p - h_2k$. Thus for fluid flow to occur through the tube, from short limb to long limb, $p_1 > p_2$, and for this to occur $h_2 > h_1$. Thus if the limbs are of equal length no flow will occur; it will only occur if the limb dipping into the reservoir is shorter than the delivering limb.



Siphon.

Siphonaptera An order of wingless insects comprising the fleas. The body of a flea is laterally compressed and bears numerous backward-directed spines. Fleas live as blood-sucking ectoparasites of mammals and birds, having mouthparts adapted to piercing their host, injecting saliva to prevent clotting, and sucking up the blood. The

long bristly legs can transmit energy stored in the elastic body wall to leap relatively long distances (over 300 mm horizontally). Apart from causing irritation, fleas can transmit disease organisms, most notably bubonic plague bacteria, which can be carried from rats to humans by the rat flea (*Xenopsylla cheopsis*). The whitish wormlike legless larvae feed on organic matter. After two moults the larva spins a cocoon and undergoes metamorphosis into the adult.

Siphunculata (Anoplura) An order of wingless insects comprising the sucking lice: blood-sucking ectoparasites of mammals, with piercing and sucking mouthparts forming a snoutlike proboscis. They constitute an irritating pest to humans and domestic animals and can transmit diseases, including typhoid. The human louse (*Pediculus humanus*) exists in two forms: the head louse (*P. humanus capitis*) and the body louse (*P. humanus corporis*).

s-isomer *See* ABSOLUTE CONFIGURATION.

Sisyphus effect *See* LASER COOLING.

Site of Special Scientific Interest *See* SSSI.

SI units Système International d'Unités: the international system of units now recommended for all scientific purposes. A coherent and rationalized system of units derived from the *m.k.s. units, SI units have now replaced *c.g.s. units and *Imperial units. The system has seven **base units** and two **dimensionless** (formerly called **supplementary**) **units** (see Appendix), all other units being derived from these nine units. There are 18 derived units with special names. Each unit has an agreed symbol (a capital letter or an initial capital letter if it is named after a scientist, otherwise the symbol consists of one or two lower-case letters). Decimal multiples of the units are indicated by a set of prefixes; whenever possible a prefix representing 10 raised to a power that is a multiple of three should be used.

Sivapithecus A genus of extinct primates that lived about 12–18 million years ago. Fossil remains of sivapithecines have been found in India and Pakistan, the Near East, and East Africa. Early discoveries of jaw fragments suggested that they chewed from side to side and had fairly short muzzles, both of which are humanoid features. However, subsequent finds, including a complete jaw, were not hominoid, and sivapithecines are now regarded as ancestral to the Asian great apes (e.g. orang-utans), not the hominids. *See also* DRYOPITHECUS; AUSTRALOPITHECUS.

skeletal electrons *See* WADE'S RULES.

skeletal muscle *See* VOLUNTARY MUSCLE.

skeleton The structure in an animal that provides mechanical support for the body, protection for internal organs, and a framework for anchoring the muscles. The skeleton may be external (*see* EXOSKELETON) or internal (*see* ENDOSKELETON). Both types require *joints to allow locomotion. The skeleton of higher vertebrates consists of a system of *bones (*see* APPENDICULAR SKELETON; AXIAL SKELETON). Soft-bodied animals have a *hydrostatic skeleton.

SEE WEB LINKS

- The e-Skeletons Project site explores the comparative skeletal anatomy of humans and other primates

skin The outer layer of the body of a vertebrate (see illustration). It is composed of two layers, the *epidermis and *dermis, with a complex nervous and blood supply. The skin may bear a variety of specialized structures, including *hair, *scales, and *feathers. This skin has an important role in protecting the body from mechanical injury, water loss, and the entry of harmful agents (e.g. disease-causing bacteria). It is also a sense organ, containing receptors sensitive to pain, temperature, and pressure. In warm-blooded animals it helps regulate body temperature by means of hair, fur, or feathers and *sweat glands.

skip distance The minimum distance from the transmitter of a radio wave at which reception is possible by means of a sky wave (*see* RADIO TRANSMISSION). If a radio wave strikes the ionosphere at a small angle of incidence the wave passes through it and is not reflected. There is therefore a minimum angle of incidence at which reflection occurs for a given frequency. This leads to a region around a transmitter in which sky waves cannot be received. As the frequency of the transmission increases the minimum angle of incidence at which ionospheric reflection occurs becomes greater. Above about 4 megahertz there may be a region of several hundred kilometres around a transmitter, which is within the skip distance and in which ground waves are too attenuated to be effectively received. In this region no reception is possible.

skull The skeleton of the head. In mammals it consists of a *cranium enclosing the brain and the bones of the face and jaw. All the joints between the individual bones of the skull are immovable (*see* SUTURE) except for the joint between the mandible (lower jaw) and the rest of the skull. There is a large opening (**foramen magnum**) at the base of the skull through which the spinal cord passes from the brain.

skyrmion A representation of a baryon in which the baryon is regarded as a soliton for a meson field theory. This picture of baryons can be justified using *quantum chromodynamics and gives very useful insights into both baryons and nuclear structure. It is named after the British physicist Tony Skyrme (1922–87), who proposed this theory of baryons in the 1960s.

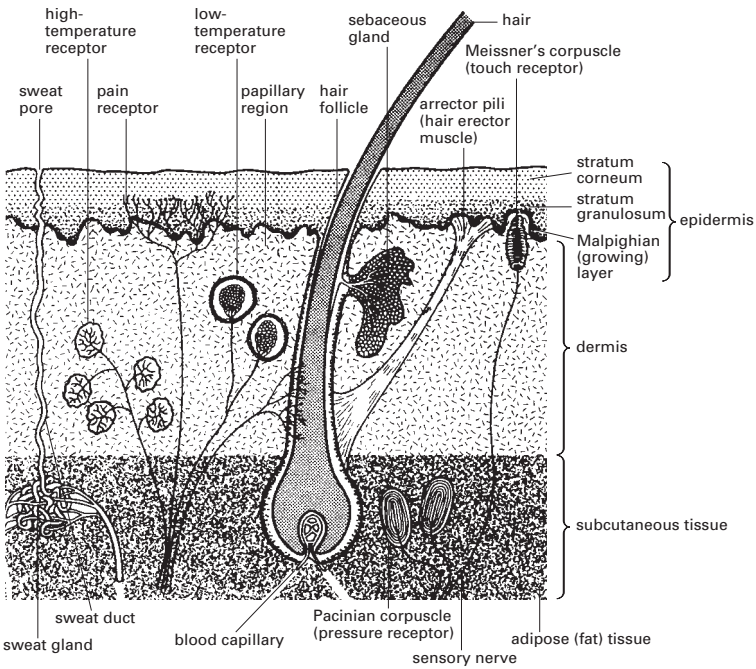
sky wave *See* RADIO TRANSMISSION.

slag Material produced during the *smelting or refining of metals by reaction of the flux with impurities (e.g. calcium silicate formed by reaction of calcium oxide flux with silicon dioxide impurities). The liquid slag can be separated from the liquid metal because it floats on the surface. *See also* BASIC SLAG.

slaked lime *See* CALCIUM HYDROXIDE.

slate A blue to grey fine-grained metamorphic rock characterized by the ease with which it cleaves into large thin sheets. It is formed mainly by the metamorphosis of mudstone or shale, in which platy minerals become aligned in parallel planes. Slate is traditionally used as a roofing material.

sleep A readily reversible state of reduced awareness and metabolic activity that occurs periodically in many animals. Usually accompanied by physical relaxation, the onset of sleep in humans and other mammals is marked by a change in the electrical activity of the brain, which is recorded by an *electroencephalogram as waves of low frequency and high amplitude (**slow-wave sleep**). This is interspersed by short bouts of high-



Skin. Structure of mammalian skin.

frequency low-amplitude waves (similar to wave patterns produced when awake) associated with restlessness, dreaming, and rapid eye movement (REM); this is called **REM** (or **paradoxical**) **sleep**. Several regions of the brain are involved in sleep, especially the reticular formation of the *brainstem.

sleep movements *See* NYCTINASTY.

slepton *See* SUPERSYMMETRY.

slime moulds Any of various small simple eukaryotic organisms that live in damp terrestrial habitats and superficially resemble fungi, to which they are unrelated. They are often seen as slimy masses on rotting wood and show *amoeboid movement, feeding by ingesting small particles of food. They exist either as free cells (**myxamoebas**) or as multinucleate aggregates of cells depending on the stage of the life cycle. When conditions become unfavourable, slime moulds form fruiting bodies (sporangia), from which spores are released. These disperse and subsequently germinate into small amoebas, thereby completing the life cycle. **Plasmodial slime moulds** live as 'giant cells' (plasmodia), formed by the fusion of individual flagellated cells and containing many nuclei. **Cellular slime moulds** live mainly as separate amoeboid cells, but aggregate to form a cellular swarm called a **pseudoplasmodium**, in which the plasma membranes of individual cells are retained. Another unrelated group, the Labyrinthomycota, consists of the **slime nets**, protists that secrete filaments along which the cells glide.

slow neutron A neutron with a kinetic energy of less than 10^2 eV (10^{-17} joule). *See also* FAST NEUTRON; THERMALIZATION.

S

sludge *See* SEWAGE.

slug **1.** (in physics) An f.p.s. unit of mass equal to the mass that will acquire an acceleration of 1 ft sec^{-2} when acted on by a force of one pound-force. **2.** (in zoology) *See* GASTROPODA.

slurry A paste consisting of a suspension of a solid in a liquid.

small intestine The portion of the *alimentary canal between the stomach and the large intestine. It is subdivided into the *duodenum, *jejunum, and *ileum. It plays an essential role in the final digestion and absorption of food.

small solar system body (SSSB) Any object in orbit around the sun that is not classified as a *planet or *dwarf planet.

smectic *See* LIQUID CRYSTAL.

smell *See* OLFACTION.

smelting The process of separating a metal from its ore by heating the ore to a high temperature in a suitable furnace in the presence of a reducing agent, such as carbon, and a fluxing agent, such as limestone. Iron ore is smelted in this way so that the metal melts and, being denser than the molten *slag, sinks below the slag, enabling it to be removed from the furnace separately.

smoke A fine suspension of solid particles in a gas.

smoker An active hydrothermal vent on the sea floor that emits mineral-containing fluids at high pressure. Minerals precipitating out of solution as they rise in the water give the appearance of smoke rising in the air. Dark sulphur compounds released from mid-ocean ridges form **black smokers**; the light-coloured emissions containing barytes or silica are **white smokers**. Sometimes deposits build up to form a tube-shaped chimney round the vent.

smooth muscle *See* INVOLUNTARY MUSCLE.

smuts A group of parasitic fungi of the phylum *Basidiomycota. Many of these species attack the ears of cereal crops, replacing the grain by a mass of dark spores. *Compare* RUSTS.

S_N1 reaction *See* NUCLEOPHILIC SUBSTITUTION.

S_N2 reaction *See* NUCLEOPHILIC SUBSTITUTION.

snakes *See* SQUAMATA.

Snell's law *See* REFRACTION.

SNG Substitute (or synthetic) natural gas; a mixture of gaseous hydrocarbons produced from coal, petroleum, etc., and suitable for use as a fuel. Before the discovery of natural gas *coal gas was widely used as a domestic and industrial fuel. This gave way to natural gas in the early part of this century in the US and other countries where natural gas was plentiful. The replacement of coal gas occurred somewhat later in the UK and other parts of Europe. More recently, interest has developed in ways of manufacturing hydrocarbon gas fuels. The main sources are coal and the naphtha fraction of petroleum. In

the case of coal three methods have been used: (1) pyrolysis – i.e. more efficient forms of destructive distillation, often with further hydrogenation of the hydrocarbon products; (2) heating the coal with hydrogen and catalysts to give hydrocarbons – a process known as **hydroliquefaction** (*see also* BERGIUS PROCESS); (3) producing carbon monoxide and hydrogen and obtaining hydrocarbons by the *Fischer–Tropsch process. SNG from naptha is made by steam *reforming.

SNP *See* SINGLE NUCLEOTIDE POLYMORPHISM.

snRNP *See* RIBONUCLEOPROTEIN.

soap A substance made by boiling animal fats with sodium hydroxide. The reaction involves the hydrolysis of *glyceride esters of fatty acids to glycerol and sodium salts of the acids present (mainly the stearate, oleate, and palmitate), giving a soft semisolid with *detergent action. Potassium hydroxide gives a more liquid product (**soft soap**). By extension, other metal salts of long-chain fatty acids are also called soaps. *See also* SAPONIFICATION.

SOAP A protocol for exchanging structured and typed information between networked computers, especially in web services over the Internet. SOAP messages are formatted in *XML and generally use *HTTP as their transport protocol; the most common type is the remote procedure call.

SEE WEB LINKS

- The W3C's XML Protocol Working Group page

social behaviour Any behaviour exhibited by a group of animals that interact with each other. Social behaviour ranges from moving as a herd in order to minimize the effects of predators to performing designated roles in highly organized societies. For example, within a colony of bees specific tasks, including tending the larvae, foraging for food, and controlling the temperature within the colony by wing fanning, are performed by different individuals. The application of evolutionary theory to social behaviour is called **sociobiology**, which is concerned primarily with genetically determined aspects of behaviour and their adaptive significance.

soda Any of a number of sodium compounds, such as caustic soda (NaOH) or, especially, washing soda ($Na_2CO_3.10H_2O$).

soda ash Anhydrous *sodium carbonate, Na_2CO_3.

soda lime A mixed hydroxide of sodium and calcium made by slaking lime with caustic soda solution (to give $NaOH + Ca(OH)_2$) and recovering greyish white granules by evaporation. The material is produced largely for industrial adsorption of carbon dioxide and water, but also finds some applications in pollution and effluent control. It is also used as a laboratory drying agent.

sodamide *See* SODIUM AMIDE.

Soddy, Frederick (1877–1956) British chemist, who worked with Ernest *Rutherford in Canada and William *Ramsay in London before finally settling in Oxford in 1919. His announcement in 1913 of the existence of *isotopes won him the 1921 Nobel Prize for physics.

sodium Symbol Na. A soft silvery reactive element belonging to group 1 (formerly IA) of the periodic table (*see* ALKALI METALS); a.n. 11; r.a.m. 22.9898; r.d. 0.97; m.p. 97.8°C; b.p. 882–889°C. Sodium occurs as the chloride in sea water and in the mineral halite. It is extracted by electrolysis in a *Downs cell. The metal is used as a reducing agent in certain reactions and liquid sodium is also a coolant in nuclear reactors. Chemically, it is highly reactive, oxidizing in air and reacting violently with water (it is kept under oil). It dissolves in liquid ammonia to form blue solutions containing solvated electrons. Sodium is a major *essential element required by animals. It is important in maintaining the *acid–base balance and in controlling the volume of extracellular fluid and functions in the transmission of nerve impulses (*see* SODIUM PUMP). The element was first isolated by Humphry Davy in 1807.

SEE WEB LINKS

- Information from the WebElements site

sodium acetate *See* SODIUM ETHANOATE.

sodium aluminate A white solid, $NaA1O_2$ or $Na_2Al_2O_4$, which is insoluble in ethanol and soluble in water giving strongly alkaline solutions; m.p. 1800°C. It is manufactured by heating bauxite with sodium carbonate and extracting the residue with water, or it may be prepared in the laboratory by adding excess aluminium to hot concentrated sodium hydroxide. In solution the ion $Al(OH)_4^-$ predominates. Sodium aluminate is used as a mordant, in the production of zeolites, in

effluent treatment, in glass manufacture, and in cleansing compounds.

sodium amide (sodamide) A white crystalline powder, $NaNH_2$, which decomposes in water and in warm ethanol, and has an odour of ammonia; m.p. 210°C; b.p. 400°C. It is produced by passing dry ammonia over metallic sodium at 350°C. It reacts with red-hot carbon to give sodium cyanide and with nitrogen(I) oxide to give sodium azide.

sodium azide A white or colourless crystalline solid, NaN_3, soluble in water and slightly soluble in alcohol; hexagonal; r.d. 1.846; decomposes on heating. It is made by the action of nitrogen(I) oxide on hot sodamide ($NaNH_2$) and is used as an organic reagent and in the manufacture of detonators.

sodium benzenecarboxylate (sodium benzoate) An either colourless crystalline or white amorphous powder, C_6H_5COONa, soluble in water and slightly soluble in ethanol. It is made by the reaction of sodium hydroxide with benzoic acid and is used in the dyestuffs industry and as a food preservative. It was formerly used as an antiseptic.

sodium benzoate *See* SODIUM BENZENECARBOXYLATE.

sodium bicarbonate *See* SODIUM HYDROGENCARBONATE.

sodium bisulphate *See* SODIUM HYDROGENSULPHATE.

sodium bisulphite *See* SODIUM HYDROGENSULPHITE.

sodium bromide A white crystalline solid, NaBr, known chiefly as the dihydrate (monoclinic; r.d. 2.17), and as the anhydrous salt (cubic; r.d. 3.20; m.p. 747°C; b.p. 1390°C). The dihydrate loses water at about 52°C and is very slightly soluble in alcohol. Sodium bromide is prepared by the reaction of bromine on hot sodium hydroxide solution or of hydrogen bromide on sodium carbonate solution. It is used in photographic processing and in analytical chemistry.

sodium carbonate Anhydrous sodium carbonate (**soda ash**, **sal soda**) is a white powder, which cakes and aggregates on exposure to air due to the formation of hydrates. The monohydrate, $Na_2CO_3.H_2O$, is a white crystalline material, which is soluble in water and insoluble in alcohol; r.d. 2.532; loses water at 109°C; m.p. 851°C.

The decahydrate, $Na_2CO_3.10H_2O$ (**washing soda**), is a translucent efflorescent crystalline solid; r.d. 1.44; loses water at 32–34°C to give the monohydrate; m.p. 851°C. Sodium carbonate may be manufactured by the *Solvay process or by suitable crystallization procedures from any one of a number of natural deposits, such as:

trona ($Na_2CO_3.NaHCO_3.2H_2O$),
natron ($Na_2CO_3.10H_2O$),
ranksite ($2Na_2CO_3.9Na_2SO_4.KCl$),
pirsonnite ($Na_2CO_3.CaCO_3.2H_2O$),
gaylussite ($Na_2CO_3.CaCO_3.5H_2O$).

The method of extraction is very sensitive to the relative energy costs and transport costs in the region involved. Sodium carbonate is used in photography, in cleaning, in pH control of water, in textile treatment, glasses and glazes, and as a food additive and volumetric reagent. *See also* SODIUM SESQUICARBONATE.

sodium chlorate(V) A white crystalline solid, $NaClO_3$; cubic; r.d. 2.49; m.p. 250°C. It decomposes above its melting point to give oxygen and sodium chloride. The compound is soluble in water and in ethanol and is prepared by the reaction of chlorine on hot concentrated sodium hydroxide. Sodium chlorate is a powerful oxidizing agent and is used in the manufacture of matches and soft explosives, in calico printing, and as a garden weedkiller.

sodium chloride (common salt) A colourless crystalline solid, NaCl, soluble in water and very slightly soluble in ethanol; cubic; r.d. 2.17; m.p. 801°C; b.p. 1413°C. It occurs as the mineral *halite (rock salt) and in natural brines and sea water. It has the interesting property of a solubility in water that changes very little with temperature. It is used industrially as the starting point for a range of sodium-based products (e.g. Solvay process for Na_2CO_3, Castner–Kellner process for NaOH), and is known universally as a preservative and seasoner of foods. Sodium chloride has a key role in biological systems in maintaining electrolyte balances.

sodium chloride structure *See* ROCK SALT STRUCTURE.

sodium cyanide A white or colourless crystalline solid, NaCN, deliquescent, soluble in water and in liquid ammonia, and slightly soluble in ethanol; cubic; m.p. 564°C; b.p. 1496°C. Sodium cyanide is now made by absorbing hydrogen cyanide in sodium hydroxide or sodium carbonate solution. The

compound is extremely poisonous because it reacts with the iron in haemoglobin in the blood, so preventing oxygen reaching the tissues of the body. It is used in the extraction of precious metals and in electroplating industries. Aqueous solutions are alkaline due to salt hydrolysis.

sodium dichromate A red crystalline solid, $Na_2Cr_2O_7.2H_2O$, soluble in water and insoluble in ethanol. It is usually known as the dihydrate (r.d. 2.52), which starts to lose water above 100°C; the compound decomposes above 400°C. It is made by melting chrome iron ore with lime and soda ash and acidification of the chromate thus formed. Sodium dichromate is cheaper than the corresponding potassium compound but has the disadvantage of being hygroscopic. It is used as a mordant in dyeing, as an oxidizing agent in organic chemistry, and in analytical chemistry.

sodium dihydrogenorthophosphate *See* SODIUM DIHYDROGENPHOSPHATE(V).

sodium dihydrogenphosphate(V) (sodium dihydrogenorthophosphate) A colourless crystalline solid, NaH_2PO_4, which is soluble in water and insoluble in alcohol, known as the monohydrate (r.d. 2.04) and the dihydrate (r.d. 1.91). The dihydrate loses one water molecule at 60°C and the second molecule of water at 100°C, followed by decomposition at 204°C. The compound may be prepared by treating sodium carbonate with an equimolar quantity of phosphoric acid or by neutralizing phosphoric acid with sodium hydroxide. It is used in the preparation of sodium phosphate (Na_3PO_4), in baking powders, as a food additive, and as a constituent of buffering systems. Both sodium dihydrogenphosphate and trisodium phosphate enriched in ^{32}P have been used to study phosphate participation in metabolic processes.

sodium dioxide *See* SODIUM SUPEROXIDE.

sodium ethanoate (sodium acetate) A colourless crystalline compound, CH_3COONa, which is known as the anhydrous salt (r.d. 1.52; m.p. 324°C) or the trihydrate (r.d. 1.45; loses water at 58°C). Both forms are soluble in water and in ethoxyethane, and slightly soluble in ethanol. The compound may be prepared by the reaction of ethanoic acid (acetic acid) with sodium carbonate or with sodium hydroxide. Because it is a salt of a strong base and a weak acid, sodium ethanoate is used in buffers for pH control in many laboratory applications, in foodstuffs, and in electroplating. It is also used in dyeing, soaps, pharmaceuticals, and in photography.

sodium fluoride A crystalline compound, NaF, soluble in water and very slightly soluble in ethanol; cubic; r.d. 2.56; m.p. 993°C; b.p. 1695°C. It occurs naturally as villiaumite and may be prepared by the reaction of sodium hydroxide or of sodium carbonate with hydrogen fluoride. The reaction of sodium fluoride with concentrated sulphuric acid may be used as a source of hydrogen fluoride. The compound is used in ceramic enamels and as a preservative agent for fermentation. It is highly toxic but in very dilute solution (less than 1 part per million) it is used in the fluoridation of water for the prevention of tooth decay on account of its ability to replace OH groups with F atoms in the material of dental enamel.

sodium formate *See* SODIUM METHANOATE.

sodium hexafluoraluminate A colourless monoclinic solid, Na_3AlF_6, very slightly soluble in water; r.d. 2.9; m.p. 1000°C. It changes to a cubic form at 580°C. The compound occurs naturally as the mineral *cryolite but a considerable amount is manufactured by the reaction of aluminium fluoride wth alumina and sodium hydroxide or directly with sodium aluminate. Its most important use is in the manufacture of aluminium in the *Hall–Heroult cell. It is also used in the manufacture of enamels, opaque glasses, and ceramic glazes.

sodium hydride A white crystalline solid, NaH; cubic; r.d. 0.92; decomposes above 300°C (slow); completely decomposed at 800°C. Sodium hydride is prepared by the reaction of pure dry hydrogen with sodium at 350°C. Electrolysis of sodium hydride in molten LiCl/KCl leads to the evolution of hydrogen; this is taken as evidence for the ionic nature of NaH and the presence of the hydride ion (H^-). It reacts violently with water to give sodium hydroxide and hydrogen, with halogens to give the halide and appropriate hydrogen halide, and ignites spontaneously with oxygen at 230°C. It is a powerful reducing agent with several laboratory applications.

sodium hydrogencarbonate (bicarbonate of soda; sodium bicarbonate) A white

crystalline solid, $NaHCO_3$, soluble in water and slightly soluble in ethanol; monoclinic; r.d. 2.159; loses carbon dioxide above 270°C. It is manufactured in the *Solvay process and may be prepared in the laboratory by passing carbon dioxide through sodium carbonate or sodium hydroxide solution. Sodium hydrogencarbonate reacts with acids to give carbon dioxide and, as it does not have strongly corrosive or strongly basic properties itself, it is employed in bulk for the treatment of acid spillage and in medicinal applications as an antacid. Sodium hydrogencarbonate is also used in baking powders (and is known as **baking soda**), dry-powder fire extinguishers, and in the textiles, tanning, paper, and ceramics industries. The hydrogencarbonate ion has an important biological role as an intermediate between atmospheric CO_2/H_2CO_3 and the carbonate ion CO_3^{2-}. For water-living organisms this is the most important and in some cases the only source of carbon.

sodium hydrogensulphate (sodium bisulphate) A colourless solid, $NaHSO_4$, known in anhydrous and monohydrate forms. The anhydrous solid is triclinic (r.d. 2.435; m.p. >315°C). The monohydrate is monoclinic and deliquescent (r.d. 2.103; m.p. 59°C). Both forms are soluble in water and slightly soluble in alcohol. Sodium hydrogensulphate was originally made by the reaction between sodium nitrate and sulphuric acid, hence its old name of **nitre cake**. It may be manufactured by the reaction of sodium hydroxide with sulphuric acid, or by heating equimolar proportions of sodium chloride and concentrated sulphuric acid. Solutions of sodium hydrogensulphate are acidic. On heating the compound decomposes (via $Na_2S_2O_7$) to give sulphur trioxide. It is used in paper making, glass making, and textile finishing.

sodium hydrogensulphite (sodium bisulphite) A white solid, $NaHSO_3$, which is very soluble in water (yellow in solution) and slightly soluble in ethanol; monoclinic; r.d. 1.48. It decomposes on heating to give sodium sulphate, sulphur dioxide, and sulphur. It is formed by saturating a solution of sodium carbonate with sulphur dioxide. The compound is used in the brewing industry and in the sterilization of wine casks. It is a general antiseptic and bleaching agent. *See also* ALDEHYDES.

sodium hydroxide (caustic soda) A white transluscent deliquescent solid, NaOH, soluble in water and ethanol but insoluble in ether; r.d. 2.13; m.p. 318°C; b.p. 1390°C. Hydrates containing 7, 5, 4, 3.5, 3, 2, and 1 molecule of water are known.

Sodium hydroxide was formerly made by the treatment of sodium carbonate with lime but its main source today is from the electrolysis of brine using mercury cells or any of a variety of diaphragm cells. The principal product demanded from these cells is chlorine (for use in plastics) and sodium hydroxide is almost reduced to the status of a by-product. It is strongly alkaline and finds many applications in the chemical industry, particularly in the production of soaps and paper. It is also used to adsorb acidic gases, such as carbon dioxide and sulphur dioxide, and is used in the treatment of effluent for the removal of heavy metals (as hydroxides) and of acidity. Sodium hydroxide solutions are extremely corrosive to body tissue and are particularly hazardous to the eyes.

sodium iodide A white crystalline solid, NaI, very soluble in water and soluble in both ethanol and ethanoic acid. It is known in both the anhydrous form (cubic; r.d. 3.67; m.p. 661°C; b.p. 1304°C) and as the dihydrate (monoclinic; r.d. 2.45). It is prepared by the reaction of hydrogen iodide with sodium carbonate or sodium hydroxide in solution. Like potassium iodide, sodium iodide in aqueous solution dissolves iodine to form a brown solution containing the I_3^- ion. It finds applications in photography and is also used in medicine as an expectorant and in the administration of radioactive iodine for studies of thyroid function and for treatment of diseases of the thyroid.

sodium methanoate (sodium formate) A colourless deliquescent solid, HCOONa, soluble in water and slightly soluble in ethanol; monoclinic; r.d. 1.92; m.p. 253°C; decomposes on further heating. The monohydrate is also known. The compound may be produced by the reaction of carbon monoxide with solid sodium hydroxide at 200°C and 10 atmospheres pressure; in the laboratory it can be conveniently prepared by the reaction of methanoic acid and sodium hydroxide. Its uses are in the production of oxalic acid (ethanedioic acid) and methanoic acid and in the laboratory it is a convenient source of carbon monoxide.

sodium monoxide A whitish-grey deliquescent solid, Na_2O; r.d. 2.27; sublimes at

1275°C. It is manufactured by oxidation of the metal in a limited supply of oxygen and purified by sublimation. Reaction with water produces sodium hydroxide. Its commercial applications are similar to those of sodium hydroxide.

sodium nitrate (Chile saltpetre) A white solid, $NaNO_3$, soluble in water and in ethanol; trigonal; r.d. 2.261; m.p. 306°C; decomposes at 380°C. A rhombohedral form is also known. It is obtained from deposits of caliche or may be prepared by the reaction of nitric acid with sodium hydroxide or sodium carbonate. It was previously used for the manufacture of nitric acid by heating with concentrated sulphuric acid. Its main use is in nitrate fertilizers.

sodium nitrite A yellow hygroscopic crystalline compound, $NaNO_2$, soluble in water, slightly soluble in ether and in ethanol; rhombohedral; r.d. 2.17; m.p. 271°C; decomposes above 320°C. It is formed by the thermal decomposition of sodium nitrate and is used in the preparation of nitrous acid (reaction with cold dilute hydrochloric acid). Sodium nitrite is used in organic *diazotization and as a corrosion inhibitor.

sodium orthophosphate *See* TRISODIUM PHOSPHATE(V).

sodium peroxide A whitish solid (yellow when hot), Na_2O_2, soluble in ice-water and decomposed in warm water or alcohol; r.d. 2.80; decomposes at 460°C. A crystalline octahydrate (hexagonal) is obtained by crystallization from ice-water. The compound is formed by the combustion of sodium metal in excess oxygen. At normal temperatures it reacts with water to give sodium hydroxide and hydrogen peroxide. It is a powerful oxidizing agent reacting with iodine vapour to give the iodate and periodate, with carbon at 300°C to give the carbonate, and with nitrogen(II) oxide to give the nitrate. It is used as a bleaching agent in wool and yarn processing, in the refining of oils and fats, and in the production of wood pulp.

sodium pump A mechanism by which sodium ions are transported out of a eukaryotic cell across the plasma membrane. The process requires energy in the form of ATP, being a form of *active transport. It maintains the differential concentrations of sodium and potassium ions on either side of the plasma membrane, which is necessary, for example, for establishing the *resting potential of a neuron.

sodium sesquicarbonate A white crystalline hydrated double salt, $Na_2CO_3.NaHCO_3.2H_2O$, soluble in water but less alkaline than sodium carbonate; r.d. 2.12; decomposes on heating. It may be prepared by crystallizing equimolar quantities of the constituent materials; it also occurs naturally as **trona** and in Searles Lake brines. It is widely used as a detergent and soap builder and, because of its mild alkaline properties, as a water-softening agent and bath-salt base. *See also* SODIUM CARBONATE.

sodium sulphate A white crystalline compound, Na_2SO_4, usually known as the anhydrous compound (orthorhombic; r.d. 2.67; m.p. 888°C) or the decahydrate (monoclinic; r.d. 1.46; which loses water at 100°C). The decahydrate is known as **Glauber's salt**. A metastable heptahydrate ($Na_2SO_4.7H_2O$) also exists. All forms are soluble in water, dissolving to give a neutral solution. The compound occurs naturally as
mirabilite ($Na_2SO_4.10H_2O$),
threnardite (Na_2SO_4), and
glauberite ($Na_2SO_4.CaSO_4$).

Sodium sulphate may be produced industrially by the reaction of magnesium sulphate with sodium chloride in solution followed by crystallization, or by the reaction of concentrated sulphuric acid with solid sodium chloride. The latter method was used in the *Leblanc process for the production of alkali and has given the name **salt cake** to impure industrial sodium sulphate. Sodium sulphate is used in the manufacture of glass and soft glazes and in dyeing to promote an even finish. It also finds medicinal application as a purgative and in commercial aperient salts.

sodium sulphide A yellow-red solid, Na_2S, formed by the reduction of sodium sulphate with carbon (coke) at elevated temperatures. It is a corrosive and readily oxidized material of variable composition and usually contains polysulphides of the type Na_2S_2, Na_2S_3, and Na_2S_4, which cause the variety of colours. It is known in an anhydrous form (r.d. 1.85; m.p. 1180°C) and as a nonahydrate, $Na_2S.9H_2O$ (r.d. 1.43; decomposes at 920°C). Other hydrates of sodium sulphide have been reported. The compound is deliquescent, soluble in water with extensive hydrolysis, and slightly soluble in alcohol. It is used in wood pulping, dyestuffs manufac-

ture, and metallurgy on account of its reducing properties. It has also been used for the production of sodium thiosulphate (for the photographic industry) and as a depilatory agent in leather preparation. It is a strong skin irritant.

sodium sulphite A white solid, Na_2SO_3, existing in an anhydrous form (r.d. 2.63) and as a heptahydrate (r.d. 1.59). Sodium sulphite is soluble in water and because it is readily oxidized it is widely used as a convenient reducing agent. It is prepared by reacting sulphur dioxide with either sodium carbonate or sodium hydroxide. Dilute mineral acids reverse this process and release sulphur dioxide. Sodium sulphite is used as a bleaching agent in textiles and in paper manufacture. Its use as an antioxidant in some canned foodstuffs gives rise to a slightly sulphurous smell immediately on opening, but its use is prohibited in meats or foods that contain vitamin B_1. Sodium sulphite solutions are occasionally used as biological preservatives.

sodium–sulphur cell A type of *secondary cell that has molten electrodes of sodium and sulphur separated by a solid electrolyte consisting of beta alumina (a crystalline form of aluminium oxide). When the cell is producing current, sodium ions flow through the alumina to the sulphur, where they form sodium polysulphide. Electrons from the sodium flow in the external circuit. The opposite process takes place during charging of the cell. Sodium–sulphur batteries have been considered for use in electric vehicles because of their high peak power levels and relatively low weight. However, some of the output has to be used to maintain the operating temperature (about 370°C) and the cost of sodium is high.

sodium superoxide (sodium dioxide) A whitish-yellow solid, NaO_2, formed by the reaction of sodium peroxide with excess oxygen at elevated temperatures and pressures. It reacts with water to form hydrogen peroxide and oxygen.

sodium thiosulphate (hypo) A colourless efflorescent solid, $Na_2S_2O_3$, soluble in water but insoluble in ethanol, commonly encountered as the pentahydrate (monoclinic; r.d. 1.73; m.p. 42°C), which loses water at 100°C to give the anhydrous form (r.d. 1.66). It is prepared by the reaction of sulphur dioxide with a suspension of sulphur in boiling sodium hydroxide solution. Aqueous solutions of sodium thiosulphate are readily oxidized in the presence of air to sodium tetrathionate and sodium sulphate. The reaction with dilute acids gives sulphur and sulphur dioxide. It is used in the photographic industry and in analytical chemistry.

sodium-vapour lamp A form of *electric lighting that gives a yellow light as a result of the luminous discharge obtained by the passage of a stream of electrons between tungsten electrodes in a tube containing sodium vapour. To facilitate starting, the tube also contains some neon; for this reason, until the lamp is warm the neon emits a characteristic pink glow. As the sodium vaporizes, the yellow light predominates. Sodium-vapour lamps are widely used as street lights because of their high luminous efficiency and because the yellow light is less absorbed than white light by fog and mist. Low-pressure sodium lamps emit a characteristic yellow light; in high-pressure lamps the atoms are sufficiently close to each other to interact and broaden the spectral lines into the orange and green regions.

soft acid *See* HSAB PRINCIPLE.

soft base *See* HSAB PRINCIPLE.

soft iron A form of iron that contains little carbon, has high relative permeability, is easily magnetized and demagnetized, and has a small hysteresis loss. Soft iron and other **soft ferromagnetic materials**, such as silicon steel, are used in making parts exposed to rapid changes of magnetic flux, such as the cores of electromagnets, motors, generators, and transformers.

By comparison, **hard ferromagnetic materials**, such as cobalt steel and various alloys of nickel, aluminium, and cobalt, have low relative permeability, are difficult to magnetize, and have a high hysteresis loss. They are used in making permanent magnets.

soft matter A general name given to noncrystalline condensed matter. This includes liquids, disordered solids (including glasses), liquid crystals, and random networks of polymers.

soft radiation Ionizing radiation of low penetrating power, usually used with reference to X-rays of long wavelength. *Compare* HARD RADIATION.

soft soap *See* SOAP.

software *See* COMPUTER.

soft water *See* HARDNESS OF WATER.

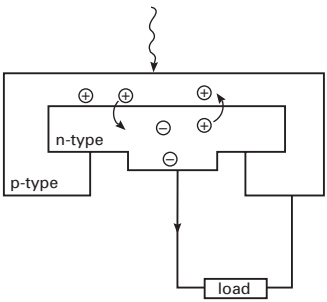
softwood *See* WOOD.

soil The layer of unconsolidated particles derived from weathered rock, organic material (*humus), water, and air that forms the upper surface over much of the earth and supports plant growth. The formation of soil depends on the parent material (i.e. the original material from which the soil is derived), the climate and topography of the area, the organisms present in the soil, and the time over which the soil has been developing. Soils are often classified in terms of their structure and texture. The structure of a soil is the way in which the individual soil particles are bound together to form aggregates or peds. The structure types include platy, blocky, granular, and crumbs. The texture of a soil denotes the proportion of the various particle sizes that it contains. The four main texture classes are sand, silt, clay, and *loam, of which loams are generally the best agricultural soils as they contain a mixture of all particle sizes. A number of distinct horizontal layers can often be distinguished in a vertical section (profile) of soil – these are known as **soil horizons**. Four basic horizons are common to most soils: an uppermost A horizon (or **topsoil**) containing the organic matter; an underlying B horizon (or **subsoil**), which contains little organic material and is strongly leached; a C horizon consisting of weathered rock; and a D horizon comprising the bedrock. *See also* BROWN EARTH; CHERNOZEM; PODZOL.

soil erosion The removal and thinning of the soil layer due to climatic and physical processes, such as high rainfall, which is greatly accelerated by certain human activities, such as *deforestation. Soil erosion can lead to a loss of agricultural land and if unchecked, eventually results in *desertification.

sol A *colloid in which small solid particles are dispersed in a liquid continuous phase.

solar cell An electric cell that uses the sun's radiation to produce usable electric current. Most solar cells consist of a single-crystal silicon *p–n* junction. When photons of light energy from the sun fall on or near the *semiconductor junction the electron–hole pairs created are forced by the electric field at the junction to separate so that the holes pass to the *p*-region and the electrons pass to the *n*-region. This displacement of free charge creates an electric current when a load is connected across the terminals of the device (see illustration). Individual silicon solar cells cannot be made with a surface area much in excess of 4000 mm^2 and the maximum power delivered by such a cell is approximately 0.6 W at about 0.5 V in full sun. The efficiency of such devices is about 15%. For practical use, therefore, solar cells have to be assembled in arrays. Panels of solar cells have been the exclusive source of power for satellites and space capsules. Their use on earth has been largely limited by their high cost, a reduction in the cost by a factor of 10 being required to make them competitive with other energy sources at present.



Solar cell. A silicon p-n junction.

solar constant The rate at which solar energy is received per unit area at the outer limit of the earth's atmosphere at the mean distance between the earth and the sun. The value is 1.366 kW m^{-2}.

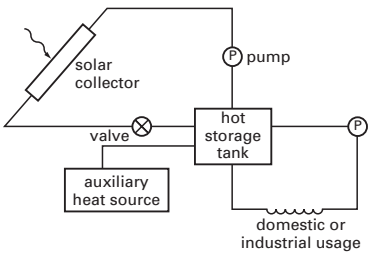
solar cycle (sunspot cycle) The 11-year period over which the sun's activity varies. The principal variable is in the number and disposition of sunspots. At the solar minimum, at the beginning of the cycle, there are no sunspots. Several weeks later they begin to appear at middle latitudes, then gradually drift towards the equator. This behaviour continues for about five years, accompanied by a general increase in the number of sunspots. The number decreases over the next six years until they disappear altogether. All activity within and on the sun, including the generation of solar flares and large prominences, can be associated with the cycle.

solar day *See* DAY.

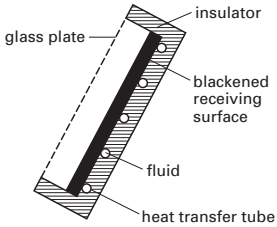
solar energy The electromagnetic energy radiated from the sun. The tiny proportion (about 5×10^{-10} of the total) that falls on the earth is indicated by the *solar constant. The total quantity of solar energy falling on the earth in one year is about 4×10^{18} J, whereas the total annual energy consumption of the earth's inhabitants is only some 3×10^{14} J. The sun, therefore, could provide all the energy needed. The direct ways of making use of solar energy can be divided into thermal methods (*see* SOLAR HEATING) and nonthermal methods (*see* SOLAR CELL).

solar flare A sudden explosive release of particles and energy from the sun's chromosphere. It characteristically takes a few minutes to reach maximum brightness, and then fades during the next hour. When charged particles reach the earth, they cause radio interference, magnetic storms, and aurorae.

solar heating A form of domestic or industrial heating that relies on the direct use of solar energy. The basic form of **solar heater** is a thermal device in which a fluid is heated by the sun's rays in a collector (see illustrations) and pumped or allowed to flow round a circuit that provides some form of heat storage and some form of auxiliary heat source for use when the sun is not shining. More complicated systems are combined heating-and-cooling devices, providing heat in the winter and air-conditioning in the summer. The simplest form of solar collector is the flat-plate collector, in which a blackened receiving surface is covered by one or more glass plates that acts like a greenhouse (*see* GREENHOUSE EFFECT) and traps the maximum amount of solar energy. Tubes attached to the receiving surface carry air, water, or some other fluid to which the absorbed heat is transferred. The whole panel is insulated at the back and can thus form part of the roof of a building. More sophisticated collectors focus the sun's rays using reflectors. *See also* SOLAR CELL.



Typical solar heating system



Flat-plate solar collector

Solar heating.

solar parallax The angle subtended by the earth's equatorial radius at the centre of the sun at the mean distance between the earth and the sun (i.e. at 1 astronomical unit). It has the value 8.794 148 arc seconds.

solar prominence *See* PROMINENCE.

solar system The sun, the eight major planets (Mercury, Venus, the earth, Mars, Jupiter, Saturn, Uranus, and Neptune) and their natural satellites, the five dwarf planets (Ceres, Pluto, Haumea, Makemake, and Eris) and their satellites, all *trans-Neptunian objects, the asteroids, the centaurs, the comets, and meteoroids. See Feature overleaf.

SEE WEB LINKS

- Data for the solar system from NASA/JPL

solar units Units based on the physical properties of the sun used to describe other celestial objects. Examples include solar luminosity (symbol $L_\odot$), solar mass ($M_\odot$), and solar radius ($R_\odot$).

solar wind A continuous outward flow of charged particles, mostly protons and electrons, from the sun's *corona into interplanetary space. The particles are controlled by the sun's magnetic field and are able to escape from the sun's gravitational field because of their high thermal energy. The average velocity of the particles in the vicinity of the earth is about 450 km s^{-1} and their density at this range is about 8×10^6 protons per cubic metre.

solar year *See* YEAR.

solder An alloy used to join metal surfaces.

S

A **soft solder** melts at a temperature in the range 200–300°C and consists of a tin–lead alloy. The tin content varies between 80% for the lower end of the melting range and 31% for the higher end. **Hard solders** contain substantial quantities of silver in the alloy. **Brazing solders** are usually alloys of copper and zinc, which melt at over 800°C.

solenoid A coil of wire wound on a cylindrical former in which the length of the former is greater than its diameter. When a current is passed through the coil a magnetic field is produced inside the coil parallel to its axis. This field can be made to operate a plunger inside the former so that the solenoid can be used to operate a circuit breaker, valve, or other electromechanical device.

solid A state of matter in which there is a three-dimensional regularity of structure, resulting from the proximity of the component atoms, ions, or molecules and the strength of the forces between them. True solids are crystalline (*see also* AMORPHOUS). If a crystalline solid is heated, the kinetic energy of the components increases. At a specific temperature, called the **melting point**, the forces between the components become unable to contain them within the crystal structure. At this temperature, the lattice breaks down and the solid becomes a liquid.

solid angle Symbol Ω. The three-dimensional 'angle' formed by the vertex of a cone. When this vertex is the centre of a sphere of radius r and the base of the cone cuts out an area s on the surface of the sphere, the solid angle in *steradians is defined as s/r^2.

solid electrolyte *See* FAST-ION CONDUCTOR.

solid solution A crystalline material that is a mixture of two or more components, with ions, atoms, or molecules of one component replacing some of the ions, atoms, or molecules of the other component in its normal crystal lattice. Solid solutions are found in certain alloys. For example, gold and copper form solid solutions in which some of the copper atoms in the lattice are replaced by gold atoms. In general, the gold atoms are distributed at random, and a range of gold–copper compositions is possible. At a certain composition, the gold and copper atoms can each form regular individual lattices (referred to as **superlattices**). Mixed crystals of double salts (such as alums) are also examples of solid solutions. Compounds can form solid solutions if they are isomorphous (*see* ISOMORPHISM).

solid-state detector *See* JUNCTION DETECTOR.

solid-state physics The study of the physical properties of solids, with special emphasis on the electrical properties of semiconducting materials in relation to their electronic structure. **Solid-state devices** are electronic components consisting entirely of solids (e.g. semiconductors, transistors, etc.) without heating elements, as in thermionic valves.

Recently the term **condensed-matter physics** has been introduced to include the study of crystalline solids, amorphous solids, and liquids.

solid superfluid (supersolid) A substance that has a lattice structure but can flow through a solid with no friction. A solid superfluid is a *Bose–Einstein condensate of atoms. The existence of supersolids was predicted theoretically in 1970. There is some experimental evidence for their existence but it cannot be regarded as conclusive.

solidus A line on a phase diagram below which a substance is solid.

soliton A stable particle-like solitary wave state that is a solution of certain equations for propagation. Solitons are thought to occur in many areas of physics and applied mathematics, such as plasmas, fluid mechanics, lasers, optics, solid-state physics, and elementary-particle physics.

solstice **1.** Either of the two points on the *ecliptic midway between the *equinoxes, at which the sun is at its greatest angular distance north (**summer solstice**) or south (**winter solstice**) of the celestial equator. **2.** The time at which the sun reaches either of these points. The summer solstice occurs on June 21 and the winter solstice on December 21 in the northern hemisphere; the dates are reversed in the southern hemisphere.

solubility The quantity of solute that dissolves in a given quantity of solvent to form a saturated solution. Solubility is measured in kilograms per metre cubed, moles per kilogram of solvent, etc. The solubility of a substance in a given solvent depends on the temperature. Generally, for a solid in a liquid, solubility increases with temperature;

SOLAR SYSTEM

In general, a solar system is an astronomical feature consisting of a central star together with the planets and other celestial bodies held in orbit around it by gravitational attraction. The term most commonly refers to the particular solar system to which our earth belongs. This is dominated by our own central star, the *sun, and contains numerous different objects, including planets and SSSBs (small solar system bodies) – dwarf planets, asteroids, comets, etc. Many objects are under secondary gravitational influence, i.e. satellites (such as our moon) held in orbit around the larger bodies and travelling with them around the sun.

The solar system itself is part of a larger system, the Galaxy, which is itself rotating. Our solar system revolves around the centre of the Galaxy once every 220 million years.

Origin of the solar system

The current theory of the origin of the solar system is the **solar nebular disc model.** It holds that the system originated within a giant molecular cloud, a vast nebula composed of hydrogen, in which clumps of denser material formed, possibly produced by shock waves from supernova explosions. One such clump, rotating and collapsing under its own gravitation, formed a flattened spinning disc, the solar nebula. The sun formed at the hot dense centre of the solar nebula, while in its cooler outer regions the planets grew by accretion. By about 4.6 billion years ago the earth had formed.

Regions of the solar system

Many astronomers divide the solar system into three regions:

- the inner solar system, containing the planets Mercury, Venus, earth, and Mars, the earth's moon and the two moons of Mars, and the main asteroid belt.
- the outer solar system (beyond 5 AU from the sun), containing the planets Jupiter, Saturn, Uranus, and Neptune, with their satellites and other objects.
- the trans-Neptunian region (beyond 30 AU), a largely unmapped region lying outside the orbit of Neptune.

Some writers define the region containing the main planets as the 'inner solar system' and the region beyond Neptune as the 'outer solar system'. The trans-Neptunian region may be partitioned further into three other regions:

- the Kuiper belt, ranging from 30–50 AU, the existence of which was confirmed in 1992 by David C. Jewett and Jane X. Luu. It was named after the Dutch-American astronomer Gerard P. Kuiper (1905–73), one of several experts who had theorized about the outer reaches of the solar system. It contains thousands of small icy bodies, called **Kuiper belt objects** or **KBOs**. It includes a number of significant objects; for example, Pluto. once regarded as a planet, is a Kuiper belt object (now also classified as a dwarf planet).
- the **scattered disc** lying beyond the Kuiper belt and perhaps an outer part of it. It is home to the dwarf planet Eris and probably to most periodic comets and centaurs.
- the **Oort cloud**, a hypothetical region way outside the Kuiper belt and scattered disc, about 1 light year from the sun, thought to be the home of long-period comets. Originally proposed in 1932 by the Estonian astronomer Ernst Öpik (1893–1985), it is named after the Dutch astronomer Jan Hendrik Oort (1900–92), who revived the idea in 1950.

The planets

There are eight bodies now recognized as *planets. They are divided into two groups. The **inner** or **terrestrial planets** – Mercury, Venus, earth, and Mars – are comparatively small. They are composed of rock and metal, with the metal part

forming a dense central core. Mercury and Venus have no natural satellites. The earth has one satellite (the moon) and Mars has two (Phobos and Deimos).

The **outer** or **giant planets** – Jupiter. Saturn, Uranus, and Neptune – are massive low-density bodies with a rocky core surrounded by deep layers consisting mainly of solid, liquid, and gaseous hydrogen and helium. They are much further from the sun and therefore much cooler. All have large numbers of satellites: Jupiter has at least 63; Saturn at least 61; Uranus 27; and Neptune 13. The outer planets also have ring systems composed of smaller bodies, rocks, dust, and ice particles.

The four largest satellites of Jupiter – Ganymede, Callisto, Io, and Europa – are known as the **Galilean satellites** after their discovery by Galileo in 1610. Ganymede is the largest natural satellite in the solar system and is in fact larger than Mercury; it is followed by Titan (Saturn), Callisto (Jupiter), Io (Jupiter), the moon (earth), Europa (Jupiter), and Triton (Neptune).

Dwarf planets

Some smaller bodies orbiting the sun are classed as *dwarf planets. Like planets, they have reached hydrostatic equilibrium but have not cleared their neighbourhoods of planetesimals. Five objects are presently classified as dwarf planets:

- **Pluto** – a Kuiper belt object ((KBO), considered to be a planet from its discovery in 1930 until 2006. It is named after the Greek god of the underworld.
- **Makemake** – another KBO, discovered in 2005 and about 75% of the size of Pluto. Its name is that of the creator of humanity in the mythology of Easter Island.
- **Ceres** – the largest member of the asteroid belt, named after the Roman goddess of agriculture.
- **Eris** – the largest dwarf planet, about 27% more massive than Pluto, found in the scattered disc. It is named after the Greek goddess of strife.
- **Haumea** – a KBO about one third the mass of Pluto. It is named after the Hawaiian goddess of fertility.

Pluto has three satellites, Haumea two, and Eris one.

Many bodies are candidates for dwarf planet status. They include the trans-Neptunian objects Orcus, Ixion, Huya, Varuna, Quaoar, and Sedna.

Other objects

The space between the orbits of Mars and Jupiter is occupied by thousands of asteroids. Most are small, often irregularly shaped chunks of rock, with perhaps only 150 of them more than 100 km across. Even smaller are the innumerable meteoroids, some no larger than grains of dust originating in comet tails. Those that enter the earth's atmosphere and burn up as trails of light (shooting stars) are termed *meteors. The largest ones that reach the ground are called meteorites.

The remaining solar system members include *comets and *centaurs. Comets consist of a nucleus of dust and ice a kilometre or two across surrounded by a gaseous coma and with a long tail that appears when the comet nears the sun. Centaurs are more like asteroids in size, but some of them develop comet-like comas. Their orbits are unstable because of the gravitational influence of the giant outer planets.

for a gas, solubility decreases. *See also* CONCENTRATION.

solubility product Symbol K_s. The product of the concentrations of ions in a saturated solution. For instance, if a compound A_xB_y is in equilibrium with its solution

$$A_xB_y(s) \rightleftharpoons xA^+(aq) + yB^-(aq)$$

the equilibrium constant is

$$K_c = [A^+]^x[B^-]^y/[A_xB_y]$$

Since the concentration of the undissolved solid can be put equal to 1, the solubility product is given by

$$K_s = [A^+]^x[B^-]^y$$

The expression is only true for sparingly soluble salts. If the product of ionic concentrations in a solution exceeds the solubility product, then precipitation occurs.

solute The substance dissolved in a solvent in forming a *solution.

solution A homogeneous mixture of a liquid (the *solvent) with a gas or solid (the **solute**). In a solution, the molecules of the solute are discrete and mixed with the molecules of solvent. There is usually some interaction between the solvent and solute molecules (*see* SOLVATION). Two liquids that can mix on the molecular level are said to be **miscible**. In this case, the solvent is the major component and the solute the minor component. *See also* SOLID SOLUTION.

solvation The interaction of ions of a solute with the molecules of solvent. For instance, when sodium chloride is dissolved in water the sodium ions attract polar water molecules, with the negative oxygen atoms pointing towards the positive Na^+ ion. Solvation of transition-metal ions can also occur by formation of coordinate bonds, as in the hexaquocopper(II) ion $[Cu(H_2O)_6]^{2+}$. Solvation is the process that causes ionic solids to dissolve, because the energy released compensates for the energy necessary to break down the crystal lattice. It occurs only with polar solvents. Solvation in which the solvent is water is called **hydration**.

Solvay process (ammonia–soda process) An industrial method of making sodium carbonate from calcium carbonate and sodium chloride. The calcium carbonate is first heated to give calcium oxide and carbon dioxide, which is bubbled into a solution of sodium chloride in ammonia. Sodium hydrogencarbonate is precipitated:

$$H_2O + CO_2(g) + NaCl(aq) + NH_3(aq) \rightarrow NaHCO_3(s) + NH_4Cl(aq)$$

The sodium hydrogencarbonate is heated to give sodium carbonate and carbon dioxide. The ammonium chloride is heated with calcium oxide (from the first stage) to regenerate the ammonia. The process was patented in 1861 by the Belgian chemist Ernest Solvay (1838–1922).

solvent A liquid that dissolves another substance or substances to form a *solution. **Polar solvents** are compounds such as water and liquid ammonia, which have dipole moments and consequently high dielectric constants. These solvents are capable of dissolving ionic compounds or covalent compounds that ionize (*see* SOLVATION). **Nonpolar solvents** are compounds such as ethoxyethane and benzene, which do not have permanent dipole moments. These do not dissolve ionic compounds but will dissolve nonpolar covalent compounds. Solvents can be further categorized according to their proton-donating and accepting properties. **Amphiprotic solvents** self-ionize and can therefore act both as proton donators and acceptors. A typical example is water:

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

Aprotic solvents neither accept nor donate protons; tetrachloromethane (carbon tetrachloride) is an example.

solvent extraction The process of separating one constituent from a mixture by dissolving it in a solvent in which it is soluble but in which the other constituents of the mixture are not. The process is usually carried out in the liquid phase, in which case it is also known as **liquid–liquid extraction**. In liquid–liquid extraction, the solution containing the desired constituent must be immiscible with the rest of the mixture. The process is widely used in extracting oil from oil-bearing materials.

solvolysis A reaction between a compound and its solvent. *See* HYDROLYSIS.

soman A highly toxic colourless volatile liquid, $C_7H_{16}FO_2P$; r.d. 1.02; m.p. –42°C; b.p. 198°C. It is an organophosphorus compound, O-pinacolyl methylphosphonofluoridate. Soman was discovered in 1944 and belongs to the G-series of *nerve agents (GD).

somatic **1.** Relating to all the cells of an animal or plant other than the reproductive cells. Thus a somatic *mutation is one that is

not heritable. **2.** Relating to organs and tissues of the body other than the gut and its associated structures. The term is applied especially to voluntary muscles, the sense organs, and the nervous system. *Compare* VISCERAL.

somatostatin (growth hormone inhibiting hormone; GHIH) A hormone, secreted by the hypothalamus, that inhibits the release of *growth hormone from the anterior pituitary gland. The secretion of somatostatin is stimulated by various factors, including very high blood glucose levels, which result from the effect that growth hormone has on glucose metabolism. It is also produced by the D cells of the *islets of Langerhans in the pancreas and can inhibit the release of glucagon and insulin from the islets.

somatotrophin *See* GROWTH HORMONE.

sonar *See* ECHO.

sonic boom A strong *shock wave generated by an aircraft when it is flying in the earth's atmosphere at supersonic speeds. This shock wave is radiated from the aircraft and where it intercepts the surface of the earth a loud booming sound is heard. The loudness depends on the speed and altitude of the aircraft and is lower in level flight than when the aircraft is undertaking a manoeuvre. The maximum increase of pressure in the shock wave during a transoceanic flight of a commercial supersonic transport (SST) is 120 Pa, equivalent to 136 decibels.

Sonic hedgehog (SHH) A protein that has a crucial role in patterning and development of tissues in vertebrates, particularly of the nervous and skeletal systems. It is homologous to **Hedgehog protein**, which performs a similar function in the fruit fly *Drosophila* – Hedgehog was so named because mutation of its gene in *Drosophila* produced flies bearing spiky denticles resembling the spines of a hedgehog. Sonic hedgehog was named after a video game character.

sonochemistry The study of chemical reactions in liquids subjected to high-intensity sound or ultrasound. This causes the formation, growth, and collapse of tiny bubbles within the liquid, generating localized centres of very high temperature and pressure, with extremely rapid cooling rates. Such conditions are suitable for studying novel reactions, decomposing polymers, and producing amorphous materials.

sonometer A device consisting essentially of a hollow sounding box with two bridges attached to its top. The string, fixed to the box at one end, is stretched between the two bridges so that the free end can run over a pulley and support a measured load. When the string is plucked the frequency of the note can be matched with that of another sound source, such as a tuning fork. It can be used to verify that the frequency (f) of a stretched string is given by $f = (1/2l)\sqrt{(T/m)}$, where l is the length of the string, m is its mass per unit length, and T is its tension.

Originally called the **monochord**, the sonometer was widely used as a tuning aid, but is now used only in teaching laboratories.

sorosis A type of *composite fruit formed from an entire inflorescence spike. Mulberry and pineapple fruits are examples.

sorption *Absorption of a gas by a solid.

sorption pump A type of vacuum pump in which gas is removed from a system by absorption on a solid (e.g. activated charcoal or a zeolite) at low temperature.

sorus **1.** Any of the spore-producing structures on the undersurface of a fern frond, visible as rows of small brown dots. **2.** A reproductive area on the thallus of some algae, e.g. *Laminaria*. **3.** Any of various spore-producing structures in certain fungi.

sound A vibration in an elastic medium at a frequency and intensity that is capable of being heard by the human ear. The frequency of sounds lie in the range 20–20 000 Hz, but the ability to hear sounds in the upper part of the frequency range declines with age (*see also* PITCH). Vibrations that have a lower frequency than sound are called **infrasounds** and those with a higher frequency are called **ultrasounds**.

Sound is propagated through an elastic fluid as a longitudinal **sound wave**, in which a region of high pressure travels through the fluid at the *speed of sound in that medium. At a frequency of about 10 kilohertz the maximum excess pressure of a sound wave in air lies between 10^{-4} Pa and 10^{3} Pa. Sound travels through solids as either longitudinal or transverse waves.

source **1.** The electrode in a field-effect *transistor from which electrons or holes enter the interelectrode space. **2.** *See* MASS FLOW.

Southern blotting A chromatographic

S

technique for isolating and identifying specific fragments of DNA, such as the fragments formed as a result of DNA cleavage by *restriction enzymes. The mixture of fragments is subjected to electrophoresis through an agarose gel, followed by denaturation to form single-stranded fragments. These are transferred, or 'blotted', onto a nitrocellulose filter where they are immobilized in their relative positions. Specific *gene probes labelled with a radioisotope or fluorescent marker are then added. These hybridize with any complementary fragments on the filter, which are subsequently revealed by autoradiography or a fluorescence detector. The technique was devised by E. M. Southern. A similar technique for detecting RNA fragments is called **Northern blotting**, by analogy. *See also* WESTERN BLOTTING.

Soxhlet apparatus An apparatus for extracting components from a solid (e.g. extracting natural products from plant material). The material used is placed in a thimble made of thick filter paper and this is held in a specially designed reflex condenser with a suitable solvent. The chamber holding the thimble fills with warm solvent and this is led back to the source via a side arm. The apparatus can be operated for long periods, with components concentrating in the source vessel. It is named after Franz Soxhlet, who devised it in 1879.

space **1.** A property of the universe that enables physical phenomena to be extended into three mutually perpendicular directions. In Newtonian physics, space, time, and matter are treated as quite separate entities. In Einsteinian physics, space and time are combined into a four-dimensional continuum (*see* SPACE–TIME) and in the general theory of *relativity matter is regarded as having an effect on space, causing it to curve. **2. (outer space)** The part of the universe that lies outside the earth's atmosphere.

space group A *group formed by the set of all symmetry operations of a crystal lattice. This set consists of translations, rotations, and reflections and their combinations, such as *glide and *screw. It was discovered in the late 19th century that there are 230 possible space groups for a lattice in three dimensions. Space groups are used in the quantum theory of solids and in structure analysis in crystallography.

space probe A crewless spacecraft that investigates features within the solar system. A **planetary probe** examines the conditions on or in the vicinity of one or more planets and a **lunar probe** is designed to obtain information about the moon. **Interplanetary probes**, such as the two Voyager probes launched in 1977, have toured the solar system and are now on the way out of it. Probes are propelled by rocket motors and once out of the earth's gravitational field use their propulsion systems for course changes. Many use panels of *solar cells, for powering internal computer operations, on-board sensors, and radio communications.

space-reflection symmetry *See* PARITY.

space–time (space–time continuum) A geometry that includes the three dimensions and a **fourth dimension** of time. In Newtonian physics, space and time are considered as separate entities and whether or not events are simultaneous is a matter that is regarded as obvious to any competent observer. In Einstein's concept of the physical universe, based on a system of geometry devised by Hermann Minkowski (1864–1909), space and time are regarded as entwined, so that two observers in relative motion could disagree regarding the simultaneity of distant events. In Minkowski's geometry, an event is identified by a **world point** in a four-dimensional continuum.

spadix A flowering shoot (a type of *spike) with a large fleshy floral axis bearing small, usually unisexual, flowers. It is protected by a large petal-like bract, the **spathe**, and is characteristic of plants of the family Araceae (e.g. calla lily).

spallation A type of nuclear reaction in which the interacting nuclei disintegrate into a large number of protons, neutrons, and other light particles, rather than exchanging nucleons between them. It is thought that most of the nuclei of light elements, such as boron, are made in this way. Spallation reactions of this type are thought to occur in interstellar space when a high-energy particle, such as a proton, hits a nucleus.

spark *See* ELECTRIC SPARK.

spark chamber A device for detecting charged particles. It consists of a chamber, filled with helium and neon at atmospheric pressure, in which a stack of 20 to 100 plates are placed; the plates are connected alternately to the positive and negative terminals

of a source of high potential (10 000 V or more). An incoming particle creates ion pairs in its track, causing the gas to become conducting and sparks to jump between the plates. The light from the sparks is focused to obtain stereoscopic photographs of the particles' tracks. It can also function as a counter (called a **spark counter**) when connected to suitable counting circuits. Some versions use crossed sets of parallel wires rather than plates; simple patterns may have a single wire near a plate, in the open atmosphere.

spark counter *See* SPARK CHAMBER.

spathe *See* SPADIX.

special creation The belief, in accordance with the Book of Genesis, that every species was individually created by God in the form in which it exists today and is not capable of undergoing any change. It was the generally accepted explanation of the origin of life until the advent of *Darwinism. The idea has recently enjoyed a revival, especially among members of the fundamentalist movement in the USA, partly because there still remain problems that cannot be explained entirely by Darwinian theory. However, special creation is contradicted by fossil evidence and genetic studies, and the pseudoscientific arguments of **creation science** cannot stand up to logical examination.

specialization **1.** Increasing *adaptation of an organism to a particular environment. **2.** *See* PHYSIOLOGICAL SPECIALIZATION.

special theory of relativity *See* RELATIVITY.

speciation The development of one or more species from an existing species. It occurs when *sympatric or *allopatric populations diverge so much from the parent population that interbreeding can no longer occur between them.

species **1.** (in biology) A category used in the *classification of organisms. Similar species are grouped into a genus and a single species may be subdivided into *subspecies or *races (*see also* BINOMIAL NOMENCLATURE). According to the biological species concept, a species comprises a group of individuals that can usually breed among themselves and produce fertile offspring. Typically, a species consists of numerous local populations distributed over a geographical range. Within a species, groups of individuals become reproductively isolated because of geographical or behavioural factors (*see* ISOLATING MECHANISM), and over time may evolve different characteristics and form new and distinct species. **2.** (in chemistry) A chemical entity, such as a particular atom, ion, or molecule.

species diversity *See* BIODIVERSITY.

specific **1.** (in physics) **a.** Denoting that an extensive physical quantity so described is expressed per unit mass. For example, the **specific latent heat** of a body is its latent heat per unit mass. When the extensive physical quantity is denoted by a capital letter (e.g. L for latent heat), the specific quantity is denoted by the corresponding lower-case letter (e.g. l for specific latent heat). **b.** In some older physical quantities the adjective 'specific' was added for other reasons (e.g. specific gravity, specific resistance). These names are now no longer used. **2.** (in biology) Relating to a species.

specific activity *See* ACTIVITY.

specific charge The ratio of the charge of an *elementary particle or other charged body to its mass.

specific gravity *See* RELATIVE DENSITY; SPECIFIC.

specific heat capacity *See* HEAT CAPACITY.

specific humidity *See* HUMIDITY.

specific impulse A measure of the thrust available from a rocket propellant. It is the ratio of the thrust produced to the fuel consumption.

specific intensity *See* PLANCK'S RADIATION LAW.

specific latent heat *See* LATENT HEAT.

specific resistance *See* RESISTIVITY; SPECIFIC.

specific surface The surface area of a particular substance per unit mass, expressed in $m^2\ kg^{-1}$. It provides a measure of the surface area available for a process, such as adsorption, for a given mass of a powder or porous substance.

specific volume The volume of a substance per unit mass. The reciprocal of density, it has the units $m^3\ kg^{-1}$.

speckle interferometer An instrument

that improves the resolving power of an astronomical telescope by reducing the distortion produced by atmospheric turbulence (which greatly mars long-exposure photographs). Many short-exposure photographs are taken, one after the other, effectively 'freezing' the turbulence effects and producing a series of point images free from distortion. The overall image is obtained by combining these images.

spectral class (spectral type) Any of a set of categories to which stars can be assigned, based on the characteristics of their spectra. The **Harvard classification**, introduced in 1890 and modified in the 1920s, is based on the seven star types known as O, B, A, F, G, K, M:

O hottest blue stars; ionized helium lines dominant

B hot blue stars; neutral helium lines dominant, no ionized helium

A blue blue-white stars; hydrogen lines dominant

F white stars; metallic lines strengthen, hydrogen lines weaken

G yellow stars; ionized calcium lines dominant

K orange-red stars; neutral metallic lines dominant, some molecular bands

M coolest red stars; molecular bands dominant

Each class is divided into 10 subclasses denoted by the digits 0 to 9. Thus the sun is described as a yellow dwarf of spectral class G2. Further categorization will assign a star to a luminosity class, indicate the presence of emission lines, etc. Other classification letters are also used, e.g. DA for white dwarf stars, or W for Wolf-Rayet stars.

S

spectrochemical series A series of ligands arranged in the order in which they cause splitting of the energy levels of d orbitals in metal complexes (*see* CRYSTAL-FIELD THEORY). The series for some common ligands has the form:

$$CN^- > NO_2^- > NH_3 > C_5H_5N > H_2O > OH^- > F^- > Cl^- > Br^- > I^-$$

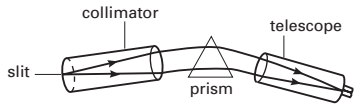
spectrograph *See* SPECTROSCOPE.

spectroheliogram A photograph of the sun's chromosphere taken at a particular wavelength of light with the aid of a high-dispersion *spectroscope. Various levels of the chromosphere can be studied by varying the wavelength slightly.

spectrometer Any of various instruments for producing a spectrum and measuring the wavelengths, energies, etc., involved. A simple type, for visible radiation, is a spectroscope equipped with a calibrated scale allowing wavelengths to be read off or calculated. In the X-ray to infrared region of the electromagnetic spectrum, the spectrum is produced by dispersing the radiation with a prism or diffraction grating (or crystal, in the case of hard X-rays). Some form of photoelectric detector is used, and the spectrum can be obtained as a graphical plot, which shows how the intensity of the radiation varies with wavelength. Such instruments are also called **spectrophotometers**. Spectrometers also exist for investigating the gamma-ray region and the microwave and radio-wave regions of the spectrum (*see* ELECTRON PARAMAGNETIC RESONANCE; NUCLEAR MAGNETIC RESONANCE). Instruments for obtaining spectra of particle beams are also called spectrometers (*see* SPECTRUM; PHOTOELECTRON SPECTROSCOPY).

spectrophotometer *See* SPECTROMETER.

spectroscope An optical instrument that produces a *spectrum for visual observation. The first such instrument was made by R. W. Bunsen; in its simplest form it consists of a hollow tube with a slit at one end by which the light enters and a collimating lens at the other end to produce a parallel beam, a prism to disperse the light, and a telescope for viewing the spectrum (see illustration). In the **spectrograph**, the spectroscope is provided with a camera to record the spectrum. For a broad range of spectroscopic work, from the ultraviolet to the infrared, a diffraction grating is used instead of a prism. *See also* SPECTROMETER.



Spectroscope.

spectroscopic binary *See* BINARY STARS.

spectroscopy The study of methods of producing and analysing *spectra using *spectroscopes, *spectrometers, spectrographs, and spectrophotometers. The interpretations of the spectra so produced can be used for chemical analysis, examining atomic and molecular energy levels and molecular structures, and for determining the

composition and motions of celestial bodies (*see* REDSHIFT).

SEE WEB LINKS

- The NIST atomic spectra database
- NIST Handbook of Basic Atomic Spectroscopic Data
- Original paper on spectroscopy by Kirchoff and Bunsen in *Annalen der Physik und der Chemie* (1860)

spectrum (*pl.* **spectra**) **1.** A distribution of entities or properties arrayed in order of increasing or decreasing magnitude. For example, a beam of ions passed through a mass spectrograph, in which they are deflected according to their charge-to-mass ratios, will have a range of masses called a **mass spectrum**. A **sound spectrum** is the distribution of energy over a range of frequencies of a particular source. **2.** A range of electromagnetic energies arrayed in order of increasing or decreasing wavelength or frequency (*see* ELECTROMAGNETIC SPECTRUM). The **emission spectrum** of a body or substance is the characteristic range of radiations it emits when it is heated, bombarded by electron or ions, or absorbs photons. The **absorption spectrum** of a substance is produced by examining, through the substance and through a spectroscope, a continuous spectrum of radiation. The energies removed from the continuous spectrum by the absorbing medium show up as black lines or bands. With a substance capable of emitting a spectrum, these are in exactly the same positions in the spectrum as some of the lines and bands in the emission spectrum.

Emission and absorption spectra may show a **continuous spectrum**, a **line spectrum**, or a **band spectrum**. A continuous spectrum contains an unbroken sequence of frequencies over a relatively wide range; it is produced by incandescent solids, liquids, and compressed gases. Line spectra are discontinuous lines produced by excited atoms and ions as they fall back to a lower energy level. Band spectra (closely grouped bands of lines) are characteristic of molecular gases or chemical compounds. *See also* ACTION SPECTRUM; SPECTROSCOPY.

speculum An alloy of copper and tin formerly used in reflecting telescopes to make the main mirror as it could be cast, ground, and polished to make a highly reflective surface. It has now been largely replaced by silvered glass for this purpose.

speed The ratio of a distance covered by a body to the time taken. Speed is a *scalar quantity, i.e. no direction is given. Velocity is a *vector quantity, i.e. both the rate of travel and the direction are specified.

speed of light Symbol c. The speed at which electromagnetic radiation travels. The speed of light in a vacuum is $2.997\ 924\ 58 \times 10^8$ m s^{-1}. When light passes through any material medium its speed is reduced (*see* REFRACTIVE INDEX). The speed of light in a vacuum is the highest speed attainable in the universe (*see* RELATIVITY; CERENKOV RADIATION). It is a universal constant and is independent of the speed of the observer. Since October 1983 it has formed the basis of the definition of the *metre.

speed of sound Symbol c or c_s. The speed at which sound waves are propagated through a material medium. In air at 20°C sound travels at 344 m s^{-1}, in water at 20°C it travels at 1461 m s^{-1}, and in steel at 20°C at 5000 m s^{-1}. The speed of sound in a medium depends on the medium's modulus of elasticity (E) and its density (ρ) according to the relationship $c = \sqrt{(E/\rho)}$. For longitudinal waves in a narrow solid specimen, E is the Young modulus; for a liquid E is the bulk modulus (*see* ELASTIC MODULUS); and for a gas $E = \gamma p$, where γ is the ratio of the principal specific *heat capacities and p is the pressure of the gas. For an ideal gas the relationship takes the form $c = \sqrt{(\gamma r T)}$, where r is the gas constant per unit mass and T is the thermodynamic temperature. This equation shows how the speed of sound in a gas is related to its temperature. This relationship can be written $c = c_0\sqrt{(1 + t/273)}$, where c_0 is the speed of sound in a particular gas at 0°C and t is the temperature in °C.

sperm **1.** A single *spermatozoon. **2.** Spermatozoa, collectively.

spermatheca (seminal receptacle) A sac or receptacle in some female or hermaphrodite animals (e.g. earthworms) in which sperm from the mate is stored until the eggs are ready to be fertilized.

spermatid A nonmotile cell, produced during *spermatogenesis, that subsequently differentiates into a mature spermatozoon. Four spermatids are formed after two meiotic divisions of a primary spermatocyte and therefore contain the *haploid number of chromosomes.

spermatogenesis The series of cell divisions in the testis that results in the produc-

tion of spermatozoa. Within the seminiferous tubules of the testis germ cells grow and divide by mitosis to produce **spermatogonia**. These divide by mitosis to produce **spermatocytes**, which divide by meiosis to produce *spermatids. The spermatids, which thus have half the number of chromosomes of the original germ cells, then develop into spermatozoa.

Spermatophyta In traditional classifications, a division of the plant kingdom containing plants that reproduce by means of *seeds. In modern systems seed plants are grouped into separate phyla, the most important of which are the *Anthophyta and *Coniferophyta.

spermatozoid *See* ANTHEROZOID.

spermatozoon (sperm) The mature mobile reproductive cell (*see* GAMETE) of male animals, which is produced by the testis (*see* SPERMATOGENESIS). It consists of a head section containing a *haploid nucleus and an **acrosome**, a membranous sac that releases enzymes allowing the sperm to penetrate the egg at fertilization; a middle section containing *mitochondria to provide the energy for movement; and a tail section, which lashes to drive the sperm forward.

sperm competition Competition between sperm from different males to reach and fertilize the egg cell of a single female. Sperm competition can occur among rodents in which a male mates a number of times with the same female, with a rest period between successive matings during which the sperm journeys towards the egg. If a second male mates with the female during a rest period its own sperm may disrupt the movement of sperm from the first male and succeed in fertilizing the egg cell. Certain animals in which sperm competition is possible have evolved features to minimize this interference. For example, in moths and butterflies the male cements the opening of the female genitalia after mating, thereby preventing further matings with other males. An ingenious mechanism operates in the fly *Johannseniella nitida*, in which the female eats a copulating male except for his genitalia, which remain in the body of the female and prevent further mating.

sphalerite (zinc blende) A mineral form of zinc sulphide, ZnS, crystallizing in the cubic system; the principal ore of zinc. It is usually yellow-brown to brownish-black in colour and occurs, often with galena, in metasomatic deposits and also in hydrothermal veins and replacement deposits. Sphalerite is mined on every continent, the chief sources including the USA, Canada, Mexico, Australia, Peru, and Poland.

sphalerite structure (zinc-blende structure) A type of ionic crystal structure in which the anions have an expanded face-centred cubic arrangement with the cations occupying one type of tetrahedral hole. The coordination number of each type of ion is 4. Examples of compounds with the sphalerite structure are ZnS, CuCl, CdS, and InAs.

SEE WEB LINKS

- An interactive version of the structure

Sphenophyta (Arthrophyta) A phylum of *tracheophyte plants, the only living members of which are the horsetails (*Equisetum*). Horsetails have a perennial creeping rhizome supporting erect jointed stems bearing whorls of thin leaves. Spores are produced by terminal conelike structures. The group has a fossil record extending back to the Palaeozoic with its greatest development in the Carboniferous period, when giant tree forms were the dominant vegetation with the *Lycophyta.

sphere The figure generated when a circle is rotated about a diameter. The volume of a sphere is $4\pi r^3/3$ and its surface area is $4\pi r^2$, where r is its radius. In Cartesian coordinates the equation of a sphere centred at the origin is $x^2 + y^2 + z^2 = r^2$.

spherical aberration *See* ABERRATION.

spherical mirror *See* MIRROR.

spherical polar coordinates *See* POLAR COORDINATES.

spherometer An instrument for measuring the curvature of a surface. The usual instrument for this purpose consists of a tripod, the pointed legs of which rest on the spherical surface at the corners of an equilateral triangle. In the centre of this triangle is a fourth point, the height of which is adjusted by means of a micrometer screw (see illustration). If the distance between each leg and the axis through the micrometer screw is l, and the height of the micrometer point above (or below) a flat surface is x, the radius (r) of the sphere is given by $r = (l^2 + x^2)/2x$.

sphincter A specialized muscle encircling an opening or orifice. Contraction of the

S

sphincter tends to close the orifice. Examples are the **anal sphincter** (round the opening of the anus) and the **pyloric sphincter** (at the lower opening of the *stomach).

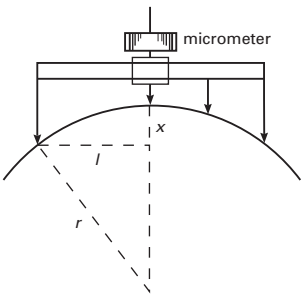
sphingolipid *See* PHOSPHOLIPID.

spiders *See* ARACHNIDA.

spiegel (spiegeleisen) A form of *pig iron containing 15–30% of manganese and 4–5% of carbon. It is added to steel in a Bessemer converter as a deoxidizing agent and to raise the manganese content of steel.

spike A type of *racemose inflorescence in which stalkless flowers arise from an undivided floral axis, as in plantain and *Orchis*. In the family Gramineae (Poaceae; sedges and grasses) the flowers are grouped in clusters called **spikelets**, which may be arranged to form a compound spike (as in wheat).

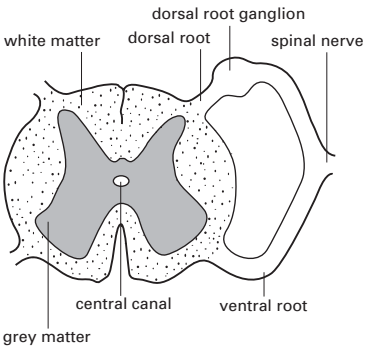
spin (intrinsic angular momentum) Symbol s. The part of the total angular momentum of a particle, atom, nucleus, etc., that can continue to exist even when the particle is apparently at rest, i.e. when its translational motion is zero and therefore its orbital angular momentum is zero. A molecule, atom, or nucleus in a specified energy level, or a particular elementary particle, has a particular spin, just as it has a particular charge or mass. According to *quantum theory, this is quantized and is restricted to multiples of $h/2\pi$, where h is the *Planck constant. Spin is characterized by a quantum number s (or m_s). For example, for an electron $s = \pm\frac{1}{2}$, implying a spin of $+h/4\pi$ when it is spinning in one direction and $-h/4\pi$ when it is spinning in the other. Because of their spin, particles also have their own intrinsic *magnetic moments and in a magnetic field the spin of the particles lines up at an angle to the direction of the field, precessing around this direction. *See also* ELECTRON-SPIN RESONANCE; NUCLEAR MAGNETIC RESONANCE.



Spherometer.

spinal column *See* VERTEBRAL COLUMN.

spinal cord The part of the vertebrate central nervous system that is posterior to the brain and enclosed within the *vertebral column. It consists of a hollow core of *grey matter (H-shaped in cross section) surrounded by an outer layer of *white matter; the central cavity contains *cerebrospinal fluid. The white matter contains numerous longitudinal nerve fibres organized into distinct tracts: **ascending tracts** consist of sensory neurons, conducting impulses towards the brain; **descending tracts** consist of motor neurons, transmitting impulses from the brain. Paired *spinal nerves arise from the spinal cord.



Spinal cord. Transverse section of the spinal cord.

spinal nerves Pairs of nerves that arise from the *spinal cord (*compare* CRANIAL NERVES). In humans there are 31 pairs (one from each of the vertebrae). Each nerve arises from a *dorsal root and a *ventral root and contains both motor and sensory fibres (i.e. they are mixed nerves). The spinal nerves form an important part of the *peripheral nervous system.

spinal reflex *See* REFLEX.

spindle **1.** A structure formed from *microtubules in the cytoplasm during cell division that moves chromatids (*see* MITOSIS) or chromosomes (*see* MEIOSIS) diametrically apart and gathers them in two clusters at opposite

ends (poles) of the cell. Broadest in the middle (the **spindle equator**) and narrowing to a point at either pole, its construction is directed by the *centrosome. The spindle becomes fully formed by metaphase, when the chromatids are attached to spindle fibres via their *centromeres and lie at the spindle equator. During anaphase this set of fibres shortens and hauls the attached chromatids towards the corresponding pole of the cell. Also, the overlapping fibres at the equator actively engage and slide past each other to elongate the entire spindle. **2.** *See* MUSCLE SPINDLE.

spindle attachment *See* CENTROMERE.

spin drag The resistance to the transport of spins in a quantum-mechanical system.

spine **1.** *See* VERTEBRAL COLUMN. **2.** A hard pointed protective structure on a plant that is formed through modification of a leaf, part of a leaf, or a stipule. The edge of the holly leaf is drawn out into spines, but in cacti the whole leaf is modified as a spine. *Compare* PRICKLE; THORN.

spinel A group of oxide minerals with the general formula $F^{2+}R_2^{3+}O_4$, where F^{2+} = Mg, Fe, Zn, Mn, or Ni and R^{3+} = Al, Fe, or Cr, crystallizing in the cubic system. The spinels are divided into three series: spinel ($MgAl_2O_4$), *magnetite, and *chromite. They occur in high-temperature igneous or metamorphic rocks.

spinel structure An ionic crystal structure shown by compounds of the type AB_2O_4. There is a face-centred cubic arrangement of O^{2-} ions. The A cations occupy one eighth of the tetrahedral holes and the B cations occupy the octahedral holes. Examples of the spinel structure are $MgAl_2O_4$, Fe_3O_4, and Mn_3O_4.

SEE WEB LINKS

- An interactive version of the structure

spin glass An alloy of a small amount of a magnetic metal (0.1–10%) with a nonmagnetic metal, in which the atoms of the magnetic element are randomly distributed through the crystal lattice of the nonmagnetic element. Examples are AuFe and CuMn. Theories of the magnetic and other properties of spin glasses are complicated by the random distribution of the magnetic atoms.

spin Hall effect An analogue of the *Hall effect for spin, i.e. there is an accumulation of particles with opposite spins on the opposite surfaces of a material in which a current is flowing. However, the analogy is not complete since an external magnetic field destroys the effect, resulting in the spins precessing around the magnetic field. The spin Hall effect is due to *spin–orbit coupling.

spin label A molecule or group that contains an unpaired electron and can be attached to another molecule. The spin of the unpaired electron can be detected by electron paramagnetic resonance. The technique of spin labelling is used to investigate proteins and biological systems.

spinneret A small tubular appendage from which silk is produced in spiders and some insects. Spiders have four to six spinnerets on the hind part of the abdomen, into which numerous silk glands open. The silk is secreted as a fluid and hardens on contact with the air. It is composed of α-keratin crystals embedded in a matrix of amino-acid chains, giving the material its flexibility and strength. Various types of silk are produced depending on its use (e.g. for webs, egg cocoons, etc.). The spinnerets that produce the cocoons of insects are not homologous with those of spiders. For example, the spinneret of the silkworm is in the pharynx and the silk is produced by modified salivary glands.

spinor A mathematical entity similar to a vector but having the property that it changes sign on each rotation through 360°. The wave function of a spin-½ particle, such as an electron, in relativistic quantum mechanics is an example of a spinor. Spinors have also been used extensively in general relativity theory. There have also been many attempts to base the theory of elementary particles on spinors.

spin–orbit coupling An interaction between the orbital angular momentum and the spin angular momentum of an individual particle, such as an electron. For light atoms, spin–orbit coupling is small so that *multiplets of many-electron atoms are described by *Russell–Saunders coupling. For heavy atoms, spin–orbit coupling is large so that multiplets of many-electron atoms are described by *j-j coupling. For medium-sized atoms the sizes of the energies associated with spin–orbit coupling are comparable to the sizes of energies associated with electrostatic repulsion between the electrons, the multiplets in this case being described as

having **intermediate coupling**. Spin–orbit coupling is large in many nuclei, particularly heavy nuclei.

spin–statistics theorem A fundamental theorem of relativistic *quantum field theory that states that half-integer *spins can only be quantized consistently if they obey Fermi–Dirac statistics and even-integer spins can only be quantized consistently if they obey Bose–Einstein statistics (*see* QUANTUM STATISTICS). This theorem enables one to understand the result of quantum statistics that wave functions for bosons are symmetric and wave functions for fermions are antisymmetric. It also provides the foundation for the *Pauli exclusion principle. It was first proved by Wolfgang Pauli in 1940.

spin transport The transport of spin in a quantum mechanical system. Spin transport is of key importance in spintronics, the branch of technology that makes use of the spin of electrons in electronic devices. The physical origin of spin transport is *spin–orbit coupling. Spin transport can be used to enhance the technological effectiveness of systems based on magnetism.

spin wave (magnon) A *collective excitation associated with magnetic systems. Spin waves occur in both ferromagnetic and antiferromagnetic systems (*see* MAGNETISM).

spiracle **1.** A small paired opening that occurs on each side of the head in cartilaginous fish. It is the reduced first *gill slit, its small size resulting from adaptations of the skeleton for the firm attachment of the jaws. In modern teleosts (bony fish) the spiracle is closed up. In tetrapods the first gill slit develops into the middle ear cavity. **2.** Any of the external openings of the *tracheae along the side of the body of an insect.

spiral galaxy *See* GALAXY.

spirillum Any rigid spiral-shaped bacterium. Generally, spirilla are Gram-negative (*see* GRAM'S STAIN), aerobic, and highly motile, bearing flagella either singly or in tufts. They occur in soil and water, feeding on organic matter.

spirits of salt A name formerly given to hydrogen chloride because this compound can be made by adding sulphuric acid to common salt (sodium chloride).

spirochaete Any nonrigid corkscrew-shaped bacterium that moves by means of flexions of the cell. Most spirochaetes are Gram-negative (*see* GRAM'S STAIN), anaerobic, and feed on dead organic matter. They are very common in sewage-polluted waters. Some, however, can cause disease; *Treponema*, the agent of syphilis, is an example.

spirometer *See* RESPIROMETER.

spleen A vertebrate organ, lying behind the stomach, that is basically a collection of *lymphoid tissue. Its functions include producing lymphocytes and destroying foreign particles. It acts as a reservoir for erythrocytes and can regulate the number in circulation. It is also the site for the breakdown of worn-out erythrocytes and it stores the iron they contain.

splicing *See* GENE SPLICING.

SPM *See* SCANNING PROBE MICROSCOPY.

sponges *See* PORIFERA.

spongy bone *See* BONE.

spongy mesophyll *See* MESOPHYLL.

spontaneous combustion Combustion in which a substance produces sufficient heat within itself, usually by a slow oxidation process, for ignition to take place without the need for an external high-temperature energy source.

spontaneous emission The emission of a photon by an atom as it makes a transition from an excited state to the ground state. Spontaneous emission occurs independently of any external electromagnetic radiation; the transition is caused by interactions between atoms and vacuum fluctuations (*see* VACUUM STATE) of the quantized electromagnetic field. The process of spontaneous emission, which cannot be described by non-relativistic *quantum mechanics, as given by formulations such as the *Schrödinger equation, is responsible for the limited lifetime of an excited state of an atom before it emits a photon. *See also* EINSTEIN COEFFICIENTS; INDUCED EMISSION; LASER; QUANTUM THEORY OF RADIATION.

spontaneous generation The discredited belief that living organisms can somehow be produced by nonliving matter. For example, it was once thought that microorganisms arose by the process of decay and even that vermin spontaneously developed from household rubbish. Controlled experiments using sterilized media by Pasteur and others finally disproved these notions. *Compare* BIOGENESIS. *See also* BIOPOIESIS.

sporangium A reproductive structure in plants that produces asexual spores. *See* SPOROPHYLL.

spore A reproductive cell that can develop into an individual without first fusing with another reproductive cell (*compare* GAMETE). Spores are produced by plants, fungi, bacteria, and some protozoa. A spore may develop into an organism resembling the parent or into another stage in the life cycle, either immediately or after a period of dormancy. In plants showing *alternation of generations, spores are formed by the *sporophyte generation and give rise to the *gametophyte generation. In ferns, the rows of brown reproductive structures on the undersurface of the fronds are spore-producing bodies.

spore mother cell (sporocyte) A diploid cell that gives rise to four haploid spores by meiosis.

sporocyte *See* SPORE MOTHER CELL.

sporogonium The *sporophyte generation in mosses and liverworts. It is made up of an absorptive **foot**, a stalk (**seta**), and a spore-producing **capsule**. It may be completely or partially dependent on the *gametophyte.

sporophore (fructification) The aerial spore-producing part of certain fungi; for example, the stalk and cap of a mushroom.

sporophyll A leaf that bears **sporangia** (spore-producing structures). In ferns the sporophylls are the normal foliage leaves, but in other plants the sporophylls are modified and arise in specialized structures such as the strobilus (cone) of clubmosses, horsetails, and gymnosperms and the flower of angiosperms. Most plants produce spores of two different sizes (small **microspores** and large **megaspores**). The sporophylls bearing these are called **microsporophylls** and **megasporophylls** respectively.

sporophyte The generation in the life cycle of a plant that produces spores. The sporophyte is *diploid but its spores are *haploid. It is either completely or partially dependent on the *gametophyte generation in mosses and liverworts but is the dominant plant in the life cycle of clubmosses, horsetails, ferns, and seed plants. *See also* ALTERNATION OF GENERATIONS.

spot test A simple test for a given substance using a reagent that changes colour when mixed with the substance. In forensic science spot tests are often called *presumptive tests.

spreadsheet A *computer program that enables a user to make mathematical calculations on rows and columns of figures. If figures are interrelated, changing (updating) one figure also automatically changes all the others that are dependent on it. The user can also enter formulae for manipulating selected figures or groups of figures in a particular way.

spring balance A simple form of *balance in which a force is measured by the extension it produces in a helical spring. The extension, which is read off a scale, is directly proportional to the force, provided that the spring is not overstretched. The device is often used to measure the weight of a body approximately.

s-process *See* ORIGIN OF THE ELEMENTS.

SPS Super Proton Synchrotron. *See* CERN.

sputtering The process by which some of the atoms of an electrode (usually a cathode) are ejected as a result of bombardment by heavy positive ions. Although the process is generally unwanted, it can be used to produce a clean surface or to deposit a uniform film of a metal on an object in an evacuated enclosure.

Squamata An order of reptiles comprising the lizards and snakes. They appeared at the end of the Triassic period, about 170 million years ago, and have invaded a wide variety of habitats. Most lizards have four legs and a long tail, eardrums, and movable eyelids. Snakes are limbless reptiles that lack eardrums; the eyes are covered by transparent immovable eyelids and the articulation of the jaws is very loose, enabling a wide gape to facilitate swallowing prey whole.

square-planar Describing a coordination compound in which four ligands positioned at the corners of a square coordinate to a metal ion at the centre of the square. *See* COMPLEX.

square wave A train of rectangular voltage pulses that alternate between two fixed values for equal lengths of time. The time of transition between each fixed value is negligible compared to the duration of the fixed value. See diagram.

squark *See* SUPERSYMMETRY.

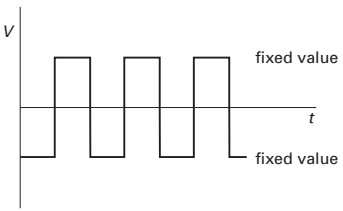
squeezed state A quantum state in a system in which the product in the Heisenberg *uncertainty principle takes the lowest possible value, i.e. the product $\delta x\,\delta p$, where δx is the uncertainty in position and δp is the uncertainty in momentum, is equal to $h/(4\pi)$, where h is the *Planck constant, rather than greater than $h/(4\pi)$, with analogous results for the uncertainty principle for other pairs of variables. The concept of a squeezed state is used extensively in quantum optics and in precision measurements.

SSSB *See* SMALL SOLAR SYSTEM BODY.

SSSI (Site of Special Scientific Interest) The legal designation for an area of land in England, Scotland, or Wales that has been identified by Natural England, Scottish Natural Heritage, or the Countryside Council for Wales as being of special interest because of its flora, fauna, or geological or physiographical features. Such sites are protected from development activities and funds are available for their conservation and management. There are over 6000 SSSIs in Britain; similar sites in Northern Ireland are designated **Areas of Special Scientific Interest** (**ASSIs**).

stability of matter The conclusion that matter consisting of a very large number of protons and electrons described by nonrelativistic *quantum mechanics is stable. An essential element in the proof of this conclusion, which was established by several authors in the 1960s, is the *Pauli exclusion principle.

stabilization energy The amount by which the energy of a delocalized chemical structure is less than the theoretical energy of a structure with localized bonds. It is obtained by subtracting the experimental heat of formation of the compound (in kJ mol^{-1}) from that calculated on the basis of a classical structure with localized bonds.



Square wave.

stabilizer **1.** A substance used to inhibit a chemical reaction, i.e. a negative catalyst. **2.** A substance used to prevent a colloid from coagulating.

stable equilibrium *See* EQUILIBRIUM.

staggered conformation *See* CONFORMATION.

staining A technique in which cells or thin sections of biological tissue that are normally transparent are immersed in one or more coloured dyes (**stains**) to make them more clearly visible through a microscope. Staining heightens the contrast between the various cell or tissue components. Stains are usually organic salts with a positive and negative ion. If the colour comes from the negative ion (organic anion), the stain is described as **acidic**, e.g. *eosin. If the colour comes from the positive ion (organic cation), the stain is described as **basic**, e.g. *haematoxylin. **Neutral stains** have a coloured cation and a coloured anion; an example is *Leishman's stain. Cell constituents are described as being **acidophilic** if they are stained with acidic dyes, **basophilic** if receptive to basic dyes, and **neutrophilic** if receptive to neutral dyes. **Vital stains** are used to colour the constituents of living cells without harming them (*see* VITAL STAINING); **nonvital stains** are used for dead tissue.

Counterstaining involves the use of two or more stains in succession, each of which colours different cell or tissue constituents. **Temporary staining** is used for immediate microscopical observation of material, but the colour soon fades and the tissue is subsequently damaged. **Permanent staining** does not distort the cells and is used for tissue that is to be preserved for a considerable period of time.

Electron stains, used in the preparation of material for electron microscopy, are described as **electron-dense** as they interfere with the transmission of electrons. Examples are lead citrate, phosphotungstic acid (PTA), and uranyl acetate (UA).

stainless steel A form of *steel containing at least 11–12% of chromium, a low percentage of carbon, and often some other elements, notably nickel and molybdenum. Stainless steel does not rust or stain and therefore has a wide variety of uses in industrial, chemical, and domestic environments. A particularly successful alloy is the steel known as 18–8, which contains 18% Cr, 8% Ni, and 0.08% C.

stalactites and stalagmites Accretions of calcium carbonate in limestone caves. Stalactites are tapering cones or pendants that hang down from the roofs of caves; stalagmites are upward projections from the cave floor and tend to be broader at their bases than stalactites. Both are formed from drips of water containing calcium hydrogencarbonate in solution and may take thousands of years to grow.

stamen One of the male reproductive parts of a flower. It consists of an upper fertile part (the *anther) on a thin sterile stalk (the **filament**).

staminode A sterile stamen.

standard cell A *voltaic cell, such as a *Clark cell, or *Weston cell, used as a standard of e.m.f.

standard deviation A measure of the dispersion of data in statistics. For a set of values a_1, a_2, a_3, …, a_n, the mean m is given by $(a_1 + a_2 + \ldots + a_n)/n$. The **deviation** of each value is the absolute value of the difference from the mean: $|m - a_1|$, etc. The standard deviation is the square root of the mean of the squares of these values, i.e.

$$\sqrt{[(|m - a_1|^2 + \ldots |m - a_n|^2)/n]}$$

When the data is continuous the sum is replaced by an integral.

standard electrode An electrode (a half cell) used in measuring electrode potential. *See* HYDROGEN HALF CELL.

standard electrode potential *See* ELECTRODE POTENTIAL.

standard form (scientific notation) A way of writing a number, especially a large or small number, in which only one integer appears before the decimal point, the value being adjusted by multiplying by the appropriate power of 10. For example, 236,214 would be written in the standard form as $2.362\ 14 \times 10^5$; likewise 0.006821047 would be written $6.821\ 047 \times 10^{-3}$. Note that in the standard form, commas are not used, the digits are grouped into threes and a space is left between groups.

standard model *See* ELEMENTARY PARTICLES.

standard solution A solution of known concentration for use in volumetric analysis.

standard state A state of a system used as a reference value in thermodynamic measurements. Standard states involve a reference value of pressure (usually one atmosphere, 101.325 kPa) or concentration (usually 1 M). Thermodynamic functions are designated as 'standard' when they refer to changes in which reactants and products are all in their standard and their normal physical state. For example, the standard molar enthalpy of formation of water at 298 K is the enthalpy change for the reaction

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)$$

$\Delta H^{\ominus}_{298} = -285.83$ kJ mol^{-1}.

Note that the superscript $^{\ominus}$ is used to denote standard state and the temperature should be indicated.

standard temperature and pressure *See* S.T.P.

standing biomass *See* STANDING CROP.

standing crop The total amount of living material in a specified population at a particular time, expressed as *biomass (**standing biomass**) or its equivalent in terms of energy. The standing crop may vary at different times of the year; for example, in a population of deciduous trees between summer and winter.

standing wave *See* STATIONARY WAVE.

stannane *See* TIN(IV) HYDRIDE.

stannate A compound formed by reaction of tin oxides (or hydroxides) with alkali. Tin oxides are amphoteric (weakly acidic) and react to give stannate ions. Tin(IV) oxide with molten alkali gives the stannate(IV) ion:

$$SnO_2 + 2OH^- \rightarrow SnO_3^{2-} + H_2O$$

In fact, there are various ions present in which the tin is bound to hydroxide groups, the main one being the hexahydroxostannate(IV) ion, $Sn(OH)_6^{2-}$. This is the negative ion present in crystalline 'trihydrates' of the type $K_2Sn_2O_3.3H_2O$.

Tin(II) oxide gives the trihydroxostannate(II) ion in alkaline solutions

$$SnO(s) + OH^-(aq) + H_2O(l) \rightarrow Sn(OH)_3^-(aq)$$

Stannate(IV) compounds were formerly referred to as **orthostannates** (SnO_4^{4-}) or **metastannates** (SnO_3^{2-}). Stannate(II) compounds were called **stannites**.

stannic compounds Compounds of tin in its higher (+4) oxidation state; e.g. stannic chloride is tin(IV) chloride.

stannite *See* STANNATE.

S

stannous compounds Compounds of tin in its lower (+2) oxidation state; e.g. stannous chloride is tin(II) chloride.

stapes (stirrup) The third of the three *ear ossicles of the mammalian middle ear.

Staphylococcus A genus of spherical nonmotile Gram-positive bacteria that occur widely as saprotrophs or parasites. The cells occur in grapelike clusters. Many species inhabit the skin and mucous membranes, and some cause disease in humans and animals. *S. aureus* infection can lead to boils and abscesses in humans; this species also produces *toxins that irritate the gastrointestinal tract and result in staphylococcal food poisoning. Certain strains are resistant to antibiotics, and infection with these is very difficult to treat. For example, some strains of methicillin-resistant *S. aureus* (**MRSA**) are now resistant to nearly all antibiotics and pose a grave threat, both to patients in hospitals and to individuals in the wider community.

star A self-luminous celestial body, such as the *sun, that generates nuclear energy within its core. Stars are not distributed uniformly throughout the universe, but are collected together in *galaxies. The age and lifetime of a star are related to its mass (*see* STELLAR EVOLUTION; HERTZSPRUNG–RUSSELL DIAGRAM).

starch A *polysaccharide consisting of various proportions of two glucose polymers, *amylose and *amylopectin. It occurs widely in plants, especially in roots, tubers, seeds, and fruits, as a carbohydrate energy store. Starch is therefore a major energy source for animals. When digested it ultimately yields glucose. Starch granules are insoluble in cold water but disrupt if heated to form a gelatinous solution. This gives an intense blue colour with iodine solutions and starch is used as an *indicator in certain titrations.

star cluster A group of stars that are sufficiently close to each other for them to be physically associated. Stars belonging to the cluster are formed together from the same cloud of interstellar gas and have approximately the same age and initial chemical composition. Because of this, and since the stars in a given cluster are at roughly the same distance from earth, observations of star clusters are of great importance in studies of stellar evolution.

There are two types of star cluster. **Open** (or **galactic**) **clusters** are fairly loose systems of between a few hundred and a few thousand members. The stars in open clusters are quite young by astronomical standards (some as young as a few million years) and have relatively high abundances of heavy elements. **Globular clusters** are approximately spherical collections of between ten thousand and a million stars. These are very old (of order 10^{10} years) and have low heavy-element abundances.

Stark effect The splitting of lines in the *spectra of atoms due to the presence of a strong electric field. It is named after the German physicist Johannes Stark (1874–1957), who discovered it in 1913. Like the normal *Zeeman effect, the Stark effect can be understood in terms of the classical electron theory of Lorentz. The Stark effect for hydrogen atoms was also described by the *Bohr theory of the atom. In terms of *quantum mechanics, the Stark effect is described by regarding the electric field as a *perturbation on the quantum states and energy levels of an atom in the absence of an electric field. This application of perturbation theory was its first use in quantum mechanics.

starquake A sudden change in the crust of a neutron star. In the case of neutron stars which are pulsars, starquakes are associated with 'glitches' in the regularity of the production of electromagnetic radiation from the pulsar. A starquake is the analogue of an earthquake for a neutron star. Ordinary stars do not have starquakes because they do not have crusts. It is possible to obtain information about the thickness and rigidity of the crust from analysing the patterns of glitches. The starquakes are associated with discontinuous slowing down of the rotating neutron star.

start codon (initiation codon) The triplet of nucleotides on a messenger *RNA molecule (*see* CODON) at which the process of *translation is initiated. In eukaryotes the start codon is AUG (*see* GENETIC CODE), which codes for the amino acid methionine; in bacteria the start codon can be either AUG, coding for *N*-formyl methionine, or GUG, coding for valine. *Compare* STOP CODON.

stat- A prefix attached to the name of a practical electrical unit to provide a name for a unit in the electrostatic system of units, e.g. statcoulomb, statvolt. *Compare* AB-. In mod-

ern practice both absolute and electrostatic units have been replaced by *SI units.

state of matter One of the three physical states in which matter can exist, i.e. *solid, *liquid, or *gas. *Plasma is sometimes regarded as the fourth state of matter.

static electricity The effects produced by electric charges at rest, including the forces between charged bodies (*see* COULOMB'S LAW) and the field they produce (*see* ELECTRIC FIELD).

statics The branch of mechanics concerned with bodies that are acted upon by balanced forces and couples so that they remain at rest or in unaccelerated motion. *Compare* DYNAMICS.

stationary orbit *See* SYNCHRONOUS ORBIT.

stationary phase **1.** *See* CHROMATOGRAPHY. **2.** *See* BACTERIAL GROWTH CURVE.

stationary state A state of a system when it has an energy level permitted by *quantum mechanics. Transitions from one stationary state to another can occur by the emission or absorption of an appropriate quanta of energy (e.g. in the form of photons).

stationary wave (standing wave) A form of *wave in which the profile of the wave does not move through the medium but remains stationary. This is in contrast to a **travelling** (or **progressive**) **wave**, in which the profile moves through the medium at the speed of the wave. A stationary wave results when a travelling wave is reflected back along its own path. In a stationary wave there are points at which the displacement is zero; these are called **nodes**. Points of maximum displacement are called **antinodes**. The distance between a node and its neighbouring antinode is one quarter of a wavelength. In a stationary wave all the points along the wave have different amplitudes and the points between successive nodes are in phase; in a travelling wave every point vibrates with the same amplitude and the phase of vibration changes for different points along its path.

statistical mechanics The branch of physics in which statistical methods are applied to the microscopic constituents of a system in order to predict its macroscopic properties. The earliest application of this method was Boltzmann's attempt to explain the thermodynamic properties of gases on the basis of the statistical properties of large assemblies of molecules.

In classical statistical mechanics, each particle is regarded as occupying a point in *phase space, i.e. to have an exact position and momentum at any particular instant. The probability that this point will occupy any small volume of the phase space is taken to be proportional to the volume. The Maxwell–Boltzmann law gives the most probable distribution of the particles in phase space.

With the advent of quantum theory, the exactness of these premises was disturbed (by the Heisenberg uncertainty principle). In the *quantum statistics that evolved as a result, the phase space is divided into cells, each having a volume h^f, where h is the Planck constant and f is the number of degrees of freedom of the particles. This new concept led to Bose–Einstein statistics, and for particles obeying the Pauli exclusion principle, to Fermi–Dirac statistics.

statistics The branch of mathematics concerned with the inferences that can be drawn from numerical data on the basis of probability. A **statistical inference** is a conclusion drawn about a population as a result of an analysis of a representative sample. *See* SAMPLING.

statocyst (otocyst) A balancing organ found in many invertebrates. It consists of a fluid-filled sac lined with sensory hairs and contains granules of calcium carbonate, sand, etc. (**statoliths**). As the animal moves the statoliths stimulate different hairs, giving a sense of the position of the body or part of it. The *semicircular canals in the ears of vertebrates act on the same principle and have a similar function.

stator The stationary electromagnetic structure of an electric motor or electric generator. *Compare* ROTOR.

steady-state theory The cosmological theory that the universe has always existed in a steady state, that it had no beginning, will have no end, and has a constant mean density. To compensate for the observed *expansion of the universe this theory postulates that matter is created throughout the universe at a rate of about 10^{-10} nucleon per metre cubed per year as a property of space. Because it has failed to account for the *microwave background radiation or the evidence of evolution in the universe it has lost favour to the *big-bang theory. It was first

proposed by Hermann Bondi (1919–2005), Thomas Gold (1920–2004), and Fred Hoyle in 1948.

steam distillation A method of distilling liquids that are immiscible with water by bubbling steam through them. It depends on the fact that the vapour pressure (and hence the boiling point) of a mixture of two immiscible liquids is lower than the vapour pressure of either pure liquid.

steam engine A *heat engine in which the thermal energy of steam is converted into mechanical energy. It consists of a cylinder fitted with a piston and valve gear to enable the high-pressure steam to be admitted to the cylinder when the piston is near the top of its stroke. The steam forces the piston to the bottom of its stroke and is then exhausted from the cylinder usually into a condenser. The reciprocating motion of the piston is converted to rotary motion of the flywheel by means of a connecting rod, crosshead, and crank. The steam engine reached its zenith at the end of the 19th century, since when it has been replaced by the steam turbine and the internal-combustion engine. *See also* RANKINE CYCLE.

steam point The temperature at which the maximum vapour pressure of water is equal to the standard atmospheric pressure (101 325 Pa). On the Celsius scale it has the value 100°C.

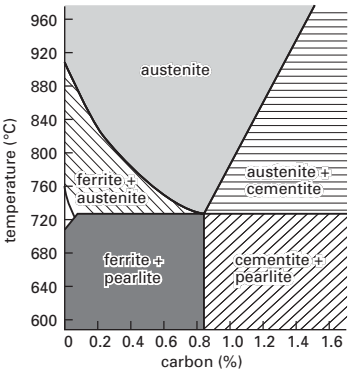
stearate (octadecanoate) A salt or ester of stearic acid.

stearic acid (octadecanoic acid) A solid saturated *fatty acid, $CH_3(CH_2)_{16}COOH$; r.d. 0.94; m.p. 71.5–72°C; b.p. 360°C (with decomposition). It occurs widely (as *glycerides) in animal and vegetable fats.

steel Any of a number of alloys consisting predominantly of iron with varying proportions of carbon (up to 1.7%) and, in some cases, small quantities of other elements (**alloy steels**), such as manganese, silicon, chromium, molybdenum, and nickel. Steels containing over 11–12% of chromium are known as *stainless steels.

Carbon steels exist in three stable crystalline phases: **ferrite** has a body-centred cubic crystal, **austenite** has a face-centred cubic crystal, and **cementite** has an orthorhombic crystal. **Pearlite** is a mixture of ferrite and cementite arranged in parallel plates. The phase diagram shows how the phases form at different temperatures and compositions.

Steels are manufactured by the *basic-oxygen process (L–D process), which has largely replaced the *Bessemer process and the *open-hearth process, or in electrical furnaces.



Steel. Phase diagram for steel.

Stefan's law (Stefan–Boltzmann law) The total energy radiated per unit surface area of a *black body in unit time is proportional to the fourth power of its thermodynamic temperature. The constant of proportionality, the **Stefan constant** (or **Stefan–Boltzmann constant**) has the value 5.6697×10^{-8} J s^{-1} m^{-2} K^{-4}. The law was discovered by Joseph Stefan (1853–93) and theoretically derived by Ludwig Boltzmann.

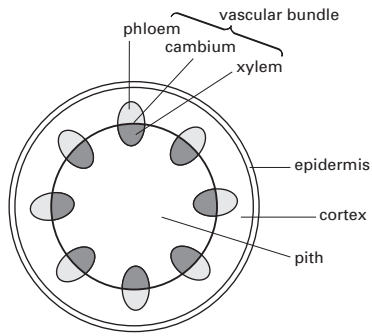
stele The vascular tissue (i.e. *xylem and *phloem) of *tracheophyte plants, together with the endodermis and pericycle (when present). The arrangement of stelar tissues is very variable. In roots the stele often forms a solid core, which better enables the root to withstand tension and compression. In stems it is often a hollow cylinder separating the cortex and pith. This arrangement makes the stem more resistant to bending stresses. Monocotyledons and dicotyledons can usually be distinguished by the pattern of their stelar tissue. In monocotyledons the vascular bundles are scattered throughout the stem whereas in dicotyledons (and gymnosperms) they are arranged in a circle around the pith.

stellar association A very loose grouping of 10–100 young stars that share a common origin, usually having been born together in

a *giant molecular cloud, and although no longer bound to each other by gravitational forces, are moving through space together.

stellar evolution The changes that occur to a *star during its lifetime, from birth to final extinction. A star is believed to form from a condensation of interstellar matter, which collects either by chance or for unexplained reasons, and grows by attracting other matter towards itself as a result of its gravitational field. This initial cloud of cold contracting matter, called a **protostar**, builds up an internal pressure as a result of its gravitational contraction. The pressure raises the temperature until it reaches $5–10 \times 10^6$ K, at which temperature the thermonuclear conversion of hydrogen to helium begins. In our *sun, a typical star, hydrogen is converted at a rate of some 10^{11} kg s^{-1} with the evolution of some 6×10^{25} J s^{-1} of energy. It is estimated that the sun contains sufficient hydrogen to burn at this rate for 10^{10} years and that it still has half its life to live as a main-sequence star (*see* HERTZSPRUNG–RUSSELL DIAGRAM). Eventually, however, this period of stability comes to an end, because the thermonuclear energy generated in the interior is no longer sufficient to counterbalance the gravitational contraction. The core, which is now mostly helium, collapses until a sufficiently high temperature is reached in a shell of unburnt hydrogen round the core to start a new phase of thermonuclear reaction. This burning of the shell causes the star's outer envelope to expand and cool, the temperature drop changes the colour from white to red and the star becomes a **red giant** or a **supergiant** if the original star was very large. The core now contracts, reaching a temperature of 10^8 K, and the helium in the core acts as the thermonuclear energy source. This reaction produces carbon, but a star of low mass relatively soon runs out of helium and the core collapses into a *white dwarf, while the outer regions drift away into space, possibly forming a **planetary nebula**. Larger stars (several times larger than the sun) have sufficient helium for the process to continue so that heavier elements, up to iron, are formed. But iron is the heaviest element that can be formed with the production of energy and when the helium has all been consumed there is a catastrophic collapse of the core, resulting in a *supernova explosion, blowing the outer layers away. The current theory suggests that thereafter the collapsed core becomes a *neutron star or a *black hole depending on its mass.

stem The part of a plant that usually grows vertically upwards towards the light and supports the leaves, buds, and reproductive structures (see illustration). The leaves develop at the *nodes and side or branch stems develop from buds at the nodes. The stems of certain species are modified as bulbs, corms, rhizomes, and tubers. Some species have twining stems; others have horizontal stems, such as *runners. Another modification is the *cladode. Erect stems may be cylindrical or angular; they may be covered with hairs, prickles, or spines and many exhibit secondary growth and become woody (*see* GROWTH RING). In addition to its supportive function, the stem contains *vascular tissue that conducts food, water, and mineral salts between the roots and leaves. It may also contain chloroplasts and carry out photosynthesis.



Stem. Transverse section through a herbaceous stem.

stem cell A cell that is not differentiated itself but can undergo unlimited division to form other cells, which either remain as stem cells or differentiate to form specialized cells. For example, **haemopoietic stem cells** in the bone marrow divide to produce daughter cells that differentiate into various types of blood cell (*see* HAEMOPOIETIC TISSUE). **Embryonic stem cells**, such as those taken from an early human embryo, are capable of differentiating into many or all of the various tissue cells found in a fully developed individual – they are described as **pluripotent**. Cultures of such cells have the potential to provide replacement tissues and organs for medical use, including transplan-

tation. However, ethical concerns have led to tight controls on research using human embryonic stem cells in many countries, including the USA and UK.

SEE WEB LINKS

- Website of the International Stem Cell Forum, which promotes good practice and progress in stem cell research

step A single stage in a chemical reaction. For example, the addition of hydrogen chloride to ethene involves three steps:

$$HCl \rightarrow H^+ + Cl^-$$

$$H^+ + C_2H_4 \rightarrow CH_3CH_2^+$$

$$CH_3CH_2^+ + Cl^- \rightarrow CH_3CH_2Cl$$

steradian Symbol sr. The dimensionless *SI unit of solid angle equal to the solid angle that encloses a surface on a sphere equal to the square of the radius of the sphere.

stere A unit of volume equal to 1 m^3. It is not now used for scientific purposes.

stereochemistry The branch of chemistry concerned with the structure of molecules and the way the arrangement of atoms and groups affects the chemical properties.

stereographic projection A type of azimuthal projection used for making maps (*see* MAP PROJECTIONS) and for specifying the structures of crystals (*see* CRYSTAL). A point *p* on a sphere (called a pole of the projection) is projected onto a plane that is a tangent to the sphere at a point diametrically opposite *p*. The sizes and sense of angles between lines or curves are preserved in this projection.

stereoisomerism *See* ISOMERISM.

stereoregular Describing a *polymer that has a regular pattern of side groups along its chain.

stereospecific Describing chemical reactions that give products with a particular arrangement of atoms in space. An example of a stereospecific reaction is the *Ziegler process for making polyethene.

steric effect An effect in which the rate or path of a chemical reaction depends on the size or arrangement of groups in a molecule.

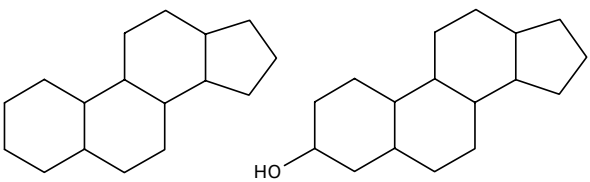
steric hindrance An effect in which a chemical reaction is slowed down or prevented because large groups on a reactant molecule hinder the approach of another reactant molecule.

sterile **1.** (of living organisms) Unable to produce offspring. *See also* HYBRID; INCOMPATIBILITY; SELF-STERILITY; STERILIZATION. **2.** Free from contaminating microorganisms. *See* STERILIZATION.

sterilization **1.** The process of destroying microorganisms that contaminate food, wounds, surgical instruments, etc. Common methods of sterilization include heat treatment (*see* AUTOCLAVE; PASTEURIZATION) and the use of *disinfectants and *antiseptics. **2.** The operation of making an animal or human incapable of producing offspring. Men are usually sterilized by tying and then cutting the *vas deferens (**vasectomy**); in women the operation often involves permanently blocking the fallopian tubes by means of clips (**tubal occlusion**). *See also* BIRTH CONTROL.

sternum (breastbone) **1.** A shield-shaped or rod-shaped bone in terrestrial vertebrates, on the ventral side of the thorax, that articulates with the *clavicle (collar bone) of the pectoral girdle and with most of the ribs. It is absent in fish, and in birds it bears a *keel. **2.** The ventral portion of each segment of the exoskeleton of arthropods.

steroid Any of a group of lipids derived from a saturated compound called cyclopentanoperhydrophenanthrene, which has a nucleus of four rings (see formulae).



Steroid.

Some of the most important steroid derivatives are the steroid alcohols, or *sterols. Other steroids include the *bile acids, which aid digestion of fats in the intestine; the sex hormones (*androgens and *oestrogens); and the *corticosteroid hormones, produced by the adrenal cortex. *Vitamin D is also based on the steroid structure.

SEE WEB LINKS

- Information about IUPAC nomenclature

sterol Any of a group of *steroid-based alcohols having a hydrocarbon side-chain of 8–10 carbon atoms. Sterols exist either as free sterols or as esters of fatty acids. Animal sterols (**zoosterols**) include *cholesterol and lanosterol. The major plant sterol (**phytosterol**) is beta-sitosterol, while fungal sterols (**mycosterols**) include *ergosterol.

stibnite A mineral form of antimony(III) sulphide, Sb_2S_3, the chief ore of antimony. It is a steel-grey crystalline solid, often containing extractable amounts of lead, mercury, and silver in addition to the antimony.

sticky end A single unpaired strand of nucleotides protruding from the end of a double-stranded DNA molecule. It is able to join with a complementary single strand, e.g. the sticky end of another DNA molecule, thus forming a single large double-stranded molecule. Sticky ends provide a means of annealing segments of DNA in genetic engineering, e.g. in the packaging of *vectors.

stigma **1.** The glandular sticky surface at the tip of a carpel of a flower, which receives the pollen. In insect-pollinated plants the stigmas are held within the flower, whereas in wind-pollinated species they hang outside it. **2.** *See* EYESPOT.

stilt root *See* PROP ROOT.

stimulated emission *See* INDUCED EMISSION; LASER.

stimulus Any change in the external or internal environment of an organism that provokes a physiological or behavioural response in the organism. In an animal specific *receptors are sensitive to stimuli.

stipe **1.** The stalk that forms the lower portion of the fruiting body of certain fungi, such as mushrooms, and supports the umbrella-shaped cap. **2.** The stalk between the holdfast and blade (**lamina**) of certain brown algae, notably kelps.

stipule An outgrowth from the petiole or leaf base of certain plants. Those of the garden pea are leaflike photosynthetic organs. The stipules of the lime tree are scalelike and protect the winter buds, whereas those of the false acacia (*Robinia*) are modified as spines.

Stirling engine A heat engine consisting of a hot cylinder and a cold cylinder separated by a regenerator acting as a heat exchanger. The cylinders enclose oscillating pistons. Heat is applied externally to the hot cylinder, causing the working fluid within it to expand and drive the piston. The fluid is cooled in the regenerator before entering the cold cylinder, where it is compressed by the piston and driven back to be heated in the regenerator before entering the hot cylinder again. Stirling engines, which were invented by Robert Stirling (1790–1878) in 1816, are silent and efficient but costly to produce. They have found limited use; interest in them revived in the 1960s.

STM *See* SCANNING TUNNELLING MICROSCOPY.

stochastic process Any process in which there is a random variable.

stock *See* GRAFT.

Stockholm Convention *See* PERSISTENT ORGANIC POLLUTANT.

stoichiometric Describing chemical reactions in which the reactants combine in simple whole-number ratios.

stoichiometric coefficient *See* CHEMICAL EQUATION.

stoichiometric compound A compound in which atoms are combined in exact whole-number ratios. *Compare* NONSTOICHIOMETRIC COMPOUND.

stoichiometric mixture A mixture of substances that can react to give products with no excess reactant.

stoichiometric sum *See* CHEMICAL EQUATION.

stoichiometry The relative proportions in which elements form compounds or in which substances react.

stokes Symbol St. A c.g.s. unit of kinematic viscosity equal to the ratio of the viscosity of a fluid in poises to its density in grams per cubic centimetre. 1 stokes = 10^{-4} m^2 s^{-1}. It is named after Sir George Stokes.

S

Stokes, Sir George Gabriel (1819–1903) British physicist and mathematician, born in Ireland, who worked at Cambridge University all his life. He is best known for *Stokes' law, concerning the movement of objects in a fluid. The *stokes is named after him.

Stokes' law A law that predicts the frictional force F on a spherical ball moving through a viscous medium. According to this law $F = 6\pi r\eta v$, where r is the radius of the ball, v is its velocity, and η is the viscosity of the medium. The sphere accelerates until it reaches a steady terminal speed. For a falling ball, F is equal to the gravitational force on the sphere, less any upthrust. The law was discovered by Sir George Stokes.

Stokes theorem A theorem that is the analogue of the *divergence theorem for the *curl of a vector. Stokes theorem states that if a surface S, which is smooth and simply connected (i.e. any closed curve on the surface can be contracted continuously into a point without leaving the surface), is bounded by a line L the vector $\boldsymbol{F}$ defined in S satisfies

$$\int_S \mathrm{curl}\boldsymbol{F}\cdot\mathrm{d}S = \int_L \boldsymbol{F}\cdot\mathrm{d}\boldsymbol{l}.$$

where $\boldsymbol{l}$ is distance. Stokes theorem was stated by Sir George Stokes as a Cambridge examination question, having been raised by Lord Kelvin in a letter to Stokes in 1850.

stolon A long aerial side stem that gives rise to a new daughter plant when the bud at its apex touches the soil. Plants that multiply in this way include blackberry and currant bushes. Gardeners often pin down stolons to the soil to aid the propagation of such plants. This process is termed **layering**.

stoma (*pl.* **stomata**) A pore, large numbers of which are present in the epidermis of leaves (especially on the undersurface) and young shoots. Stomata function in gas exchange between the plant and the atmosphere. Each stoma is bordered by two semicircular **guard cells** (specialized epidermal cells), whose movements (due to changes in water content) control the size of the aperture. The term stoma is also used to mean both the pore and its associated guard cells.

stomach The portion of the vertebrate *alimentary canal between the oesophagus and the small intestine. It is a muscular organ, capable of dramatic changes in size and shape, in which ingested food is stored and undergoes preliminary digestion. Cells lining the stomach produce *gastric juice, which is thoroughly mixed with the food by muscular contractions of the stomach. The resultant acidic partly digested food mass (*chyme) is discharged into the *duodenum through the pyloric *sphincter for final digestion and absorption. Some herbivorous animals (the Ruminantia) have multichambered stomachs from which food is regurgitated, rechewed, and swallowed again.

stomium A region of thin-walled cells in certain spore-producing structures that ruptures to release the spores. For example, in the sporangium of the fern *Dryopteris* the stomium ruptures when the annulus dries out.

stop A circular aperture that limits the effective size of a lens in an optical system. It may be adjustable, as the iris diaphragm in a camera, or have a fixed diameter, as the disk used in some telescopes.

stop codon The triplet of nucleotides on a messenger *RNA molecule (*see* CODON) at which the process of *translation ends. It is recognized by proteins called release factors, which attach to the binding site for an aminoacyl tRNA molecule. This effectively stops the formation of a polypeptide chain at that point. The three stop codons are UGA, UAA, and UAG (*see* GENETIC CODE). *Compare* START CODON.

stopping power A measure of the ability of matter to reduce the kinetic energy of a particle passing through it. The **linear stopping power**, $-\mathrm{d}E/\mathrm{d}x$, is energy loss of a particle per unit distance. The **mass stopping power**, $(1/\rho)\mathrm{d}E/\mathrm{d}x$, is the linear stopping power divided by the density (ρ) of the substance. The **atomic stopping power**, $(1/n)\mathrm{d}E/\mathrm{d}x = (A/\rho N)\mathrm{d}E/\mathrm{d}x$, is the energy loss per atom per unit area perpendicular to the particle's motion, i.e. n is the number of atoms in unit volume of the substance, N is the Avogadro number, and A is the relative atomic mass of the substance. The relative stopping power is the ratio of the stopping power of a substance to that of a standard substance, usually aluminium, oxygen, or air.

storage compound *See* FOOD RESERVES.

storage ring A large evacuated toroidal ring forming a part of some particle accelerators. The rings are designed like *synchrotrons, except that they do not accelerate the particles circling within them but supply just sufficient energy to make up for losses

(mainly *synchrotron radiation). The storage rings are usually built tangentially to the associated accelerator so that particles can be transferred accurately between them. At *CERN in Geneva, two interlaced storage rings are used, containing protons rotating in opposite directions. At the intersections very high collision energies (up to 1700 GeV) can be achieved.

s.t.p. Standard temperature and pressure, formerly known as **N.T.P.** (normal temperature and pressure). The standard conditions used as a basis for calculations involving quantities that vary with temperature and pressure. These conditions are used when comparing the properties of gases. They are 273.15 K (or 0°C) and 101 325 Pa (or 760.0 mmHg).

straight chain *See* CHAIN.

strain A measure of the extent to which a body is deformed when it is subjected to a *stress. The **linear strain** or **tensile strain** is the ratio of the change in length to the original length. The **bulk strain** or **volume strain** is the ratio of the change in volume to the original volume. The **shear strain** is the angular distortion in radians of a body subjected to a *shearing force. *See also* ELASTICITY; ELASTIC MODULUS.

strain gauge A device used to measure a small mechanical deformation in a body (*see* STRAIN). The most widely used devices are metal wires or foils or semiconductor materials, such as a single silicon crystal, which are attached to structural members; when the members are stretched under tensile *stress the resistance of the metal or semiconductor element increases. By making the resistance a component in a *Wheatstone-bridge circuit an estimate of the strain can be made by noting the change in resistance. Other types of strain gauge rely on changes of capacitance or the magnetic induction between two coils, one of which is attached to the stressed member.

strain hardening (work hardening) An increase in the resistance to the further plastic deformation of a body as a result of a rearrangement of its internal structure when it is strained, particularly by repeated stress. *See also* ELASTICITY.

strange attractor *See* ATTRACTOR.

strange matter Matter composed of up, down, and strange quarks (rather than the up and down quarks found in normal nucleons). It has been suggested that strange matter may have been formed in the *early universe, and that pieces of this matter (called **S-drops**) may still exist.

strangeness Symbol *s*. A property of certain elementary particles called hadrons (K-mesons and hyperons) that decay more slowly than would have been expected from the large amount of energy released in the process. These particles were assigned the quantum number *s* to account for this behaviour. For nucleons and other nonstrange particles $s = 0$; for strange particles *s* does not equal zero but has an integral value. In quark theory (*see* ELEMENTARY PARTICLES) hadrons with the property of strangeness contain a strange quark or its antiquark.

stratification **1.** The arrangement of the components of an entity in layers (**strata**). Stratification is a feature of sedimentary rocks and *soils. Thermal stratification can occur in some lakes (*see* THERMOCLINE). **2.** The practice of placing certain seeds between layers of peat or sand and then exposing them to low temperatures for a period, which is required before they will germinate. *See* VERNALIZATION.

stratigraphy The branch of geology concerned with the origin, composition, sequence, and correlation of rock strata. It forms the basis of historical geology and has also found practical application in mineral exploration, especially that of petroleum.

stratosphere *See* EARTH'S ATMOSPHERE.

stratum corneum The layer of dead keratinized cells that forms the outermost layer of mammalian *epidermis. It provides a water-resistant barrier between the external environment and the living cells of the *skin.

streamline flow A type of fluid flow in which no *turbulence occurs and the particles of the fluid follow continuous paths, either at constant velocity or at a velocity that alters in a predictable and regular way (*see also* LAMINAR FLOW).

Streptococcus A genus of spherical Gram-positive bacteria occurring widely in nature, typically as chains or pairs of cells. Many are saprotrophic and exist as usually harmless commensals inhabiting the skin, mucous membranes, and intestine of humans and animals. Others are parasites, some of which cause diseases, including scarlet fever (*S.*

pyogenes; group A streptococci), endocarditis (*S. viridans*), and pneumonia and meningitis (*S. pneumoniae*).

streptomycin *See* ACTINOBACTERIA; ANTIBIOTICS.

stress The force per unit area on a body that tends to cause it to deform (*see* STRAIN). It is a measure of the internal forces in a body between particles of the material of which it consists as they resist separation, compression, or sliding in response to externally applied forces. **Tensile stress** and **compressive stress** are axial forces per unit area applied to a body that tend either to extend it or compress it linearly. **Shear stress** is a tangential force per unit area that tends to shear a body. *See also* ELASTICITY; ELASTIC MODULUS.

stretch reflex (myotatic reflex) The *reflex initiated when a muscle is stretched; an example is the **knee-jerk reflex**. Stretching of a muscle causes impulses to be generated in the *muscle spindles. These impulses are transmitted by sensory neurons to the spinal cord, where the sensory neurons synapse with motor neurons; these initiate contraction of the same muscle so that it returns to its original length. Since the reflex action involves the transmission of impulses across only one set of synapses, the response is rapid and described as **monosynaptic**.

striated muscle *See* VOLUNTARY MUSCLE.

stridulation The production of sounds by insects rubbing one part of the body against another. The parts of the body involved vary from species to species. Stridulation is typical of the Orthoptera (grasshoppers, crickets, cicadas), in which the purpose of the sounds is usually to bring the sexes together, although they are also used in territorial behaviour, warning, etc.

string A one-dimensional object used in theories of elementary particles and in cosmology (**cosmic string**). **String theory** replaces the idea of a pointlike elementary particle (used in quantum field theory) by a line or loop (a closed string). States of a particle may be produced by standing waves along this string. The combination of string theory with supersymmetry leads to *superstring theory.

string landscape The very large number (about 10^{500}) of possible states in string theory. It is postulated that the universe we inhabit, including the small but non-zero value of the *cosmological constant, is therefore one of 10^{500} possible universes. The string landscape is a very controversial idea, which is far from being universally accepted.

stripping reaction A nuclear or chemical reaction in which part of an incident particle combines with the target while the rest of the incident particle proceeds almost unchanged. A standard example of a stripping reaction is a (d, p) reaction in which a *deuteron is the incident particle and a nucleus is the target particle with the neutron from the deuteron combining with the target nucleus and the proton from the deuteron proceeding almost without disruption.

strobilus **1.** A type of *composite fruit that is formed from a complete inflorescence. It produces *achenes enclosed in bracts and when mature becomes cone-shaped. The hop fruit is an example. **2.** *See* CONE.

stroboscope A device for making a moving body intermittently visible in order to make it appear stationary. It may consist of a lamp flashing at regular intervals or a shutter that enables it to be seen intermittently. **Stroboscopic photography** is the taking of very short-exposure pictures of moving objects using an electronically controlled flash lamp.

stroma Tissue that forms the framework of an organ; for example, the tissue of the ovary that surrounds the reproductive cells, or the gel-like matrix of *chloroplasts that surrounds the grana.

stromatolite A rocky cushion-like mass formed by the unchecked growth of millions of lime-secreting cyanobacteria. Stromatolites are found only in areas where other organisms that would normally keep down the bacterial numbers cannot survive, such as extremely salty bays. Such bacteria were abundant during the *Proterozoic and *Archaean eons, from as early as 3500 million years ago. The white rings of fossilized microorganisms found in rocks of this age are the remains of stromatolites.

strong acid An *acid that is completely dissociated in aqueous solution.

strong electrolyte An *electrolyte that is completely dissociated into its component ions in aqueous solution (as opposed to a weak electrolyte, which is incompletely dissociated).

strong interaction *See* FUNDAMENTAL INTERACTIONS.

strontia *See* STRONTIUM OXIDE.

strontianite A mineral form of *strontium carbonate, $SrCO_3$.

strontium Symbol Sr. A soft yellowish metallic element belonging to group 2 (formerly IIA) of the periodic table (*see* ALKALINE-EARTH METALS); a.n. 38; r.a.m. 87.62; r.d. 2.6; m.p. 769°C; b.p. 1384°C. The element is found in the minerals strontianite ($SrCO_3$) and celestine ($SrSO_4$). It can be obtained by roasting the ore to give the oxide, followed by reduction with aluminium (i.e. the *Goldschmidt process). The element, which is highly reactive, is used in certain alloys and as a vacuum getter. The isotope strontium–90 is present in radioactive fallout (half-life 28 years), and can be metabolized with calcium so that it collects in bone. Strontium was discovered by Martin Klaproth (1743–1817) and Thomas Hope (1766–1844) in 1798 and isolated by Humphry Davy in 1808.

SEE WEB LINKS

- Information from the WebElements site

strontium bicarbonate *See* STRONTIUM HYDROGENCARBONATE.

strontium carbonate A white solid, $SrCO_3$; orthorhombic; r.d. 3.7; decomposes at 1340°C. It occurs naturally as the mineral **strontianite** and is prepared industrially by boiling celestine (strontium sulphate) with ammonium carbonate. It can also be prepared by passing carbon dioxide over strontium oxide or hydroxide or by passing the gas through a solution of strontium salt. It is a phosphor, used to coat the glass of cathode-ray screens, and is also used in the refining of sugar, as a slagging agent in certain metal furnaces, and to provide a red flame in fireworks.

strontium chloride A white compound, $SrCl_2$. The anhydrous salt (cubic; r.d. 3.05; m.p. 872°C; b.p. 1250°C) can be prepared by passing chlorine over heated strontium. It is deliquescent and readily forms the hexahydrate, $SrCl_2.6H_2O$ (r.d. 2.67). This can be made by neutralizing hydrochloric acid with strontium carbonate, oxide, or hydroxide. Strontium chloride is used for military flares.

strontium hydrogencarbonate (strontium bicarbonate) A compound, $Sr(HCO_3)_2$, which is stable only in solution. It is formed by the action of carbon dioxide on a suspension of strontium carbonate in water. On heating, this process is reversed.

strontium oxide (strontia) A white compound, SrO; r.d. 4.7; m.p. 2430°C, b.p. 3000°C. It can be prepared by the decomposition of heated strontium carbonate, hydroxide, or nitrate, and is used in the manufacture of other strontium salts, in pigments, soaps and greases, and as a drying agent.

strontium sulphate A white solid, $SrSO_4$; r.d. 3.96; m.p. 1605°C. It can be made by dissolving strontium oxide, hydroxide, or carbonate in sulphuric acid. It is used as a pigment in paints and ceramic glazes and to provide a red colour in fireworks.

structural formula *See* FORMULA.

structural gene *See* OPERON.

structural isomerism *See* ISOMERISM.

structure formation The process by which *large-scale structure, such as galaxies, forms in the universe. It is thought that quantum fluctuations in the early universe and the *Jeans instability in an expanding universe are the key factors in understanding structure formation. A complete quantitative theory of structure formation does not exist at present.

Strukturbericht A system used to describe crystal structure. It consists of a capital letter followed by a number. The capital letter indicates the atomic nature of the material. A stands for monoatomic, B for diatomic with equal numbers of atoms of each type, C for diatomic with a ratio of 2:1 for atoms of each type, D is as C but with a ratio of 3:1, E ... K are more complicated types of compounds, L are alloys, O are organic compounds, and S are silicates. The number gives the order of the discovery of that particular structure. The term is German for 'structure report'.

strychnine A colourless poisonous crystalline alkaloid found in certain plants.

style The stalk of a carpel, between the stigma and the ovary. In many plants it is elongated to aid pollination.

styrene *See* PHENYLETHENE.

subarachnoid space The space between the *arachnoid membrane and the *pia mater, two of the membranes (*meninges)

that surround the brain and spinal cord. It is filled with *cerebrospinal fluid.

subatomic particle *See* ELEMENTARY PARTICLES.

subclavian artery A paired artery that passes beneath the collar bone (clavicle) and branches to supply blood to the arm. The left subclavian artery arises from the aorta; the right from the innominate artery.

subcritical *See* CRITICAL MASS; CRITICAL REACTION; MULTIPLICATION FACTOR.

subcutaneous tissue The tissue that lies immediately beneath the *dermis (*see* SKIN). It is made up of loose fibrous *connective tissue, muscle, and fat (*see* ADIPOSE TISSUE), which in some animals (e.g. whales and hibernating mammals) forms an insulating layer or an important food store.

suberin A mixture of waxy substances, similar to *cutin, present in the thickened cell walls of many trees and shrubs, particularly in corky tissues. The deposition of suberin (**suberization**) provides a protective water-impermeable layer.

sublimate A solid formed by sublimation.

sublimation A direct change of state from solid to gas.

sublittoral **1.** Designating or occurring in the shallow-water zone of a sea, over the continental shelf and below the low tide mark. **2.** Designating or occurring in the zone of a lake below the littoral zone, to a depth of 6–10 metres.

submillimetre astronomy A combination of radio and infrared astronomy techniques that focus on collecting radiation in the wavelength range 0.3–1.0 mm. This is the part of the spectrum in which a large number of molecular emission lines are present. *Giant molecular clouds are a primary source of such emissions.

subnet mask In computing, a specification of which part of an IP address (*see* TCP/IP) represents the network identity. It is a 32-bit bitmap where '1' means that bit position is part of the network identity and '0' that it is part of the host address. This bitmap always take the form of a single block of 1's (the network identity part) followed by a single block of 0's (the host address part). It is important that routers can distinguish efficiently between those packets originating on its network whose destination is on the same network and those that that require routing over an inter-network. This operation requires isolating the network identity part of the IPA address, and an AND operation with the subnet mask is a very efficient way to do this. For convenience, subnet masks are usually represented either as the decimal form of four 8-bit numbers or as an integer representing the network identity. Thus, 255.255.255.0 and /24 both indicate a 24-bit network identity and an 8-bit host address.

subshell *See* ATOM.

subsoil *See* SOIL.

subsonic speed A speed that is less than *Mach 1.

subspecies A group of individuals within a *species that breed more freely among themselves than with other members of the species and resemble each other in more characteristics. Reproductive isolation of a subspecies may become so extreme that a new species is formed (*see* SPECIATION). Subspecies are sometimes given a third Latin name, e.g. the mountain gorilla, *Gorilla gorilla beringei* (*see also* BINOMIAL NOMENCLATURE).

substantive dye *See* DYES.

substantivity The affinity of a dye for its substrate.

substituent **1.** An atom or group that replaces another in a substitution reaction. **2.** An atom or group regarded as having replaced a hydrogen atom in a chemical derivative. For example, dibromobenzene ($C_6H_4Br_2$) is a derivative of benzene with bromine substituents.

substitute natural gas *See* SNG.

substitution (in genetics) A *point mutation in which one base pair in the DNA sequence is replaced by another. Substitutions may or may not cause the incorporation of an incorrect amino acid in a protein chain; when an incorrect amino acid is inserted, it may or may not affect the functioning of that protein. Sickle-cell anaemia is an example of a substitution mutation in which thymine is replaced by adenine in the triplet coding for the sixth amino acid in the β-chain of haemoglobin.

substitution reaction (displacement reaction) A reaction in which one atom or molecule is replaced by another atom or

molecule. *See* ELECTROPHILIC SUBSTITUTION; NUCLEOPHILIC SUBSTITUTION.

substrate **1.** The substance that is affected by the action of a catalyst; for example, the substance upon which an *enzyme acts in a biochemical reaction. **2.** The substance on which some other substance is adsorbed or in which it is absorbed. Examples include the material to which a dye is attached, the porous solid absorbing a gas, and the *matrix trapping isolated atoms, radicals, etc. **3.** (in biology) The material on which a sedentary organism (such as a barnacle or a plant) lives or grows. The substrate may provide nutrients for the organism or it may simply act as a support.

subtractive process *See* COLOUR.

succession (in ecology) The sequence of communities that develops in an area from the initial stages of colonization until a stable mature **climax community** is achieved. Many factors, including climate and changes brought about by the colonizing organisms, influence the nature of a succession; for example, after many years shrubs produce soil deep enough to support trees, which then shade out the shrubs. *See also* SERE.

succinate A salt of succinic acid (*butanedioic acid), a four-carbon fatty acid. Succinate occurs in living organisms as an intermediate in metabolism, especially in the *Krebs cycle.

succulent A plant that conserves water by storing it in fleshy leaves or stems. Succulents are found either in dry regions or in areas where there is sufficient water but it is not easily obtained, as in salt marshes. Such plants are often modified to reduce water loss by transpiration. For example, the leaves of cacti are reduced to spines.

succus entericus *See* INTESTINAL JUICE.

sucker (turion) A shoot that arises from an underground root or stem and grows at the expense of the parent plant. Suckers can be dug up with a portion of root attached and used to propagate a plant. If, however, a plant is grafted onto a different rootstock, as many roses are, any suckers will be of the wild rootstock, rather than the ornamental scion, and must be removed.

sucrase A carbohydrate-digesting enzyme, produced in the brush border of the small intestine, that breaks down the disaccharide sucrose into the monosaccharides glucose and fructose.

sucrose (cane sugar; beet sugar; saccharose) A sugar comprising one molecule of glucose linked to a fructose molecule. It occurs widely in plants and is particularly abundant in sugar cane and sugar beet (15–20%), from which it is extracted and refined for table sugar. If heated to 200°C, sucrose becomes caramel.

sugar (saccharide) Any of a group of water-soluble *carbohydrates of relatively low molecular weight and typically having a sweet taste. The simple sugars are called *monosaccharides. More complex sugars comprise between two and ten monosaccharides linked together: *disaccharides contain two, trisaccharides three, and so on. The name is often used to refer specifically to *sucrose (cane or beet sugar).

SEE WEB LINKS

- Information about IUPAC nomenclature

sugar of lead *See* LEAD(II) ETHANOATE.

sulpha drugs *See* SULPHONAMIDES.

sulphamic acid A colourless crystalline solid, NH_2SO_2OH, which is extremely soluble in water and normally exists as the *zwitterion $H_3N^+.SO_3^-$. It is a strong acid, readily forming sulphamate salts. It is used in electroplating, hard-water scale removers, herbicides, and artificial sweeteners.

sulphanes Compounds of hydrogen and sulphur containing chains of sulphur atoms. They have the general formula H_2S_n. The simplest is hydrogen sulphide, H_2S; other members of the series are H_2S_2, H_2S_3, H_2S_4, etc. *See* SULPHIDES.

SEE WEB LINKS

- Information about IUPAC nomenclature

sulphanilic acid (4-aminobenzene sulphonic acid) A colourless crystalline solid, $H_2NC_6H_4SO_2OH$, made by prolonged heating of *phenylamine (aniline) sulphate. It readily forms *diazo compounds and is used to make dyes and sulpha drugs.

sulphate A salt or ester of sulphuric(VI) acid. Organic sulphates have the formula R_2SO_4, where R is an organic group. Sulphate salts contain the ion SO_4^{2-}.

sulphides **1.** Inorganic compounds of sulphur with more electropositive elements. Compounds of sulphur with nonmetals are

covalent compounds, e.g. hydrogen sulphide (H_2S). Metals form ionic sulphides containing the S^{2-} ion; these are salts of hydrogen sulphide. **Polysulphides** can also be produced containing the polymeric ion S_x^{2-}.
2. (thio ethers) Organic compounds that contain the group –S– linked to two hydrocarbon groups. Organic sulphides are named from the linking groups, e.g. dimethyl sulphide (CH_3SCH_3), ethyl methyl sulphide ($C_2H_5SCH_3$). They are analogues of ethers in which the oxygen is replaced by sulphur (hence the alternative name) but are generally more reactive than ethers. Thus they react with halogen compounds to form *sulphonium compounds and can be oxidized to *sulphoxides.

sulphinate (dithionite; hyposulphite) A salt that contains the negative ion $S_2O_4^{2-}$, usually formed by the reduction of sulphites with excess SO_2. Solutions are not very stable and decompose to give thiosulphate and hydrogensulphite ions. The structure is $^-O_2S–SO_2^-$.

sulphinic acid (dithionous acid; hyposulphurous acid) An unstable acid, $H_2S_2O_4$, known in the form of its salts (sulphinates). *See also* SULPHURIC ACID.

sulphite A salt or ester derived from sulphurous acid. The salts contain the trioxosulphate(IV) ion SO_3^{2-}. The sulphites generally have reducing properties.

sulphonamides Organic compounds containing the group $–SO_2.NH_2$. The sulphonamides are amides of sulphonic acids. Many have antibacterial action and are also known as **sulpha drugs**, including sulphadiazine, $NH_2C_6H_4SO_2NHC_4H_3N_2$, and several others. They act by preventing bacteria from reproducing and are used to treat a variety of bacterial infections, especially of the gut and urinary system.

sulphonate A salt or ester of a sulphonic acid.

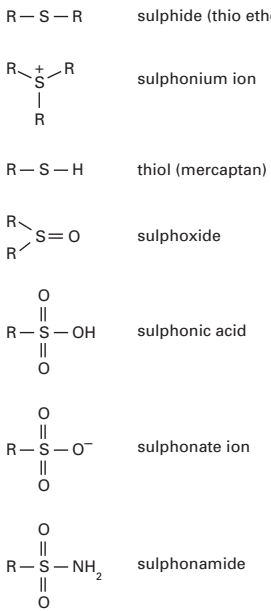
sulphonation A type of chemical reaction in which a $–SO_3H$ group is substituted on a benzene ring to form a *sulphonic acid. The reaction is carried out by refluxing with concentrated sulphuric(VI) acid for a long period. It can also occur with cold disulphuric(VI) acid ($H_2S_2O_7$). Sulphonation is an example of electrophilic substitution in which the electrophile is a sulphur trioxide molecule, SO_3.

sulphonic acids Organic compounds containing the $–SO_2.OH$ group. Sulphonic acids are formed by reaction of aromatic hydrocarbons with concentrated sulphuric acid. They are strong acids, ionizing completely in solution to form the sulphonate ion, $–SO_2.O^-$.

SEE WEB LINKS

- Information about IUPAC nomenclature

sulphonium compounds Compounds containing the ion R_3S^+ (sulphonium ion), where R is any organic group. Sulphonium compounds can be formed by reaction of organic sulphides with halogen compounds. For example, diethyl sulphide, $C_2H_5SC_2H_5$, reacts with chloromethane, CH_3Cl, to give diethylmethylsulphonium chloride, $(C_2H_5)_2.CH_3.S^+Cl^-$.



Sulphonium compounds. Examples of organic sulphur compounds.

sulphoxides Organic compounds containing the group =S=O (**sulphoxide group**) linked to two other groups, e.g. dimethyl sulphoxide, $(CH_3)_2SO$.

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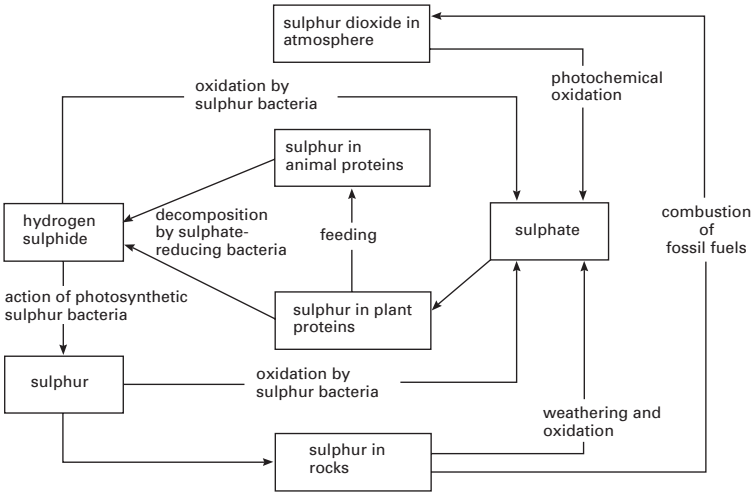
- Information about IUPAC nomenclature



Sulphur cycle.

sulphur Symbol S. A yellow nonmetallic element belonging to *group 16 (formerly VIB) of the periodic table; a.n. 16; r.a.m. 32.06; r.d. 2.07 (rhombic); m.p. 112.8°C; b.p. 444.674°C. The element occurs in many sulphide and sulphate minerals and native sulphur is also found in Sicily and the USA (obtained by the *Frasch process). It can also be obtained from hydrogen sulphide by the *Claus process.

Sulphur has various allotropic forms. Below 95.6°C the stable crystal form is rhombic; above this temperature the element transforms into a triclinic form. These crystalline forms both contain cyclic S_8 molecules. At temperatures just above its melting point, molten sulphur is a yellow liquid containing S_8 rings (as in the solid form). At about 160°C, the sulphur atoms form chains and the liquid becomes more viscous and dark brown. If the molten sulphur is cooled quickly from this temperature (e.g. by pouring into cold water) a reddish-brown solid known as **plastic sulphur** is obtained. Above 200°C the viscosity decreases. Sulphur vapour contains a mixture of S_2, S_4, S_6, and S_8 molecules. **Flowers of sulphur** is a yellow powder obtained by subliming the vapour. It is used as a plant fungicide. The element is also used to produce sulphuric acid and other sulphur compounds.

Sulphur is an *essential element in living organisms, occurring in the amino acids cysteine and methionine and therefore in many proteins. It is also a constituent of various cell metabolites, e.g. coenzyme A. Sulphur is absorbed by plants from the soil as the sulphate ion (SO_4^{2-}). *See* SULPHUR CYCLE.

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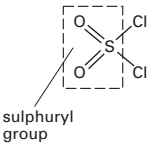
- Information from the WebElements site

sulphur bridge *See* DISULPHIDE BRIDGE.

sulphur cycle The cycling of sulphur between the biotic (living) and abiotic (nonliving) components of the environment (*see* BIOGEOCHEMICAL CYCLE). Most of the sulphur in the abiotic environment is found in rocks, although a small amount is present in the atmosphere as sulphur dioxide (SO_2), produced by combustion of fossil fuels. Sulphate (SO_4^{2-}), derived from the weathering and oxidation of rocks, is taken up by plants and incorporated into sulphur-containing proteins. In this form sulphur is passed along food chains to animals. Decomposition of dead organic matter and faeces by anaerobic sulphate-reducing bacteria returns sulphur to the abiotic environment in the form of hydrogen sulphide (H_2S). Hydrogen sulphide can be converted back to sulphate or to elemental sulphur by the action of photosynthetic and sulphide-oxidizing bacteria. Elemental sulphur becomes incorporated into rocks.

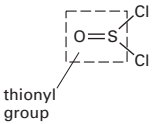
sulphur dichloride *See* DISULPHUR DICHLORIDE.

sulphur dichloride dioxide (sulphuryl chloride) A colourless liquid, SO_2Cl_2; r.d. 1.67; m.p. –54.1°C; b.p. 69°C. It decomposes in water but is soluble in benzene. The compound is formed by the action of chlorine on sulphur dioxide in the presence of an iron(III) chloride catalyst or sunlight. It is used as a chlorinating agent and a source of the related fluoride, SO_2F_2.



Sulphur dichloride dioxide.

sulphur dichloride oxide (thionyl chloride) A colourless fuming liquid, $SOCl_2$; m.p. –105°C; b.p. 78.8°C. It hydrolyses rapidly in water but is soluble in benzene. It may be prepared by the direct action of sulphur on chlorine monoxide or, more commonly, by the reaction of phosphorus(V) chloride with sulphur dioxide. It is used as a chlorinating agent in synthetic organic chemistry (replacing –OH groups with Cl).



Sulphur dichloride oxide.

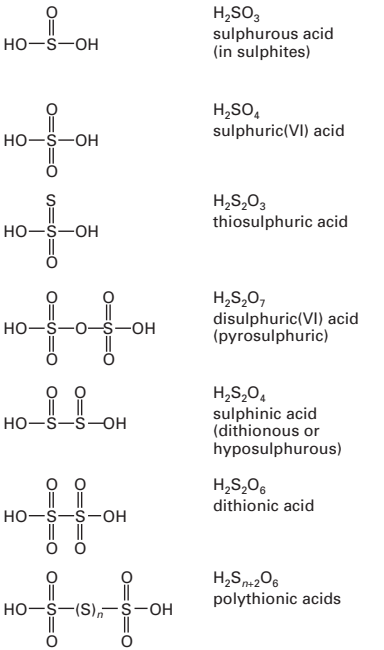
sulphur dioxide (sulphur(IV) oxide) A colourless liquid or pungent gas, SO_2, formed by sulphur burning in air; r.d. 1.43 (liquid); m.p. –72.7°C; b.p. –10°C. It can be made by heating iron sulphide (pyrites) in air. The compound is a reducing agent and is used in bleaching and as a fumigant and food preservative. Large quantities are also used in the *contact process for manufacturing sulphuric acid. It dissolves in water to give a mixture of sulphuric and sulphurous acids. *See also* ACID RAIN.

sulphuretted hydrogen *See* HYDROGEN SULPHIDE.

sulphuric acid (oil of vitriol) A colourless oily liquid, H_2SO_4; r.d. 1.84; m.p. 10.36°C; b.p. 338°C. The pure acid is rarely used; it is commonly available as a 96–98% solution (m.p. 3.0°C). The compound also forms a range of hydrates:
$H_2SO_4.H_2O$ (m.p. 8.62°C);
$H_2SO_4.2H_2O$ (m.p. –38/39°C);
$H_2SO_4.6H_2O$ (m.p. –54°C);
$H_2SO_4.8H_2O$ (m.p. –62°C).
Its full systematic name is **tetraoxosulphuric(VI) acid**.

Until the 1930s, sulphuric acid was manufactured by the *lead-chamber process, but this has now been replaced by the *contact process (catalytic oxidation of sulphur dioxide). It is extensively used in industry, the main applications being fertilizers (32%), chemicals (16%), paints and pigments (15%), detergents (11%), and fibres (9%).

In concentrated sulphuric acid there is extensive hydrogen bonding and several competing equilibria, to give species such as



Sulphuric acid. Structures of some oxo acids of sulphur.

H_3O^+, HSO_4^-, $H_3SO_4^+$, and $H_2S_2O_7$. Apart from being a powerful protonating agent (it protonates chlorides and nitrates producing hydrogen chloride and nitric acid), the compound is a moderately strong oxidizing agent. Thus, it will dissolve copper:

$$Cu(s) + H_2SO_4(l) \rightarrow CuO(s) + H_2O(l) + SO_2(g)$$

$$CuO(s) + H_2SO_4(l) \rightarrow CuSO_4(aq) + H_2O(l)$$

It is also a powerful dehydrating agent, capable of removing H_2O from many organic compounds (as in the production of acid *anhydrides). In dilute solution it is a strong dibasic acid forming two series of salts, the sulphates and the hydrogensulphates.

sulphuric(IV) acid *See* SULPHUROUS ACID.

sulphur monochloride *See* DISULPHUR DICHLORIDE.

sulphur mustard A chemical warfare agent, $C_4H_8Cl_2S$; r.d. 1.27; m.p. 14.4°C; b.p. 217°C. It is a potent blistering agent, first used in 1915 by Germany in World War I. It is often known simply as **mustard gas**, although it is an oily liquid, which can be dispersed as an aerosol. It was one of the early chemicals used in chemotherapy treatment of cancer. The systematic name is bis(2-chlorethyl) sulphide. *See also* NITROGEN MUSTARD.

sulphurous acid (sulphuric(IV) acid) A weak dibasic acid, H_2SO_3, known in the form of its salts: the sulphites and hydrogensulphites. It is considered to be formed (along with sulphuric acid) when sulphur dioxide is dissolved in water. It is probable, however, that the molecule H_2SO_3 is not present and that the solution contains hydrated SO_2. It is a reducing agent. The systematic name is **trioxosulphuric(IV) acid**. *See also* SULPHURIC ACID.

sulphur(IV) oxide *See* SULPHUR DIOXIDE.

sulphur(VI) oxide *See* SULPHUR TRIOXIDE.

sulphur trioxide (sulphur(VI) oxide) A colourless fuming solid, SO_3, which has three crystalline modifications. In decreasing order of stability these are: α, r.d. 1.97; m.p. 16.83°C; b.p. 44.8°C; β, m.p. 16.24°C; sublimes at 50°C; r.d. 2.29; γ, m.p. 16.8°C; b.p. 44.8°C. All are polymeric, with linked SO_4 tetrahedra: the γ-form has an icelike structure and is obtained by rapid quenching of the vapour; the β-form has infinite helical chains; and the α-form has infinite chains with some cross-linking of the SO_4 tetrahedra. Even in the vapour, there are polymeric species, and not discrete sulphur trioxide molecules (hence the compound is more correctly called by its systematic name **sulphur(VI) oxide**).

Sulphur trioxide is prepared by the oxidation of sulphur dioxide with oxygen in the presence of a vanadium(V) oxide catalyst. It may be prepared in the laboratory by distilling a mixture of concentrated sulphuric acid and phosphorus(V) oxide. It reacts violently with water to give sulphuric(VI) acid and is an important intermediate in the preparation of sulphuric acid and oleum.

sulphuryl chloride *See* SULPHUR DICHLORIDE DIOXIDE.

sulphuryl group The group $=SO_2$, as in *sulphur dichloride oxide.

sulphydryl group *See* THIOLS.

summation **1.** (in neurophysiology) The combined effect of the changes in electric potential elicited in one or more postsynaptic membranes by the transmission of impulses at *synapses that is sufficient to trigger an action potential in the postsynaptic neuron. Summation occurs when one or a few postsynaptic potentials alone are insufficient to elicit a response in the postsynaptic neuron; it may consist of the effect of two or more potentials evoked simultaneously at different synapses on the same neuron (**spatial summation**) or in rapid succession at the same synapse (**temporal summation**). **2.** *See* SYNERGISM.

sun The *star at the centre of the *solar system of which the planet earth is a member. A typical main-sequence dwarf star (*see* HERTZSPRUNG–RUSSELL DIAGRAM; STELLAR EVOLUTION), the sun is some 149 600 000 km from earth. It has a diameter of about 1 392 000 km and a mass of 1.9×10^{30} kg. Hydrogen and helium are the primary constituents (about 75% hydrogen, 25% helium), with less than 1% of heavier elements. In the central core, some 400 000 km in diameter, hydrogen is converted into helium by thermonuclear reactions, which generate vast quantities of energy. This energy is radiated into space and provides the earth with all the light and heat necessary to have created and maintained life on earth (*see* SOLAR CONSTANT). The surface of the sun, the *photosphere, forms the boundary between its opaque interior and its transparent atmos-

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phere. It is here that *sunspots occur. Above the photosphere is the *chromosphere and above this the *corona, which extends tenuously into interplanetary space. *See also* SOLAR WIND.

sunspot A dark patch in the sun's *photosphere resulting from a localized fall in temperature to about 4000 K. Most spots have a central very dark umbra surrounded by a lighter penumbra. Sunspots tend to occur in clusters and to last about two weeks. The number of sunspots visible fluctuates over an an 11-year cycle – often called the **sunspot cycle** (*see* SOLAR CYCLE). The cause of sunspots is thought to be the presence of intense localized magnetic fields, which suppress the convection currents that bring hot gases to the photosphere.

superatom *See* BOSE–EINSTEIN CONDENSATION.

supercluster *See* GALAXY CLUSTER.

supercomputer An extremely high-power computer that has a large amount of main *memory and very fast processors, capable of several billion operations per second. Often the processors run in parallel (*see* PARALLEL PROCESSING). Examples include the Cray computers, which are used for weather forecasting and other applications that need rapid real-time processing of large amounts of data.

superconductivity The absence of measurable electrical resistance in certain substances at temperatures close to 0 K. First discovered in 1911 in mercury, superconductivity is now known to occur in some 26 metallic elements and many compounds and alloys. The temperature below which a substance becomes superconducting is called the **transition temperature** (or **critical temperature**). Compounds are now known that show superconductivity at liquid-nitrogen temperatures.

The theoretical explanation of the phenomenon was given by John Bardeen, Leon Cooper (1930–), and John Schrieffer (1931–) in 1957 and is known as the **BCS theory**. According to this theory an electron moving through an elastic crystal lattice creates a slight distortion of the lattice as a result of Coulomb forces between the positively charged lattice and the negatively charged electron. If this distortion persists for a finite time it can affect a second passing electron. In 1956 Cooper showed that the effect of this phenomenon is for the current to be carried in superconductors not by individual electrons but by bound pairs of electrons, the **Cooper pairs**. The BCS theory is based on a *wave function in which all the electrons are paired. Because the total momentum of a Cooper pair is unchanged by the interaction between one of its electrons and the lattice, the flow of electrons continues indefinitely.

Superconducting coils in which large currents can circulate indefinitely can be used to create powerful magnetic fields and are used for this purpose in some particle accelerators and in other devices.

Superconductivity can also occur by a slightly more complicated mechanism than BCS theory in *heavy-fermion systems. In 1986, Georg Bednorz (1950–) and Karl Müller (1927–) found an apparently completely different type of superconductivity. This is called **high-temperature superconductivity**, since the critical temperature is very much higher than for BCS superconductors; some high-temperature superconductors have critical temperatures greater than 100 K. A typical high-temperature superconductor is $YBa_2Cu_3O_{1-7}$.

At the present time a theory of high-temperature superconductivity has not yet been established.

SEE WEB LINKS

- Properties of superconducting elements at the NPL website

supercooling **1.** The cooling of a liquid to below its freezing point without a change from the liquid to solid state taking place. In this metastable state the particles of the liquid lose energy but do not fall into place in the lattice of the solid crystal. If the liquid is seeded with a small crystal, crystallization usually takes place and the temperature returns to the freezing point. Crystallization can also be induced by the presence of particles of dust, by mechanical vibration, or by rough surfaces. This is a common occurrence in the atmosphere where water droplets frequently remain unfrozen at temperatures well below 0°C until disturbed, following which they rapidly freeze. The supercooled droplets, for example, rapidly freeze on passing aircraft forming 'icing', which can be a hazard. **2.** The analogous cooling of a vapour to make it supersaturated until a disturbance causes condensation to occur, as in the Wilson *cloud chamber.

supercritical *See* CRITICAL MASS; CRITICAL REACTION; MULTIPLICATION FACTOR.

superexchange *See* MAGNETISM.

superficial expansivity *See* EXPANSIVITY.

superfluidity The property of liquid helium at very low temperatures that enables it to flow without friction. Both helium isotopes possess this property, but ^{4}He becomes superfluid at 2.172 K, whereas ^{3}He does not become superfluid until a temperature of 0.00093 K is reached. There is a basic connection between superfluidity and *superconductivity, so that sometimes a superconductor is called a charged superfluid. The temperature at which superfluidity occurs is called the **lambda point**.

supergiant The largest and most luminous type of star. They are formed from the most massive stars and are therefore very rare. They lie above the giants on the *Hertzsprung–Russell diagram. *See also* STELLAR EVOLUTION.

supergravity A *unified-field theory for all the known fundamental interactions that involves *supersymmetry. Supergravity is most naturally formulated as a *Kaluza–Klein theory in eleven dimensions. The theory contains particles of spin 2, spin 3/2, spin 1, spin 1/2, and spin 0. Although supersymmetry means that the infinities in the calculations are less severe than in other attempts to construct a quantum theory of gravity, it is not clear whether perturbation theory in supergravity gives finite answers due to the great complexity of the calculations. It is thought by many physicists that to obtain a consistent quantum theory of gravity one has to abandon *quantum field theories, since they deal with point objects, and move to theories based on extended objects, such as *superstrings and *supermembranes, and therefore that supergravity is not a complete theory of the fundamental interactions. However, it may well be a key ingredient in such a theory since it is related to *superstring theory by duality.

superheating The heating of a liquid to above its normal boiling point by increasing the pressure.

superheterodyne receiver A widely used type of radio receiver in which the incoming radio-frequency signal is mixed with an internally generated signal from a local oscillator. The output of the mixer has a carrier frequency equal to the difference between the transmitted frequency and the locally generated frequency, still retains the transmitted modulation, and is called the **intermediate frequency** (IF). The IF signal is amplified and demodulated before being passed to the audio-frequency amplifier. This system enables the IF signal to be amplified with less distortion, greater gain, better selectivity, and easier elimination of noise than can be achieved by amplifying the radio-frequency signal.

super high frequency (SHF) A radio frequency in the range 3–30 gigahertz.

superionic conductor An ionic solid in which the electrical conductivity due to the motion of ions is similar to that of a molten salt, i.e. a much higher conductivity than is usually observed in ionic solids.

superior Describing a structure that is positioned above or higher than another structure in the body. For example, in flowering plants the ovary is described as superior when located above the other organs of the flower. *Compare* INFERIOR.

superlattice *See* SOLID SOLUTION.

supermembrane theory A unified theory of the *fundamental interactions involving *supersymmetry, in which the basic entities are two-dimensional extended objects (**supermembranes**). They are thought to have about the same length scale as *superstrings, i.e. 10^{-35} m. At the present time there is no experimental evidence for supermembranes.

supernatant liquid The clear liquid remaining when a precipitate has settled.

supernova The explosive death of a star in which the energy radiated by the star suddenly increases by a factor of 10^{10}. It takes several weeks or months to fade and while it lasts it dominates the whole galaxy in which it is observed. It is estimated that there could be a supernova explosion in a galaxy as big as the Milky Way every 30 years, although only six have actually been observed in our Galaxy in the last 1000 years. A supernova explosion occurs when a star has burnt up all its available nuclear fuel and the core collapses catastrophically (*see* STELLAR EVOLUTION). Normal main-sequence stars like the sun can expect to end their lives as *white dwarfs but more massive stars explode catastrophically, producing in some cases a

*neutron star, in others a *black hole. *Compare* NOVA.

supernova remnant The expanding gas shell left behind by a supernova, at the heart of which lies a fast-rotating *neutron star or *pulsar.

superoxides A group of inorganic compounds that contain the O_2^- ion. They are formed in significant quantities only for sodium, potassium, rubidium, and caesium. They are very powerful oxidizing agents and react vigorously with water to give oxygen gas and OH^- ions. The superoxide ion has an unpaired electron and is paramagnetic and coloured (orange).

superphosphate A commercial phosphate mixture consisting mainly of monocalcium phosphate. It is made by treating phosphate rock with sulphuric acid; the product contains 16–20% 'available' P_2O_5:

$$Ca_{10}(PO_4)_6F_2 + 7H_2SO_4 \rightarrow 3Ca(H_2PO_4)_2 + 7CaSO_4 + 2HF$$

Triple-superphosphate is made by using phosphoric(V) acid in place of sulphuric acid; the product contains 45–50% 'available' P_2O_5:

$$Ca_{10}(PO_4)_6F_2 + 14H_3PO_4 \rightarrow 10Ca(H_2PO_4)_2 + 2HF$$

superplasticity The ability of some metals and alloys to stretch uniformly by several thousand percent at high temperatures, unlike normal alloys, which fail after being stretched 100% or less. Since 1962, when this property was discovered in an alloy of zinc and aluminium (22%), many alloys and ceramics have been shown to possess this property. For superplasticity to occur, the metal grain must be small and rounded and the alloy must have a slow rate of deformation.

Super Proton Synchrotron *See* CERN.

supersaturated solution *See* SATURATED.

supersaturation **1.** The state of the atmosphere in which the relative humidity is over 100%. This occurs in pure air where no condensation nuclei are available. Supersaturation is usually prevented in the atmosphere by the abundance of condensation nuclei (e.g. dust, sea salt, and smoke particles). **2.** The state of any vapour whose pressure exceeds that at which condensation usually occurs (at the prevailing temperature).

supersonic *See* MACH NUMBER.

superstring theory A unified theory of the *fundamental interactions involving supersymmetry, in which the basic objects are one-dimensional objects (**superstrings**). Superstrings are thought to have a length scale of about 10^{-35} m and, since very short distances are associated with very high energies, they should have energy scales of about 10^{19} GeV, which is far beyond the energy of any accelerator that can be envisaged.

Strings associated with bosons are only consistent as quantum theories in a 26-dimensional *space–time; those associated with fermions are only consistent as quantum theories in 10-dimensional space–time. It is thought that four macroscopic dimensions arise by a *Kaluza–Klein theory mechanism, with the remaining dimensions being 'curled up' to become very small, although other possibilities for the higher dimensions have been put forward.

One of the most attractive features of the theory of superstrings is that it leads to spin 2 particles, which are identified as *gravitons. Thus, a superstring theory automatically contains a quantum theory of the gravitational interaction. It is thought that superstrings are free of the infinities that cannot be removed by *renormalization, which plague attempts to construct a quantum field theory incorporating gravity. There is some evidence that superstring theory is free of infinities but not a complete proof yet.

supersymmetry A *symmetry that can be applied to elementary particles so as to include both bosons and fermions. In the simplest supersymmetry theories, every boson has a corresponding fermion partner and every fermion has a corresponding boson partner. The boson partners of existing fermions have names formed by adding 's' to the beginning of the name of the fermion, e.g. **selectron**, **squark**, and **slepton**. The fermion partners of existing bosons have names formed by replacing '-on' at the end of the boson's name by '-ino' or by adding '-ino', e.g. **gluino**, **photino**, **wino**, and **zino**.

It is thought that particles associated with supersymmetry may be one of the ingredients of dark matter (*see* MISSING MASS).

If supersymmetry is relevant to observed elementary particles then it must be a *bro-

ken symmetry, although there is no convincing evidence at present to show at what energy it would be broken. There is, in fact, no experimental evidence for the theory, although it is thought that the idea of strings with supersymmetry may be the best approach to unifying the four fundamental interactions (*see* SUPERSTRING THEORY).

supervolcano *See* VOLCANO.

supination Rotation of the lower forearm so that the hand faces forwards or upwards with the radius and ulna parallel. *Compare* PRONATION.

supplementary units *See* SI UNITS.

suppressed-carrier transmission *See* TRANSMITTER.

suppressor grid A wire grid in a pentode *thermionic valve placed between the *screen grid and the anode to prevent electrons produced by *secondary emission from the anode from reaching the screen grid.

supramolecular chemistry A field of chemical research concerned with the formation and properties of large assemblies of molecules held together by intramolecular forces (hydrogen bonds, van der Waals' forces, etc.). One feature of supramolecular chemistry is that of **self-assembly** (*see* SELF-ORGANIZATION), in which the structure forms spontaneously as a consequence of the nature of the molecules. The molecular units are sometimes known as **synthons**. Another aspect is the study of very large molecules able to be used in complex chemical reactions in a fashion similar to, for example, the actions of the naturally occurring haemoglobin and nucleic acid molecules. Typical examples are the *helicate and *texaphyrin molecules and *dendrimers. Such molecules have great potential in such areas as medicine, electronics, and optics. The field also includes **host–guest chemistry**, which is concerned with molecules specifically designed to accept other molecules. Examples include *crown ethers, *cryptands, and *calixarenes.

suprarenal glands *See* ADRENAL GLANDS.

surd A quantity that cannot be expressed as a *rational number. It consists of the root of an arithmetic member (e.g. $\sqrt{3}$), which cannot be exactly determined, or the sum or difference of such roots.

surface tension Symbol γ. The property of a liquid that makes it behave as if its surface is enclosed in an elastic skin. The property results from intermolecular forces: a molecule in the interior of a liquid experiences a force of attraction from other molecules equally from all sides, whereas a molecule at the surface is only attracted by molecules below it in the liquid. The surface tension is defined as the force acting over the surface per unit length of surface perpendicular to the force. It is measured in newtons per metre. It can equally be defined as the energy required to increase the surface area by one square metre, i.e. it can be measured in joules per metre squared (which is equivalent to $N\ m^{-1}$).

The surface tension of water is very strong, due to the intermolecular hydrogen bonding, and is responsible for the formation of drops, bubbles, and meniscuses, as well as the rise of water in a capillary tube (**capillarity**), the absorption of liquids by porous substances, and the ability of liquids to wet a surface. Capillarity is very important in plants as it is largely responsible for the transport of water, against gravity, within the plant.

SEE WEB LINKS

- Values of surface tension at the NPL website

surfactant (surface active agent) A substance, such as a *detergent, added to a liquid to increase its wetting properties by reducing its *surface tension.

surveying The practice of accurately measuring and recording the relative altitudes, angles, and distances of features on, above, or below the land surface from which maps and plans can be plotted. Surveying is necessary to locate and measure property lines; to lay out buildings, bridges, roads, dams, and other constructions; and to obtain topographic information for mapping and charting. A number of methods are used depending on the degree of precision that is required. The chief methods include triangulation, trilateration, levelling (*see* LEVEL), plane tabling, and traversing.

susceptance Symbol *B*. The reciprocal of the *reactance of a circuit and thus the imaginary part of its *admittance. It is measured in siemens.

susceptibility 1. (magnetic susceptibility) Symbol χ_m. The dimensionless quantity describing the contribution made by a sub-

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stance when subjected to a magnetic field to the total magnetic flux density present. It is equal to $\mu_r - 1$, where μ_r is the relative *permeability of the material. Diamagnetic materials have a low negative susceptibility, paramagnetic materials have a low positive susceptibility, and ferromagnetic materials have a high positive value. **2. (electric susceptibility)** Symbol χ_e. The dimensionless quantity referring to a *dielectric equal to $P/\varepsilon_0 E$, where P is the electric polarization, E is the electric intensity producing it, and ε_0 is the electric constant. The electric susceptibility is also equal to $\varepsilon_r - 1$, where ε_r is the relative *permittivity of the dielectric.

suspension A mixture in which small solid or liquid particles are suspended in a liquid or gas.

suture The line marking the junction of two body structures. Examples are the immovable joints between the bones of the skull and, in plants, the seam along the edge of a pea or bean pod.

swallowing *See* DEGLUTITION.

swash A surge of turbulent seawater that rushes up the shore after a wave breaks; it runs back down the slope as a backwash. The swash can carry materials, such as driftwood, seashells, and seaweed, which are often left on the beach as a line marking the extent of high tide. On a falling tide the backwash may form a series of channels.

sweat The salty fluid secreted by the *sweat glands onto the surface of the skin. Excess body heat is used to evaporate sweat, thereby resulting in cooling of the skin surface. Small amounts of urea are excreted in sweat.

sweat gland A small gland in mammalian skin that secretes *sweat. The distribution of sweat glands on the body surface varies between species: they occur over most of the body surface in humans and higher primates but have a more restricted distribution in other mammals.

swim bladder (air bladder) An air-filled sac lying above the alimentary canal in bony fish that regulates the buoyancy of the animal. Air enters or leaves the bladder either via a pneumatic duct opening into the oesophagus or stomach or via capillary blood vessels, so that the specific gravity of the fish always matches the depth at which it is swimming. This makes the fish weightless, so less energy is required for locomotion. In lungfish it also has a respiratory function. The lungs of tetrapods are homologous with the swim bladder, which has developed its hydrostatic function by specialization.

syconus A type of *composite fruit formed from a hollow fleshy inflorescence stalk inside which tiny flowers develop. Small *drupes, the 'pips', are produced by the female flowers. An example is the fig.

sylvite (sylvine) A mineral form of *potassium chloride, KCl.

symbiont An organism that is a partner in a symbiotic relationship (*see* SYMBIOSIS).

symbiosis An interaction between individuals of different species (**symbionts**). The term symbiosis is usually restricted to interactions in which both species benefit (*see* MUTUALISM), but it may be used for other close associations, such as *commensalism. Many symbioses are obligatory (i.e. the participants cannot survive without the interaction); for example, a lichen is an obligatory symbiotic relationship between an alga or a cyanobacterium and a fungus.

symmetry **1.** (in physics) The set of invariances of a system. Upon application of a symmetry operation on a system, the system is unchanged. Symmetry is studied mathematically using *group theory. Some of the symmetries are directly physical. Examples include reflections and rotation for molecules and translation in crystal lattices. Symmetries can be **discrete** (i.e. have a finite number), such as the set of rotations for an octahedral molecule, or **continuous** (i.e. do not have a finite number), such as the set of rotations for atoms or nuclei. More general and abstract symmetries can occur, as in the symmetries associated with *gauge theories. *See also* BROKEN SYMMETRY; SUPERSYMMETRY. **2.** (in biology) *See* BILATERAL SYMMETRY; RADIAL SYMMETRY.

sympathetic nervous system Part of the *autononomic nervous system. Its postganglionic neurons release mainly noradrenaline; preganglionic neurons release acetylcholine. Its actions tend to antagonize those of the *parasympathetic nervous system, thus achieving a balance in the organs they serve. For example, the sympathetic nervous system decreases salivary gland secretion, increases heart rate, and constricts blood vessels, while the parasympathetic nervous system has opposite effects.

sympatric Describing groups of similar organisms that, although in close proximity and theoretically capable of interbreeding, do not interbreed because of differences in behaviour, flowering time, etc. *See* ISOLATING MECHANISM. *Compare* ALLOPATRIC.

symphysis A *joint that is only slightly movable; examples are the joints between the vertebrae of the vertebral column and that between the two pubic bones in the pelvic girdle. The bones at a symphysis articulate by means of smooth layers of cartilage and strong fibres.

symplast The system of *protoplasts in plants, which are interconnected by *plasmodesmata. This forms a continuous system of cytoplasm bounded by the plasma membranes of the cells. The movement of water through the symplast is known as the **symplast pathway**. It is the only means by which water crosses the *endodermis. *Compare* APOPLAST.

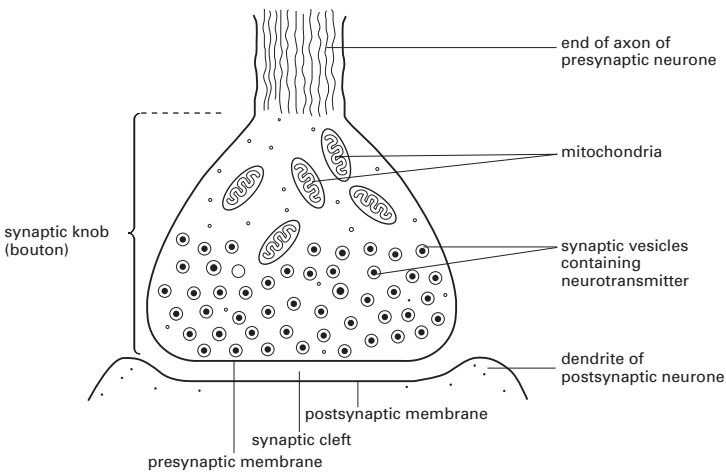
sympodium The composite primary axis of growth in such plants as lime and horse chestnut. After each season's growth the shoot tip of the main stem stops growing (sometimes terminating in a flower spike); growth is continued by the tip of one or more of the lateral buds. *Compare* MONOPODIUM.

synapse The junction between two adjacent neurons (nerve cells), i.e. between the axon ending of one (the **presynaptic neuron**) and the dendrites of the next (the **postsynaptic neuron**). The swollen tip of the axon of the presynaptic neuron, called the **synaptic knob** (or **bouton**), contains vesicles of *neurotransmitter substance. At a synapse, the membranes of the two cells (the **pre-** and **postsynaptic membranes**) are in close contact, with only a minute gap (the **synaptic cleft**) between them. A nerve *impulse is transmitted across the synapse by the release from the presynaptic membrane of neurotransmitter, which diffuses across the synaptic cleft to the postsynaptic membrane. This triggers the propagation of the impulse from the dendrite along the length of the postsynaptic neuron. Most neurons have more than one synapse. *See also* EXCITATORY POSTSYNAPTIC POTENTIAL.

synapsis (in genetics) *See* PAIRING.

syncarpy The condition in which the female reproductive organs (*carpels) of a flower are joined to each other. It occurs, for example, in the primrose. *Compare* APOCARPY.

synchrocyclotron A form of *cyclotron in which the frequency of the accelerating potential is synchronized with the increasing period of revolution of a group of the accelerated particles, resulting from their rela-



Synapse.

tivistic increase in mass as they reach *relativistic speeds. The accelerator is used with protons, deuterons, and alpha particles.

synchronous motor *See* ELECTRIC MOTOR.

synchronous orbit (geosynchronous orbit) An orbit of the earth made by an artificial *satellite with a period exactly equal to the earth's period of rotation on its axis, i.e. 23 hours 56 minutes 4.1 seconds. If the orbit is inclined to the equatorial plane the satellite will appear from the earth to trace out a figure-of-eight track once every 24 hours. If the orbit lies in the equatorial plane and is circular, the satellite will appear to be stationary. This is called a **stationary orbit** (or **geostationary orbit**) and it occurs at an altitude of 35 900 km. Most communication satellites are in stationary orbits, with three or more spaced round the orbit to give worldwide coverage.

synchronous rotation The rotation of a natural satellite in which the period of rotation is equal to its orbital period. The moon, for example, is in synchronous rotation about the earth and therefore completes one axial rotation in 27.322 days, the same time as it takes to complete one orbit of the earth. The result is that the moon always presents the same face to the earth.

synchrotron A particle accelerator used to impart energy to electrons and protons in order to carry out experiments in particle physics and in some cases to make use of the *synchrotron radiation produced. The particles are accelerated in closed orbits (often circular) by radio-frequency fields. Magnets are spaced round the orbit to bend the trajectory of the particles and separate focusing magnets are used to keep the particles in a narrow beam. The radio-frequency accelerating cavities are interspersed between the magnets. The motion of the particles is automatically synchronized with the rising magnetic field, as the field strength has to increase as the particle energy increases; the frequency of the accelerating field also has to increase synchronously.

synchrotron radiation (magneto-bremsstrahlung) Electromagnetic radiation that is emitted by charged particles moving at relativistic speeds in circular orbits in a magnetic field. The rate of emission is inversely proportional to the product of the radius of curvature of the orbit and the fourth power of the mass of the particles. For this reason, synchrotron radiation is not a problem in the design of proton *synchrotrons but it is significant in electron synchrotrons. The greater the circumference of a synchrotron, the less important is the loss of energy by synchrotron radiation. In *storage rings, synchrotron radiation is the principal cause of energy loss.

However, since the 1950s it has been realized that synchrotron radiation is itself a very useful tool and many accelerator laboratories have research projects making use of the radiation on a secondary basis to the main high-energy research. The radiation used for these purposes is primarily in the ultraviolet and X-ray frequencies.

Much of the microwave radiation from celestial radio sources outside the Galaxy is believed to originate from electrons moving in curved paths in celestial magnetic fields; it is also called synchrotron radiation as it is analogous to the radiation occurring in a synchrotron. Synchrotron radiation is also predicted to exist for gravitational radiation.

SEE WEB LINKS

- Website of the Advanced Light Source facility at Berkeley
- Website for the Diamond Light Source at Harwell

syncline *See* FOLD.

syncytium A group of animal cells in which cytoplasmic continuity is maintained. For example, the cells of striated muscle form a syncytium. In some syncytia the cells remain discrete but are joined together by cytoplasmic bridges.

syndiotactic *See* POLYMER.

synecology The study of ecology at the level of the *community. A synecological study aims to investigate the relationships between different species that form a community and their interactions with the surrounding environment. Synecology involves both *biotic and *abiotic factors. *Compare* AUTECOLOGY.

synergism (summation) **1.** The phenomenon in which the combined action of two substances (e.g. drugs or hormones) produces a greater effect than would be expected from adding the individual effects of each substance. **2.** The combined action of one muscle (the **synergist**) with another (the **agonist**) in producing movement. *Compare* ANTAGONISM.

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syngamy *See* FERTILIZATION.

synodic month (lunation) The interval between two successive new *moons. It is equal to 29 days, 12 hours, and 44 minutes.

synodic period The mean time taken by any object in the solar system to move between successive returns to the same position, relative to the sun as seen from the earth. Since a planet is best observed at opposition the synodic period of a planet, *S*, is easier to measure than its *sidereal period, *P*. For inferior planets $1/S = 1/P - 1/E$; for superior planets $1/S = 1/E - 1/P$, where E is the sidereal period of the earth.

synoptic chart *See* SYNOPTIC METEOROLOGY.

synoptic meteorology The branch of meteorology concerned with the study and analysis of weather information that is obtained simultaneously over a large area. It is based on the analysis of the **synoptic chart**, which is built up from simultaneous observations at weather stations of such elements as wind speed and direction, air temperature, cloud cover, and air pressure over an area at a particular time. Synoptic meteorology is applied chiefly to weather forecasting.

synovial membrane The membrane that lines the ligament surrounding a freely movable joint (such as that at the hip or elbow). It secretes a fluid (**synovial fluid**) that lubricates the layers of cartilage forming the articulating surfaces of the joint.

synthesis The formation of chemical compounds from more simple compounds.

synthesis gas A mixture of two parts hydrogen and one part carbon monoxide made from methane and steam heated under pressure. It is used in the manufacture of various organic chemicals, including hydrocarbons, methanol, and other alcohols. *See also* HABER PROCESS.

synthetic Describing a substance that has been made artificially; i.e. one that does not come from a natural source.

synthetic metal A substance that is not a metal but has free electrons that can contribute to electrical conductivity. Conducting polymers are examples of synthetic metals.

synthon *See* SUPRAMOLECULAR CHEMISTRY.

syrinx The sound-producing organ of a bird, situated at the lower end of the trachea where it splits into the bronchi. It has a complex structure with a number of vibrating membranes.

systematics The study of the diversity of organisms and their natural relationships. It is sometimes used as a synonym for *taxonomy. The term **biosystematics** describes the experimental study of diversity, especially at the species level. Biosystematic methods include breeding experiments, biochemical work (known as **chemosystematics**), and cytotaxonomy. *See also* MOLECULAR SYSTEMATICS.

Système International d'Unités *See* SI UNITS.

systemic circulation The part of the circulatory system of birds and mammals that transports oxygenated blood from the left ventricle of the heart to the tissues in the body and returns deoxygenated blood from the tissues to the right atrium of the heart. *Compare* PULMONARY CIRCULATION. *See* DOUBLE CIRCULATION.

systems biology An approach that seeks to study organisms as complete systems – networks of interacting genes, biomolecules, and biochemical reactions. It thus attempts to integrate all relevant structural and functional information, rather than focusing on, say, just one particular gene or protein at a time. This involves amassing and organizing data obtained from genomics, proteomics, and other areas of bioinformatics and managing and analysing the data to identify patterns, formulate hypotheses, and ultimately create computer models that will enable accurate predictions of cellular and organismal responses. Such models will have a radical impact on medicine and biology in the future.

systems software *See* APPLICATIONS SOFTWARE.

systole The phase of the heart beat during which the ventricles of the heart contract to force blood into the arteries. *Compare* DIASTOLE. *See* BLOOD PRESSURE.

syzygy The situation that occurs when the sun, the moon (or a planet), and the earth are in a straight line. This occurs when the moon (or planet) is at *conjunction or *opposition.