T

2,4,5-T 2,4,5-trichlorophenoxyacetic acid (2,4,5-trichlorophenoxyethanoic acid): a synthetic *auxin formerly widely used as a herbicide and defoliant. It is now banned in many countries as it tends to become contaminated with the toxic chemical *dioxin.

tabun A highly toxic colourless or brown liquid, $C_5H_{11}N_2O_2P$; r.d. 1.09; m.p. –50°C; b.p. 247.5°C. It is an organophosphorus compound, ethyl N,N-dimethylphosphoramidocyanidate. Tabun was discovered in 1936 and belongs to the G-series of *nerve agents (GA). It was used by Iraq in the Iran–Iraq war (1980–88).

tachometer An instrument for measuring angular speed, especially the number of revolutions made by a rotating shaft in unit time. Various types of instrument are used, including mechanical, electrical, and electronic devices. The widely used electrical-generator tachometer consists of a small generator in which the output voltage is a measure of the rate of rotation of the shaft that drives it.

tachyon A hypothetical particle that has a speed in excess of the *speed of light. According to electromagnetic theory, a charged particle travelling through a medium at a speed in excess of the speed of light in that medium emits *Cerenkov radiation. A charged tachyon would emit Cerenkov radiation even in a vacuum. No such particle has yet been detected. According to the special theory of *relativity, it is impossible to accelerate a particle up to the speed of light because its energy E, given by $E = mc^2/\sqrt{(1 - v^2/c^2)}$, would have to become infinite. The theory, however, does not forbid the existence of particles with $v > c$ (where c is the speed of light). In such cases the expression in the brackets becomes negative and the energy would be imaginary.

tactic movement *See* TAXIS.

tactic polymer *See* POLYMER.

taiga A terrestrial *biome consisting mainly of evergreen coniferous forests (mainly pine, fir, and spruce), which occurs across subarctic North America and Eurasia. In certain parts, such as northeastern Siberia, deciduous conifers and broadleaved trees, such as larch and birch, are dominant. Over most of the taiga the ground is permanently frozen within about one metre of the surface, which prevents water from filtering down to deeper levels in the soil. This means that bogs may form in depressions. For at least six months of the year temperatures are below freezing but there is a short growing season lasting 3–5 months. The soil in taiga areas is acidic and infertile. *Compare* TUNDRA.

Takayama test *See* HAEMOCHROMOGEN TEST.

talc A white or pale-green mineral form of magnesium silicate, $Mg_3Si_4O_{10}(OH)_2$, crystallizing in the triclinic system. It forms as a secondary mineral by alteration of magnesium-rich olivines, pyroxenes, and amphiboles of ultrabasic rocks. It is soaplike to touch and very soft, having a hardness of 1 on the Mohs' scale. Massive fine-grained talc is known as **soapstone** or **steatite**. Talc in powdered form is used as a lubricant, as a filler in paper, paints, and rubber, and in cosmetics, ceramics, and French chalk. It occurs chiefly in the USA, Russia, France, and Japan.

tandem generator A type of particle generator, essentially consisting of a *Van de Graaff generator that maintains one electrode at a high positive potential; this electrode is placed between two earthed electrodes. Negative ions are accelerated from earth potential to the positively charged electrode, where surplus electrons are stripped from the ions to produce positive ions, which are accelerated again from the positive electrode back to earth. Thus the ions are accelerated twice over by a single high potential. This tandem arrangement enables energies up to 30 MeV to be achieved.

tangent **1.** A line that touches a curve or a plane that touches a surface. **2.** *See* TRIGONOMETRIC FUNCTIONS.

tangent galvanometer A type of galvanometer, now rarely used, in which a small magnetic needle is pivoted horizontally at the centre of a vertical coil that is adjusted to be parallel to the horizontal component of the earth's magnetic field. When a current I is passed through the coil, the needle is deflected so that it makes an angle θ with its equilibrium position parallel to the earth's field. The value of I is given by $I = (2Hr\tan\theta)/n$, where H is the strength of the earth's horizontal component of magnetizing force, r is the radius of the coil, and n is the number of turns in the coil. Although not now used for measuring current, the instrument provides a means of measuring the earth's magnetizing force.

tanh *See* HYPERBOLIC FUNCTIONS.

tannic acid A yellowish complex organic compound present in certain plants. It is used in dyeing as a mordant.

tannin One of a group of complex organic chemicals commonly found in leaves, unripe fruits, and the bark of trees. Their function is uncertain though the unpleasant taste may discourage grazing animals. Some tannins have commercial uses, notably in the production of leather and ink.

tantalum Symbol Ta. A heavy blue-grey metallic *transition element; a.n. 73; r.a.m. 180.948; r.d. 16.63; m.p. 2996°C; b.p. 5427°C. It is found with niobium in the ore columbite–tantalite $(Fe,Mn)(Ta,Nb)_2O_6$. It is extracted by dissolving in hydrofluoric acid, separating the tantalum and niobium fluorides to give K_2TaF_7, and reduction of this with sodium. The element contains the stable isotope tantalum–181 and the long-lived radioactive isotope tantalum–180 (0.012%; half-life $>10^7$ years). There are several other short-lived isotopes. The element is used in certain alloys and in electronic components. Tantalum parts are also used in surgery because of the unreactive nature of the metal (e.g. in pins to join bones). Chemically, the metal forms a passive oxide layer in air. It forms complexes in the +2, +3, +4, and +5 oxidation states. Tantalum was identified in 1802 by Anders Ekeberg (1767–1813) and first isolated in 1820 by Jöns Berzelius.

SEE WEB LINKS

- Information from the WebElements site

tapetum A reflecting layer, containing crystals of guanine, in the *choroid of the eye of many nocturnal vertebrates. It reflects light back onto the retina, thus improving vision and causing the eyes to shine in the dark.

tapeworms *See* CESTODA.

tap root *See* ROOT.

tar Any of various black semisolid mixtures of hydrocarbons and free carbon, produced by destructive distillation of *coal or by *petroleum refining.

tarsal (tarsal bone) One of the bones that form the ankle (*see* TARSUS) in terrestrial vertebrates.

tar sand *See* OIL SAND.

tarsus The ankle (or corresponding part of the hindlimb) in terrestrial vertebrates, consisting of a number of small bones (**tarsals**). The number of tarsal bones varies with the species: humans, for example, have seven.

tartaric acid A white crystalline naturally occurring carboxylic acid, $(CHOH)_2(COOH)_2$; r.d. 1.8; m.p. 171–174°C. It can be obtained from tartar (potassium hydrogen tartrate) deposits from wine vats, and is used in baking powders and as a foodstuffs additive. The compound is optically active (*see* OPTICAL ACTIVITY). The systematic name is **2,3-dihydroxybutanedioic acid**.

tartrate A salt or ester of *tartaric acid.

taste **1.** The sense that enables the flavour of different substances to be distinguished (*see* TASTE BUD). **2.** The flavour of a substance.

SEE WEB LINKS

- A tutorial on the sense of taste, compiled by Tim Jacob of Cardiff University

taste bud A small sense organ in most vertebrates, specialized for the detection of taste. In terrestrial animals taste buds are concentrated on the upper surface of the *tongue. They are sensitive to four types of taste: sweet, salt, bitter, or sour. The taste bud transmits information about a particular type of taste to the brain via nerve fibres. The four types of taste bud show distinct distribution patterns on the surface of the human tongue.

In fishes, taste buds are distributed over the entire surface of the body and provide information about the surrounding water.

TATA box (Hogness box) A sequence of nucleotides that serves as the main recogni-

tion site for the attachment of RNA polymerase in the *promoter of eukaryotic genes. Located at around 25 nucleotides before the start of transcription, it consists of the seven-base *consensus sequence TATAAAA, and is analogous to the *Pribnow box in prokaryotic promoters.

TATP *See* TRIACETONE TRIPEROXIDE.

Tatum, Edward *See* BEADLE, GEORGE WELLS.

tau particle *See* ELEMENTARY PARTICLES; LEPTON.

tautomerism A type of *isomerism in which the two isomers (**tautomers**) are in equilibrium. *See* KETO–ENOL TAUTOMERISM.

taxis (taxic response; tactic movement) The movement of a cell (e.g. a gamete) or a microorganism in response to an external stimulus. Certain microorganisms have a light-sensitive region that enables them to move towards or away from high light intensities (positive and negative *phototaxis respectively). Many bacteria move in response to chemical stimuli (**chemotaxis**); a specific example is **aerotaxis**, in which atmospheric oxygen is the stimulus. Taxic responses are restricted to cells that possess cilia, flagella, or some other means of locomotion. The term is usually not applied to the movements of higher animals. *Compare* KINESIS; TROPISM.

taxon (*pl.* **taxa**) Any named taxonomic group of any *rank in the hierarchical *classification of organisms. Thus the taxa Papilionidae, Lepidoptera, Hexapoda, and Uniramia are named examples of a family, order, class, and phylum, respectively.

taxonomy The study of the theory, practice, and rules of *classification of living and extinct organisms. The naming, description, and classification of a given organism draws on evidence from a number of fields. **Classical taxonomy** is based on morphology and anatomy. **Cytotaxonomy** compares the size, shape, and number of chromosomes of different organisms. **Numerical taxonomy** uses mathematical procedures to assess similarities and differences and establish taxonomic groups. *See also* SYSTEMATICS.

Taylor series The infinite power series of derivatives into which a function f(x) can be expanded, for a fixed value of the variable $x = a$:

$$f(x) = f(a) + f'(a)(x - a) + f''(a)(x - a)^2/2! + \ldots$$

When $a = 0$, the series formed is known as **Maclaurin's series**:

$$f(x) = f(0) + f'(0)x + f''(0)x^2/2! + \ldots$$

The series was discovered by Brook Taylor (1685–1731) and the special case was named after Colin Maclaurin (1698–1746).

TCA cycle *See* KREBS CYCLE.

T cell (T lymphocyte) Any of a population of *lymphocytes that are the principal agents of cell-mediated *immunity. T cells are derived from the bone marrow but migrate to the thymus to mature (hence *T* cell). After leaving the thymus, and when presented with antigen, a T cell becomes 'armed' to act as an **effector T cell** when it subsequently encounters its specific antigen. Subpopulations of T cells play different roles in the immune response and can be characterized by their surface antigens (*see* CD). **Helper T cells** carry the CD4 antigen and recognize foreign antigens provided these are presented by cells (such as macrophages and B lymphocytes) bearing class II *histocompatibility antigens. The helper T cell binds to its target cell by means of **T-cell receptors**. Helper T cells are essential in the majority of infections for stimulating B cells to proliferate and differentiate into clones of antibody-producing plasma cells.

Cytotoxic T cells, which carry the CD8 antigen, recognize foreign antigen on the surface of virus-infected cells and destroy the cell by releasing cytolytic proteins. **Suppressor T cells** (or **regulatory T cells**) are important in regulating the activity of other lymphocytes and are crucial in maintaining tolerance to self tissues.

TCP/IP *Trademark.* Transmission Control Protocol/Internet Protocol: the obligatory standard to be used by any system connecting to the *Internet. The two protocols were originally developed on the DARPA net. They were devised to optimize the performance of networks that are based on unreliable data-transmission systems operating at relatively low data rates.

The Internet Protocol, IP, is the lower of the two protocols. It provides a connectionless datagram service, and a managed address structure for data transmission. In IP version 4 (**IPv4**), the dominant version on the Internet, an **IP address** is a 32-bit number. The interpretation of these bits was formerly rigid and divided IP addresses into four classes, A to D. This system has been su-

perseded since 1993 by Classless Inter-Domain Routing.

The explosive growth of the Internet has resulted in the IPv4 32-bit address space becoming restrictive. IP version 6 (**IPv6**) seeks to remedy this by using 128-bit IP addresses, with 64 bits being used for both the network identity and the host address. IPv6 is gradually being adopted on the Internet. IP allows a long datagram to be fragmented into numbered packets, which can then be transmitted and reassembled in their correct sequence at the destination system. It is intended to be used in conjunction with the Transmission Control Protocol, TCP.

TCP provides error-free delivery of arbitrarily long messages, known as **segments**, with the data being released to the host system in the same order as the original transmission. It achieves this by a 'sliding window' mechanism. As data are transmitted, they are accompanied by a checksum; at the receiving end the checksum is verified and an acknowledgment is returned to the transmitter, which indicates the position of the last data to be successfully received. The transmitter will not send data beyond a certain point, determined by the size of the window, i.e. the gap between the last data to be sent and the last data for which an acknowledgment has been received. If the checksum fails at any point, the transmitter will retransmit data from the point immediately following the latest acknowledgment of correct receipt.

SEE WEB LINKS

- The TCP (version 4) specification
- The IP (version 4) specification
- The IP (version 6) specification

***t*-distribution** In *statistics, a probability distribution made up of the *means of random samples from a collection of samples that have a *normal distribution of unknown *variance. *See also* NORMAL DISTRIBUTION; POISSON DISTRIBUTION.

tebi- *See* BINARY PREFIXES.

technetium Symbol Tc. A radioactive metallic *transition element; a.n. 43; m.p. 2172°C; b.p. 4877°C. The element can be detected in certain stars and is present in the fission products of uranium. It was first made by Carlo Perrier and Emilio Segrè (1905–89) by bombarding molybdenum with deuterons to give technetium–97. The most stable isotope is technetium–99 (half-life 2.6×10^6 years); this is used to some extent in labelling for medical diagnosis. There are sixteen known isotopes. Chemically, the metal has properties intermediate between manganese and rhenium.

SEE WEB LINKS

- Information from the WebElements site

technicolour theory *See* HIGGS FIELD.

teeth *See* DECIDUOUS TEETH; PERMANENT TEETH; DENTITION; TOOTH.

Teflon Trade name for a form of *polytetrafluoroethene.

Teichmann test *See* HAEMATIN TEST.

tektite A small black, greenish, or yellowish glassy object found in groups on the earth's surface and consisting of a siliceous material unrelated to the geological formations in which it is found. Tektites are believed to have formed on earth as a result of the impact of meteorites.

telecommunications The study and application of means of transmitting information, either by wires or by electromagnetic radiation.

Teleostei The major superorder of the *Osteichthyes (bony fish), containing about 20 000 species. Teleosts have colonized an extensive variety of habitats and show great diversity of form. The group includes the eel, seahorse, plaice, and salmon. They have been the dominant fish since the Cretaceous period (about 70 million years ago).

telescope An instrument that collects electromagnetic radiation from a distant object in order to produce an image of it or enable the radiation to be analysed. See Feature.

television The transmission and reception of moving images by means of radio waves or cable. The scene to be transmitted is focused onto a photoelectric screen in the television *camera. This screen is scanned by an electron beam. The camera produces an electric current, the instantaneous magnitude of which is proportional to the brightness of the portion of the screen being scanned. In Europe the screen is scanned by 625 lines and 25 such frames are produced every second. In the USA 525 lines and 30 frames per second are used. The picture signal so produced is used to modulate a VHF or UHF carrier wave and is transmitted with an independent sound signal, but with colour information (if any) incorporated into

OPTICAL ASTRONOMICAL TELESCOPES

Optical astronomical telescopes fall into two main classes: **refracting telescopes** (or **refractors**), which use lenses to form the primary image, and **reflecting telescopes** (or **reflectors**), which use mirrors.

Refracting telescopes

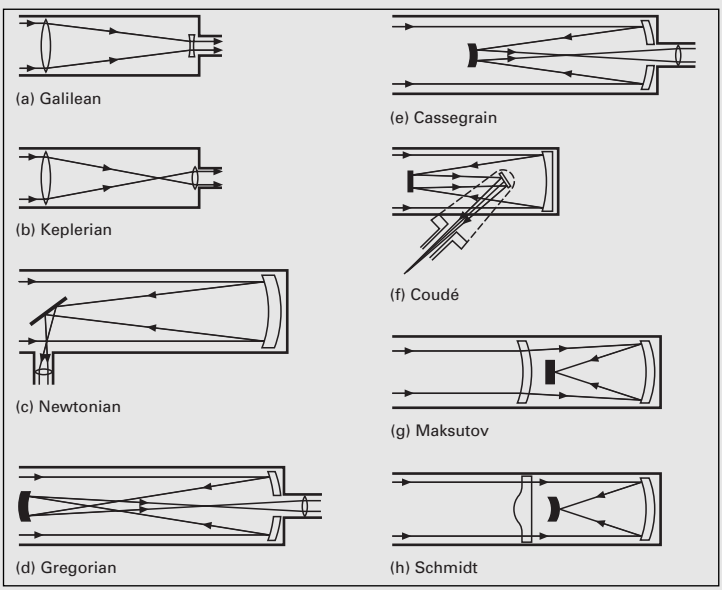
The refracting telescopes use a converging lens to collect the light and the resulting image is magnified by the eyepiece. This type of instrument was first constructed in 1608 by Hans Lippershey (1587–1619) in Holland and developed in the following year as an astronomical instrument by Galileo, who used a diverging lens as eyepiece. The **Galilean telescope** was later improved by Johannes Kepler (1571–1630), who substituted a converging eyepiece lens. This form is still in use for small astronomical telescopes (the **Keplerian telescope**).

Reflecting telescopes

The first reflecting telescope was produced by Newton in 1668. This used a concave mirror to collect and focus the light and a small secondary mirror at an angle of 45° to the main beam to reflect the light into the magnifying eyepiece. This design is known as the **Newtonian telescope**. The **Gregorian telescope**, designed by James Gregory (1638–75), and the **Cassegrainian telescope**, designed by N. Cassegrain (*fl*. 1670s), use different secondary optical systems. The **coudé telescope** (French: angled) is sometimes used with larger instruments as it increases their focal lengths.

Catadioptic telescopes

Catadioptic telescopes use both lenses and mirrors. The most widely used astronomical instruments in this class are the **Maksutov telescope** and the **Schmidt camera**.



the brief gaps between the picture lines. The signals received by the receiving aerial are demodulated in the receiver; the demodulated picture signal controls the electron beam in a cathode-ray tube, on the screen of which the picture is reconstructed. *See also* COLOUR TELEVISION.

television tube *See* CATHODE RAYS.

tellurides Binary compounds of tellurium with other more electropositive elements. Compounds of tellurium with nonmetals are covalent (e.g. H_2Te). Metal tellurides can be made by direct combination of the elements and are ionic (containing Te^{2-}) or nonstoichiometric interstitial compounds (e.g. Pd_4Te, $PdTe_2$).

tellurium Symbol Te. A silvery metalloid element belonging to *group 16 (formerly VIB) of the periodic table; a.n. 52; r.a.m. 127.60; r.d. 6.24 (crystalline); m.p. 449.5°C; b.p. 989.8°C. It occurs mainly as *tellurides in ores of gold, silver, copper, and nickel and it is obtained as a by-product in copper refining. There are eight natural isotopes and nine radioactive isotopes. The element is used in semiconductors and small amounts are added to certain steels. Tellurium is also added in small quantities to lead. Its chemistry is similar to that of sulphur. It was discovered by Franz Müller (1740–1825) in 1782.

SEE WEB LINKS

- Information from the WebElements site

telomere The end of a chromosome, which consists of tandemly repeated short sequences of DNA that perform the function of ensuring that each cycle of *DNA replication has been completed.

telophase A stage of cell division. In *mitosis the chromatids that separated from each other at *anaphase collect at the poles of the spindle. A nuclear membrane forms around each group, producing two daughter nuclei with the same number and kind of chromosomes as the original cell nucleus. In the first telophase of *meiosis, complete chromosomes from the pairs that separated at first anaphase form the daughter nuclei. The number of chromosomes in these nuclei is therefore half the number in the original one. In the second telophase, daughter nuclei are formed from chromatids (as in mitosis).

temperament The way in which the intervals between notes on keyboard instruments are distributed throughout the scale to ensure that music in all keys sounds in tune. The problem can be illustrated by a piano keyboard. Taking a low C and a high C seven octaves above, the interval should be $2^7 = 128$. However, in passing through the cycle of 12 keys, each using as its fundamental the fifth of its predecessor, the interval between Cs becomes $(3/2)^{12} = 129.75$. The difference between 129.75 and 128 is known as the **comma of Pythagoras**. The **equal-temperament scale**, which has been in use since the time of J. S. Bach, distributes the comma of Pythagoras equally between the 12 intervals of the scale over seven octaves. Thus each fifth becomes $(128)^{1/12} = 1.4983$. All forms of temperament involve a measure of compromise; this system is now regarded as the best.

temperature The property of a body or region of space that determines whether or not there will be a net flow of heat into it or out of it from a neighbouring body or region and in which direction (if any) the heat will flow. If there is no heat flow the bodies or regions are said to be in **thermodynamic equilibrium** and at the same temperature. If there is a flow of heat, the direction of the flow is from the body or region of higher temperature. Broadly, there are two methods of quantifying this property. The empirical method is to take two or more reproducible temperature-dependent events and assign **fixed points** on a scale of values to these events. For example, the Celsius temperature scale uses the freezing point and boiling point of water as the two fixed points, assigns the values 0 and 100 to them, respectively, and divides the scale between them into 100 degrees. This method is serviceable for many practical purposes (*see* TEMPERATURE SCALES), but lacking a theoretical basis it is awkward to use in many scientific contexts. In the 19th century, Lord Kelvin proposed a thermodynamic method to specify temperature, based on the measurement of the quantity of heat flowing between bodies at different temperatures. This concept relies on an absolute scale of temperature with an *absolute zero of temperature, at which no body can give up heat. He also used Sadi Carnot's concept of an ideal frictionless perfectly efficient heat engine (*see* CARNOT CYCLE). This Carnot engine takes in a quantity of heat q_1 at a temperature T_1, and exhausts heat q_2 at T_2, so that $T_1/T_2 = q_1/q_2$. If

T_2 has a value fixed by definition, a Carnot engine can be run between this fixed temperature and any unknown temperature T_1, enabling T_1 to be calculated by measuring the values of q_1 and q_2. This concept remains the basis for defining **thermodynamic temperature**, quite independently of the nature of the working substance. The unit in which thermodynamic temperature is now expressed is the *kelvin. In practice thermodynamic temperatures cannot be measured directly; they are usually inferred from measurements with a gas thermometer containing a nearly ideal gas. This is possible because another aspect of thermodynamic temperature is its relationship to the *internal energy of a given amount of substance. This can be shown most simply in the case of an ideal monatomic gas, in which the internal energy per mole (U) is equal to the total kinetic energy of translation of the atoms in one mole of the gas (a monatomic gas has no rotational or vibrational energy). According to *kinetic theory, the thermodynamic temperature of such a gas is given by $T = 2U/3R$, where R is the universal *gas constant.

temperature coefficient A coefficient that determines the rate of change of some physical property with change in temperature. For example, the dependence of the resistance (R) of a material on the Celsius temperature t, is given by $R = R_0 + \alpha t + \beta t^2$, where R_0 is the resistance at 0°C and α and β are constants. If β is negligible, then α is the **temperature coefficient of resistance**.

temperature inversion An abnormal increase in air temperature that occurs in the troposphere, the lowest level of the earth's atmosphere. This can lead to pollutants becoming trapped in the troposphere (*see* AIR POLLUTION).

temperature scales A number of empirical scales of *temperature have been in use: the *Celsius scale is widely used for many purposes and in certain countries the *Fahrenheit scale is still used. These scales both rely on the use of **fixed points**, such as the freezing point and the boiling point of water, and the division of the **fundamental interval** between these two points into units of temperature (100 degrees in the case of the Celsius scale and 180 degrees in the Fahrenheit scale).

However, for scientific purposes the scale in use is the **International Practical Temperature Scale** (**IPTS**), which is designed to conform as closely as possible to thermodynamic temperature and is expressed in the unit of thermodynamic temperature, the *kelvin. The 1968 version of the table (known as IPTS-68) had 11 fixed points defined by both Celsius and thermodynamic temperatures. The most recent version (IPTS-90), introduced in 1990, has 16 fixed points with temperatures expressed in kelvins:

Triple point of hydrogen: 13.8033
Boiling point of hydrogen (33 321.3 Pa): 17.035
Boiling point of hydrogen (101 292 Pa): 20.27
Triple point of neon: 24.5561
Triple point of oxygen: 54.3584
Triple point of argon: 83.8058
Triple point of mercury: 234.3156
Triple point of water: 273.16 (0.01°C)
Melting point of gallium: 302.9146
Freezing point of indium: 429.7485
Freezing point of tin: 505.078
Freezing point of zinc: 692.677
Freezing point of aluminium: 933.473
Freezing point of silver: 1234.93
Freezing point of gold: 1337.33
Freezing point of copper: 1357.77

Methods for measuring intermediate temperatures between these fixed points are specified; for example, at low temperatures (0–5 K) they are measured by means of vapour-pressure determinations of ^{3}He and ^{4}He; at high temperatures (above 1234.93 K) a radiation pyrometer is used.

tempering The process of increasing the toughness of an alloy, such as steel, by heating it to a predetermined temperature, maintaining it at this temperature for a predetermined time, and cooling it to room temperature at a predetermined rate. In steel, the purpose of the process is to heat the alloy to a temperature that will enable the excess carbide to precipitate out of the supersaturated solid solution of *martensite and then to cool the saturated solution fast enough to prevent further precipitation or grain growth. For this reason steel is quenched rapidly by dipping into cold water.

template Any molecule that acts as a pattern for the synthesis of a new molecule. For example, the two nucleotide chains of a DNA molecule can separate and each acts as a template for the synthesis of the missing chain (*see* DNA REPLICATION).

temporary hardness *See* HARDNESS OF WATER.

temporary magnetism Magnetism in a

body that is present when the body is in a magnetic field but that largely disappears when it is removed from the field.

tendon A thick strand or sheet of tissue that attaches a muscle to a bone. Tendons consist of *collagen fibres and are therefore inelastic: they ensure that the force exerted by muscular contraction is transmitted to the relevant part of the body to be moved.

tendril A slender branched or unbranched structure found in many climbing plants. It may be a modified stem, leaf, leaflet, or petiole. Tendrils respond to contact with solid objects by twining around them (*see* THIGMOTROPISM). The cells that touch the object lose water and decrease in volume in comparison to the outer cells, thus causing the tendril to curve.

tensile strength A measure of the resistance that a material offers to tensile *stress. It is defined as the stress, expressed as the force per unit cross-sectional area, required to break it.

tensimeter A form of differential manometer with two sealed bulbs attached to the limbs. It is used to measure the difference in vapour pressure between liquids sealed into the bulbs. If one liquid has a known vapour pressure (often water is used) that of the other can be determined.

tensiometer Any apparatus for measuring *surface tension.

tentacle Any of the soft flexible appendages in aquatic invertebrate animals that are used principally for feeding. Water flows over the tentacles, which are able to capture food and direct it to the oral aperture. Tentacles are possessed by many cnidarians, some echinoderms (including sea cucumbers), and by cephalopod molluscs, in which the tentacles bear rows of suckers.

tera- Symbol T. A prefix used in the metric system to denote one million million times. For example, 10^{12} volts = 1 teravolt (TV).

teratogen Any environmental factor that acts on a fetus to cause congenital abnormality. Examples include ionizing radiation (e.g. X-rays), nutritional deficiencies, drugs (e.g. thalidomide), toxic chemicals, and virus infections (e.g. rubella).

terbium Symbol Tb. A silvery metallic element belonging to the *lanthanoids; a.n. 65; r.a.m. 158.92; r.d. 8.23 (20°C); m.p. 1356°C; b.p. 3123°C. It occurs in apatite and xenotime, from which it is obtained by an ion-exchange process. There is only one natural isotope, terbium–159, which is stable. Seventeen artificial isotopes have been identified. It is used as a dopant in semiconducting devices. It was discovered by Carl Mosander (1797–1858) in 1843.

SEE WEB LINKS

- Information from the WebElements site

terephthalic acid (1,4-benzenedicarboxylic acid) A colourless crystalline solid, $C_6H_4(COOH)_2$, m.p. 300°C. It is made by oxidizing *p*-xylene (1,4-dimethylebenzene) and used for making polyesters, such as Terylene.

terminal **1.** The point at which electrical connection is made to a device or system. **2.** A device at which data is put into a *computer or taken from it.

terminal speed The constant speed finally attained by a body moving through a fluid under gravity when there is a zero resultant force acting on it. *See* STOKES' LAW.

terminator The boundary, on the surface of the moon or a planet, between the sunlit area and the dark area.

ternary compound A chemical compound containing three different elements.

terpenes A group of unsaturated hydrocarbons present in plants (*see* ESSENTIAL OIL). Terpenes consist of isoprene units, $CH_2{:}C(CH_3)CH{:}CH_2$. Monoterpenes have two units, $C_{10}H_{16}$, sesquiterpenes three units, $C_{15}H_{24}$, diterpenes four units, $C_{20}H_{32}$, etc. **Terpenoids**, which are derivatives of terpenes, include abscisic acid and gibberellin (*plant hormones) and the *carotenoid and *chlorophyll pigments.

SEE WEB LINKS

- Information about IUPAC nomenclature

terrestrial magnetism *See* GEOMAGNETISM.

territory A fixed area that an animal or group of animals defends against intrusion from others of its species by various types of **territorial behaviour**. Outside the territory (which may contain food sources, hiding places, and nesting sites) others are not threatened. Many mammals indicate their territory boundaries with scent markings, while birds sing territorial songs that repel

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would-be intruders. Animals in neighbouring territories normally respect each other's boundaries, which reduces overt *aggression. Some animals are territorial only at certain times of the year, usually the breeding season (*see* COURTSHIP).

Tertiary Formerly, the older geological period of the Cenozoic era (*compare* QUATERNARY). It began about 65 million years ago, following the Cretaceous period, and extended to the beginning of the Quaternary, about 2 million years ago. The Tertiary period was characterized by the rise of the modern mammals and the development of shrubs, grasses, and other flowering plants. It has been replaced by the *Palaeogene and *Neogene periods.

tertiary alcohol *See* ALCOHOLS.

tertiary amine *See* AMINES.

tertiary colour A colour obtained by mixing two *secondary colours.

tertiary consumer *See* CONSUMER.

tertiary structure *See* PROTEIN.

tervalent (trivalent) Having a valency of three.

Terylene Trade name for a type of *polyester used in synthetic fibres.

tesla Symbol T. The SI unit of magnetic flux density equal to one weber of magnetic flux per square metre, i.e. 1 T = 1 Wb m^{-2}. It is named after Nikola Tesla (1870–1943), Croatian-born US electrical engineer.

Tesla coil A device for producing a high-frequency high-voltage current. It consists of a *transformer with a high turns ratio, the primary circuit of which includes a spark gap and a fixed capacitor; the secondary circuit is tuned by means of a variable capacitor to resonate with the primary. It was devised by Nikola Tesla. Tesla coils are commonly used to excite luminous discharges in glass vacuum apparatus, in order to detect leaks.

testa (seed coat) The lignified or fibrous protective covering of a seed that develops from the integuments of the ovule after fertilization. *See also* HILUM; MICROPYLE.

test cross A mating (cross) made to identify hidden *recessive alleles in an individual of unknown genotype. This individual is crossed with one that is *homozygous for the allele being investigated (i.e. a homozygous recessive). The homozygous recessive individual may be the parent of the individual being investigated (*see* BACK CROSS).

testis (testicle) The reproductive organ in male animals in which spermatozoa are produced. In vertebrates there are two testes; as well as sperm, they produce steroid hormones (*see* ANDROGEN). In most animals the testes are within the body cavity but in mammals, although they develop within the body near the kidneys, they come to hang outside the body cavity in a *scrotum. Most of the vertebrate testis is made up of a mass of **seminiferous tubules**, in which the sperms develop. It is connected to the outside by means of the *vas deferens. *See* REPRODUCTIVE SYSTEM.

testis-determining factor (TDF; SRY protein) A protein that plays a crucial role in sex determination in mammals. It is encoded by the **SRY** (sex reversal on Y) gene on the Y chromosome, and switches embryonic development from the default female pathway to the male pathway, by driving testis formation. Male development is then consolidated by secretion of the male sex hormone testosterone by the testes.

testosterone The principal male sex hormone. *See* ANDROGEN.

tetrachloroethene A colourless nonflammable volatile liquid, CCl_2:CCl_2; r.d. 1.6; m.p. –22°C; b.p. 121°C. It is used as a solvent.

tetrachloromethane (carbon tetrachloride) A colourless volatile liquid with a characteristic odour, virtually insoluble in water but miscible with many organic liquids, such as ethanol and benzene; r.d. 1.586; m.p. –23°C; b.p. 76.54°C. It is made by the chlorination of methane (previously by chlorination of carbon disulphide). The compound is a good solvent for waxes, lacquers, and rubbers and the main industrial use is as a solvent, but safer substances (e.g. 1,1,1-trichloroethane) are increasingly being used. Moist carbon tetrachloride is partly decomposed to phosgene and hydrogen chloride and this provides a further restriction on its use.

tetrad A group of four *haploid cells formed at the end of the second division of *meiosis.

tetradecanoic acid (myristic acid) A saturated carboxylic acid, $CH_3(CH_2)_{12}COOH$; r.d. 0.86; m.p. 58.8°C; b.p. 250.5°C (100 mmHg). Its glycerides are found in nutmeg,

palm oil, and butter fat. Compounds are used in cosmetics and skin-care preparations. The traditional name comes from the Latin name for nutmeg, *Myristica fragrans*.

tetraethyl lead *See* LEAD(IV) TETRAETHYL.

tetragonal *See* CRYSTAL SYSTEM.

tetrahedral angle **1.** (in geometry) The solid angle bounded by three faces of a tetrahedron. **2.** (in chemistry) The angle between the bonds in a *tetrahedral compound (approximately 109° for a regular tetrahedron).

tetrahedral compound A compound in which four atoms or groups situated at the corners of a tetrahedron are linked (by covalent or coordinate bonds) to an atom at the centre of the tetrahedron. *See also* COMPLEX.

tetrahedron A polyhedron with four triangular faces. In a **regular tetrahedron** all four triangles are congruent equilateral triangles. It constitutes a regular triangular *pyramid.

tetrahydrate A crystalline hydrate containing four moles of water per mole of compound.

tetrahydrofuran (THF) A colourless volatile liquid, C_4H_8O; r.d. 0.89; m.p. –65°C; b.p. 67°C. It is made by the acid hydrolysis of polysaccharides in oat husks, and is widely used as a solvent.

tetrahydroxomonoxodiboric(III) acid *See* BORIC ACID.

tetraoxophosphoric(V) acid *See* PHOSPHORIC(V) ACID.

tetraoxosulphuric(VI) acid *See* SULPHURIC ACID.

tetraploid Describing a nucleus, cell, or organism that has four times ($4n$) the haploid number (n) of chromosomes. *See also* POLYPLOID.

Tetrapoda In some classifications, a superclass of jawed chordates (*Gnathostomata) comprising all vertebrate animals with four limbs, i.e. the amphibians, reptiles, birds, and mammals. The skeleton of the limbs of all tetrapods is based on the same five-digit pattern (*see* PENTADACTYL LIMB).

tetravalent (quadrivalent) Having a valency of four.

tetrode A *thermionic valve with a **screen grid** placed between the anode and the control grid of a *triode to reduce the capacitance between these two electrodes and so improve the valve's performance as an amplifier or oscillator at high frequencies. The screen grid is maintained at a fixed potential.

texaphyrin A synthetic molecule similar to a porphyrin but containing five central nitrogen atoms rather than four, thus increasing the size of the central 'hole' and enabling larger cations, such as cadmium, to be bound stably. *See also* SUPRAMOLECULAR CHEMISTRY.

thalamus **1.** (in anatomy) Part of the vertebrate *forebrain that lies above the hypothalamus. It relays sensory information to the cerebral cortex and is also concerned with the translation of impulses into conscious sensations. **2.** (in botany) *See* RECEPTACLE.

thallium Symbol Tl. A greyish metallic element belonging to *group 13 (formerly IIIB) of the periodic table; a.n. 81; r.a.m. 204.39; r.d. 11.85 (20°C); m.p. 303.5°C; b.p. 1457±10°C. It occurs in zinc blende and some iron ores and is recovered in small quantities from lead and zinc concentrates. The naturally occurring isotopes are thallium–203 and thallium–205; eleven radioisotopes have been identified. It has few uses – experimental alloys for special purposes and some minor uses in electronics. The sulphate has been used as a rodenticide. Thallium(I) compounds resemble those of the alkali metals. Thallium(III) compounds are easily reduced to the thallium(I) state and are therefore strong oxidizing agents. The element was discovered by Sir William Crookes in 1861.

SEE WEB LINKS

- Information from the WebElements site

thallus A relatively undifferentiated vegetative body with no true roots, stems, leaves, or vascular system. It is found in the algae, fungi, mosses, and liverworts and in the gametophyte generation of clubmosses, horsetails, and ferns.

theca *See* CAPSULE.

theobromine (3,7-dimethylxanthine) An alkaloid, $C_7H_8N_4O_2$, structurally related to caffeine. It is found in small quantities in tea and larger quantities in the cacao tree, hence its presence in cocoa and chocolate. Like theophylline it is used in treating certain respiratory conditions. Note that the com-

pound contains no bromine. The name comes from the name of the cacao tree, *Theobroma cacao. See also* METHYLXANTHINES.

theodolite An optical surveying instrument for measuring horizontal and vertical angles. It consists of a sighting telescope, with crosshairs in the eyepiece for focusing on the target, which can be rotated in both the horizontal and vertical planes. It is mounted on a tripod and a spirit level is used to indicate when the instrument is horizontal. The angles are read off graduated circles seen through a second eyepiece in the instrument.

theophylline (1,3-dimethylxanthine) An alkaloid, $C_7H_8N_4O_2$, structurally related to caffein. It is found in small quantities in tea and is used medicinally for certain respiratory conditions. *See also* METHYLXANTHINES.

theoretical physics The study of physics by formulating and analysing theories that describe natural processes. Theoretical physics is complementary to the study of physics by experiment, which is called **experimental physics**. A large part of theoretical physics consists of analysing the results of experiments to see whether or not they obey particular theories. The branch of theoretical physics concerned with the mathematical aspects of theories in physics is called **mathematical physics**.

theory *See* LAWS, THEORIES, AND HYPOTHESES.

theory of everything (TOE) A theory that provides a unified description of all known types of elementary particles, all known forces in the universe, and the evolution of the universe. Some believe that *superstring theory is potentially a theory of everything. Others believe that it is impossible to formulate a theory of everything and that any such theory could only claim to be a theory for all forces, particles, and observations concerning the evolution of the universe known at the time. It is thought that a *quantum field theory or a *unified-field theory cannot be a theory of everything. A theory of everything should explain the number of dimensions in the universe and why the number of observable dimensions is four.

therapeutic half-life (in pharmacology) The time taken for half the dose of a drug to be excreted: used to calculate the most effective and nontoxic dosing intervals. It can be determined by administering a therapeutic dose of the drug labelled with a radioisotope (*see* LABELLING) and measuring the time for half of it to be excreted in the urine.

therm A practical unit of energy defined as 10^5 British thermal units. 1 therm is equal to 1.055×10^8 joules.

thermal analysis A technique for chemical analysis and the investigation of the products formed by heating a substance. In **differential thermal analysis** (**DTA**) a sample is heated, usually in an inert atmosphere, and a plot of weight against temperature made. In **differential scanning calorimetry** (**DSC**) heat is added to or removed from a sample electrically as the temperature is increased, thus allowing the enthalpy changes due to thermal decomposition to be studied.

thermal capacity *See* HEAT CAPACITY.

thermal conductivity *See* CONDUCTIVITY.

thermal diffusion The diffusion that takes place in a fluid as a result of a temperature gradient. If a column of gas is maintained so that the lower end is cooler than the upper end, the heavier molecules in the gas will tend to remain at the lower-temperature end and the lighter molecules will diffuse to the higher-temperature end. This property has been used in the separation of gaseous isotopes (*see* CLUSIUS COLUMN).

thermal equilibrium *See* EQUILIBRIUM.

thermal expansion *See* EXPANSIVITY.

thermalization The reduction of the kinetic energy of neutrons in a thermal *nuclear reactor by means of a *moderator; the process of producing thermal neutrons.

thermal neutrons *See* MODERATOR; NUCLEAR REACTOR; THERMALIZATION.

thermal reactor *See* NUCLEAR REACTOR.

thermionic emission The emission of electrons, usually into a vacuum, from a heated conductor. The emitted current density, J, is given by the **Richardson** (or **Richardson–Dushman**) **equation**, i.e. $J = AT^2\exp(-W/kT)$, where T is the thermodynamic temperature of the emitter, W is its *work function, k is the Boltzmann constant, and A is a constant. Thermionic emission is the basis of the *thermionic valve and the *electron gun in cathode-ray tubes.

thermionics The branch of electronics concerned with the study and design of devices based on the emission of electrons from metal or metal-oxide surfaces as a result of high temperatures. The primary concern of thermionics is the design of *thermionic valves and the electron guns of cathode-ray tubes and other devices.

thermionic valve An electronic valve based on *thermionic emission. In such valves the cathode is either directly heated by passing a current through it or indirectly heated by placing it close to a heated filament. Directly heated cathodes are usually made of tungsten wire, whereas indirectly heated cathodes are usually coated with barium and strontium oxides. Most electronic valves are thermionic vacuum devices, although a few have cold cathodes and some are gas-filled (*see* THYRATRON). *See* DIODE; TRIODE; TETRODE; PENTODE.

thermistor An electronic device the resistance of which decreases as its temperature increases. It consists of a bead, rod, or disk of various oxides of manganese, nickel, cobalt, copper, iron, or other metals. Thermistors are used as thermometers, often forming one element in a resistance bridge. They are used for this purpose in such applications as bearings, cylinder heads, and transformer cores. They are also used to compensate for the increased resistance of ordinary resistors when hot, and in vacuum gauges, time-delay switches, and voltage regulators.

thermite A stoichiometric powdered mixture of iron(III) oxide and aluminium for the reaction:

$$2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe$$

The reaction is highly exothermic and the increase in temperature is sufficient to melt the iron produced. It has been used for localized welding of steel objects (e.g. railway lines) in the **Thermit process**. Thermite is also used in incendiary bombs.

thermochemistry The branch of physical chemistry concerned with heats of chemical reaction, heats of formation of chemical compounds, etc.

thermocline A steep temperature gradient that exists in the middle zone (the **metalimnion**) of a lake and gives rise to thermally induced vertical stratification of the water. The metalimnion lies between the relatively warm **epilimnion** above and the cold **hypolimnion** below. The thermocline may represent a temperature change of 1°C for every incremental depth of 1 metre of water. It may be short-lived, especially in shallow lakes where wind action can mix the water from different levels. However, it can exist for most of the summer period in temperate lakes and sometimes nearly all year in tropical lakes. A thermocline can speed up the process of eutrophication by preventing the diffusion of oxygen from the epilimnion to the hypolimnion (*see* EUTROPHIC).

thermocouple A device consisting of two dissimilar metal wires or semiconducting rods welded together at their ends. A thermoelectric e.m.f. is generated in the device when the ends are maintained at different temperatures, the magnitude of the e.m.f. being related to the temperature difference. This enables a thermocouple to be used as a thermometer over a limited temperature range. One of the two junctions, called the **hot** or **measuring junction**, is exposed to the temperature to be measured. The other, the **cold** or **reference junction**, is maintained at a known reference temperature. The e.m.f. generated is measured by a suitable millivoltmeter or potentiometer incorporated into the circuit. *See* SEEBECK EFFECT; THERMOPILE.

thermodynamics The study of the laws that govern the conversion of energy from one form to another, the direction in which heat will flow, and the availability of energy to do work. It is based on the concept that in an isolated system anywhere in the universe there is a measurable quantity of energy called the *internal energy (U) of the system. This is the total kinetic and potential energy of the atoms and molecules of the system of all kinds that can be transferred directly as heat; it therefore excludes chemical and nuclear energy. The value of U can only be changed if the system ceases to be isolated. In these circumstances U can change by the transfer of mass to or from the system, the transfer of heat (Q) to or from the system, or by the work (W) being done on or by the system. For an adiabatic ($Q = 0$) system of constant mass, $\Delta U = W$. By convention, W is taken to be positive if work is done on the system and negative if work is done by the system. For nonadiabatic systems of constant mass, $\Delta U = Q + W$. This statement, which is equivalent to the law of conservation of energy, is known as the **first law of thermodynamics**.

All natural processes conform to this law,

but not all processes conforming to it can occur in nature. Most natural processes are irreversible, i.e. they will only proceed in one direction (*see* REVERSIBLE PROCESS). The direction that a natural process can take is the subject of the **second law of thermodynamics**, which can be stated in a variety of ways. R. Clausius (1822–88) stated the law in two ways: "heat cannot be transferred from one body to a second body at a higher temperature without producing some other effect" and "the entropy of a closed system increases with time". These statements introduce the thermodynamic concepts of *temperature (T) and *entropy (S), both of which are parameters determining the direction in which an irreversible process can go. The temperature of a body or system determines whether heat will flow into it or out of it; its entropy is a measure of the unavailability of its energy to do work. Thus T and S determine the relationship between Q and W in the statement of the first law. This is usually presented by stating the second law in the form $\Delta U = T\Delta S - W$.

The second law is concerned with changes in entropy (ΔS). The **third law of thermodynamics** provides an absolute scale of values for entropy by stating that for changes involving only perfect crystalline solids at *absolute zero, the change of the total entropy is zero. This law enables absolute values to be stated for entropies.

One other law is used in thermodynamics. Because it is fundamental to, and assumed by, the other laws of thermodynamics it is usually known as the **zeroth law of thermodynamics**. This states that if two bodies are each in thermal equilibrium with a third body, then all three bodies are in thermal equilibrium with each other. *See also* ENTHALPY; FREE ENERGY.

SEE WEB LINKS

- A tutorial from the Division of Chemical Education, Purdue University, Indiana
- Thermodynamic properties from the Committee on Data for Science and Technology

thermodynamic temperature *See* TEMPERATURE.

thermoelectricity An electric current generated by temperature difference. *See* SEEBECK EFFECT. The converse effects, the *Peltier effect and the *Thomson effect, are also sometimes known as thermoelectric effects.

thermogenesis The production of heat within tissues to raise body temperature or as an adaptive response (**adaptive thermogenesis**) to 'burn off' excess food energy intake. Heat production occurs especially in birds and mammals, animals that maintain their temperature within a narrow range (i.e. *endotherms), but is also found in some 'cold-blooded' vertebrates and invertebrates. There are two types of thermogenesis. **Shivering** involves repeated rapid contractions of antagonistic sets of skeletal muscles, which produce little net movement so that most of the chemical energy (in the form of ATP) is converted to heat rather than mechanical work. **Nonshivering thermogenesis** takes place in *fat cells (adipose tissue) and involves the breakdown of stored fat to generate heat in situ instead of its being transported to the liver for conversion to ATP. This process is activated by the sympathetic nervous system. Certain mammals have deposits of a special adipose tissue called *brown fat that is adapted to provide the body with bursts of intense heat. Stimulation of brown fat oxidation enables rapid warming during the arousal of hibernating animals, for example. Brown fat deposits are also present in human babies and other neonate mammals, to help protect them against hypothermia.

thermograph **1.** A recording thermometer used in meteorology to obtain a continuous record of temperature changes over a period on a graph. **2.** A record so obtained. **3. (thermogram)** A record obtained by the technique of *thermography.

thermography A medical technique that makes use of the infrared radiation from the human skin to detect an area of elevated skin temperature that could be associated with an underlying cancer. The heat radiated from the body varies according to the local blood flow, thus an area of poor circulation produces less radiation. A tumour, on the other hand, has an abnormally increased blood supply and is revealed on the **thermogram** (or **thermograph**) as a 'hot spot'. Thermography was formerly used in mammography before the advent of more sensitive techniques.

thermoluminescence *Luminescence produced in a solid when its temperature is raised. It arises when free electrons and *holes, trapped in a solid as a result of exposure to ionizing radiation, unite and emit photons of light. The process is made use of

in **thermoluminescent dating**, which assumes that the number of electrons and holes trapped in a sample of pottery is related to the length of time that has elapsed since the pottery was fired. By comparing the luminescence produced by heating a piece of pottery of unknown age with the luminescence produced by heating similar materials of known age, a fairly accurate estimate of the age of an object can be made.

thermoluminescent dating *See* THERMOLUMINESCENCE.

thermolysis (pyrolysis) The chemical decomposition of a substance by heat. It is an important process in chemical manufacture, such as the thermal *cracking of hydrocarbons in the petroleum industry.

thermometer An instrument used for measuring the *temperature of a substance. A number of techniques and forms are used in thermometers depending on such factors as the degree of accuracy required and the range of temperatures to be measured, but they all measure temperature by making use of some property of a substance that varies with temperature. For example, **liquid-in-glass thermometers** depend on the expansion of a liquid, usually mercury or alcohol coloured with dye. These consist of a liquid-filled glass bulb attached to a partially filled capillary tube. In the **bimetallic thermometer** the unequal expansion of two dissimilar metals that have been bonded together into a narrow strip and coiled is used to move a pointer round a dial. The **gas thermometer**, which is more accurate than the liquid-in-glass thermometer, measures the variation in the pressure of a gas kept at constant volume. The **resistance thermometer** is based on the change in resistance of conductors or semiconductors with temperature change. Platinum, nickel, and copper are the metals most commonly used in resistance thermometers. *See also* PYROMETRY; THERMISTOR; THERMOCOUPLE.

thermonuclear reaction *See* NUCLEAR FUSION; THERMONUCLEAR REACTOR.

thermonuclear reactor (fusion reactor) A reactor in which *nuclear fusion takes place with the controlled release of energy. Although thermonuclear reactors do not yet exist, intense research in many parts of the world is being carried out with a view to achieving such a machine. There are two central problems in the creation of a self-sustaining thermonuclear reactor: heating the reacting nuclides to the enormous *ignition temperature (about 40×10^6 K for a deuterium–tritium reaction) and containing the reacting nuclides for long enough for the fusion energy released to exceed the energy required to achieve the ignition temperature (*see* LAWSON CRITERION). The two methods being explored are **magnetic containment** and **pellet fusion**.

In the closed magnetic-containment device the fusion *plasma is contained in a toroidal-shaped reactor, called a **tokamak**, in which strong magnetic fields guide the charged plasma particles round the toroid without allowing them to contact the container walls. In open-ended magnetic systems the plasma is trapped between magnetic mirrors (strong magnetic fields) at the two ends of a straight containment vessel.

In pellet fusion the objective is to heat and compress a tiny pellet of the nuclear fuels, by means of a laser or an electron beam, so rapidly that fusion is achieved before the pellet flies apart. Results with this type of equipment have been comparable to those achieved by magnetic confinement.

thermonuclear weapon *See* NUCLEAR WEAPONS.

thermophilic Describing an organism that lives and grows optimally at extremely high temperatures, typically over 40°C. The majority are prokaryotes, such as the archaebacteria found in hot springs and in undersea hydrothermal vents. *See* EXTREMOPHILE.

thermopile A device used to detect and measure the intensity of radiant energy. It consists of a number of *thermocouples connected together in series to achieve greater sensitivity. The hot junctions of the thermocouples are blackened and exposed to the radiation to be detected or measured, while the cold junctions are shielded from the radiation. The thermoelectric e.m.f. generated enables the hot junction excess temperature to be calculated and the radiant intensity to be deduced. They are used in various applications, from a safety device that ceases to produce an electric current if a pilot light blows out to an instrument to measure the heat radiation received from the sun.

thermoplastic *See* PLASTICS.

thermoregulation Regulation of body temperature by any means, whether physiological or behavioural. Some animals, partic-

ularly mammals and birds, can maintain a fairly constant internal body temperature (*see* HOMOIOTHERMY), whereas in others the body temperature varies with the temperature of the environment (*see* POIKILOTHERMY). *See also* THERMOGENESIS.

thermosetting *See* PLASTICS.

thermostat A device that controls the heating or cooling of a substance in order to maintain it at a constant temperature. It consists of a temperature-sensing instrument connected to a switching device. When the temperature reaches a predetermined level the sensor switches the heating or cooling source on or off according to a predetermined program. The sensing thermometer is often a *bimetallic strip that triggers a simple electrical switch. Thermostats are used for space-heating controls, in water heaters and refrigerators, and to maintain the environment of a scientific experiment at a constant temperature.

THF *See* TETRAHYDROFURAN.

thiamine *See* VITAMIN B COMPLEX.

thigmotropism (haptotropism) The growth of an aerial plant organ in response to localized physical contact. For example, when a tendril of sweet pea touches a supporting structure, it curves in the direction of the support and coils around it. *See* TROPISM.

thin-layer chromatography A technique for the analysis of liquid mixtures using *chromatography. The stationary phase is a thin layer of an absorbing solid (e.g. alumina) prepared by spreading a slurry of the solid on a plate (usually glass) and drying it in an oven. A spot of the mixture to be analysed is placed near one edge and the plate is stood upright in a solvent. The solvent rises through the layer by capillary action carrying the components up the plate at different rates (depending on the extent to which they are absorbed by the solid). After a given time, the plate is dried and the location of spots noted. It is possible to identify constituents of the mixture by the distance moved in a given time. The technique needs careful control of the thickness of the layer and of the temperature. *See also* R_F VALUE.

thiocyanate A salt or ester of thiocyanic acid.

thiocyanic acid An unstable gas, HSCN.

thio ethers *See* SULPHIDES.

thiol group *See* THIOLS.

thiols (mercaptans; thio alcohols) Organic compounds that contain the group –SH (called the **thiol group**, **mercapto group**, or **sulphydryl group**). Thiols are analogues of alcohols in which the oxygen atom is replaced by a sulphur atom. They are named according to the parent hydrocarbon; e.g. ethane thiol (C_2H_5SH). A characteristic property is their strong disagreeable odour. For example the odour of garlic is produced by ethane thiol. Unlike alcohols they are acidic, reacting with alkalis and certain metals to form saltlike compounds. The older name, mercaptan, comes from their ability to react with ('seize') mercury.

thionyl chloride *See* SULPHUR DICHLORIDE OXIDE.

thionyl group The group =SO, as in *sulphur dichloride oxide.

thiophene A colourless liquid, C_4H_4S, b.p. 84°C. It is a cyclic aromatic compound with a ring containing four carbon atoms and one sulphur atom. It is made from butane and sulphur and occurs as an impurity in commercial benzene. Thienyl compounds are formed by substituting various groups in the ring. Thiophene has a smell resembling benzene and is used as a solvent.

thiosulphate A salt containing the ion $S_2O_3^{2-}$ formally derived from thiosulphuric acid. Thiosulphates readily decompose in acid solution to give elemental sulphur and hydrogensulphite (HSO_3^-) ions.

thiosulphuric acid An unstable acid, $H_2S_2O_3$, formed by the reaction of sulphur trioxide with hydrogen sulphide. *See also* SULPHURIC ACID.

thiourea A white crystalline solid, $(NH_2)_2CS$; r.d. 1.4; m.p. 182°C. It is used as a fixer in photography.

thixotropy *See* NEWTONIAN FLUID.

Thompson, Benjamin *See* RUMFORD, COUNT.

Thomson, Sir Joseph John (1856–1940) British physicist, who became a professor at Cambridge University in 1884. He is best known for his work on *cathode rays, which led to his discovery of the *electron in 1897. He went on to study the conduction of electricity through gases, and it is for this work that he was awarded the Nobel Prize for physics in 1906.

Thomson, William *See* KELVIN, BARON.

Thomson effect (Kelvin effect) When an electric current flows through a conductor, the ends of which are maintained at different temperatures, heat is evolved at a rate approximately proportional to the product of the current and the temperature gradient. If either the current or the temperature gradient is reversed heat is absorbed rather than being evolved. It is named after Sir William Thomson (later Lord Kelvin).

Thomson scattering The scattering of electromagnetic radiation by free charged particles, especially electrons, when the photon energy is small compared with the energy equivalent to the *rest mass of the charged particles. The energy lost by the radiation is accounted for by classical theory as a result of the radiation emitted by the charged particles when they are accelerated in the transverse electric field of the radiation. It is named after Sir J. J. Thomson.

thoracic cavity The space within the *thorax, which in vertebrates contains the heart, lungs, and rib cage.

thoracic duct The main collecting vessel of the *lymphatic system, running longitudinally in front of the backbone. The thoracic duct drains its lymph into the superior vena cava.

thoracic vertebrae The *vertebrae of the upper back, which articulate with the *ribs. They lie between the *cervical vertebrae and the *lumbar vertebrae and are distinguished by a number of articulating facets for attachment of the ribs. In humans there are 12 thoracic vertebrae.

thorax The anterior region of the body trunk of animals. In vertebrates it contains the heart and lungs within the rib cage. It is particularly well-defined in mammals, being separated from the *abdomen by the *diaphragm. In insects the thorax is divided into an anterior **prothorax**, a middle **mesothorax**, and a posterior **metathorax**, each of which bears a pair of legs; the hindmost two segments also both carry a pair of wings. In other arthropods, especially crustaceans and arachnids, the thorax is fused with the head to form a **cephalothorax**.

thoria *See* THORIUM.

thorium Symbol Th. A grey radioactive metallic element belonging to the *actinoids; a.n. 90; r.a.m. 232.038; r.d. 11.5–11.9 (17°C); m.p. 1740–1760°C; b.p. 4780–4800°C. It occurs in monazite sand in Brazil, India, and USA. The isotopes of thorium have mass numbers from 223 to 234 inclusive; the most stable isotope, thorium–232, has a half-life of 1.39×10^{10} years. It has an oxidation state of (+4) and its chemistry resembles that of the other actinoids. It can be used as a nuclear fuel for breeder reactors as thorium–232 captures slow neutrons to breed uranium–233. Thorium dioxide (**thoria**, ThO_2) is used on gas mantles and in special refractories. The element was discovered by J. J. Berzelius in 1829.

SEE WEB LINKS

- Information from the WebElements site

thorium series *See* RADIOACTIVE SERIES.

thorn A hard side stem with a sharp point at the tip, replacing the growing point. In some plants the development of thorns and subsequent suppression of the growing points may be a response to dry conditions. Examples are the thorns of gorse and hawthorn. *Compare* PRICKLE; SPINE.

thread cell (nematoblast; cnidoblast) A specialized cell found only in the ectoderm of the *Cnidaria. It contains a **nematocyst**, a fluid-filled sac within which lies a long hollow coiled thread. When a small sensory projection (**cnidocil**) on the surface of the thread cell is touched, e.g. by prey, the thread is shot out and adheres to the prey, coils round it, or injects poison into it. Numerous thread cells on the tentacles of jellyfish produce their sting.

three-body problem *See* MANY-BODY PROBLEM.

threnardite A mineral form of *sodium sulphate, Na_2SO_4.

threonine *See* AMINO ACID.

threshold **1.** (in physics) The minimum value of a parameter or variable that will produce a specified effect. **2.** (in physiology) The minimum intensity of a stimulus that is necessary to initiate a response.

threshold frequency *See* PHOTOELECTRIC EFFECT.

thrombin An enzyme that catalyses the conversion of fibrinogen to fibrin. *See* BLOOD CLOTTING; PROTHROMBIN.

thrombocyte *See* PLATELET.

thromboplastin A glycoprotein, released

from damaged tissues at the site of a wound, that initiates the cascade of reactions leading to the formation of a blood clot. *See* BLOOD CLOTTING.

thrombosis The obstruction of a blood vessel by a mass of blood cells and fibrin (**thrombus**), which can result from excessive *blood clotting.

thromboxane A_2 *See* PROSTAGLANDIN.

thrust The propelling force generated by an aircraft engine or rocket. It is usually calculated as the product of the rate of mass discharge and the velocity of the exhaust gases relative to the vehicle.

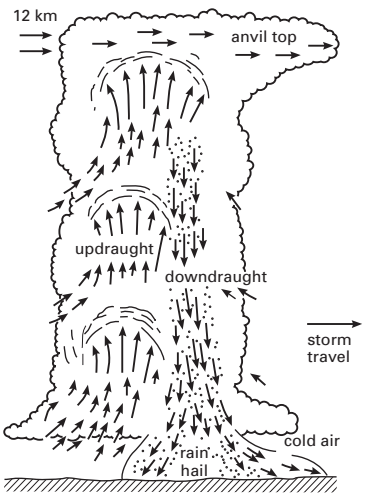
thulium Symbol Tm. A soft grey metallic element belonging to the *lanthanoids; a.n. 69; r.a.m. 168.934; r.d. 9.321 (20°C); m.p. 1545°C; b.p. 1947°C. It occurs in apatite and xenotime. There is one natural isotope, thulium–169, and seventeen artificial isotopes have been produced. There are no uses for the element, which was discovered by Per Cleve (1840–1905) in 1879.

SEE WEB LINKS

- Information from the WebElements site

thumb drive *See* USB DRIVE.

thunderstorm A convective storm accompanied by *lightning and thunder and a variety of weather conditions, especially heavy rain or hail, high winds, and sudden temperature changes. Thunderstorms originate when intense heating causes a parcel of moist air to rise, leading to instability and the development of cumulonimbus cloud – a towering cloud with a characteristic anvil-shaped top (see illustration). The exact mechanisms of thunderstorms are not fully understood. They occur most frequently in the tropics but are also common in the mid-latitudes.



Thunderstorm. Cross section through a thunderstorm cell.

thymidine A nucleoside consisting of one thymine molecule linked to a D-deoxyribose sugar molecule.

thymine A *pyrimidine derivative and one of the major component bases of *nucleotides and the nucleic acid *DNA.

thymus An organ, present only in vertebrates, that is concerned with development of *lymphoid tissue, particularly the white blood cells involved in cell-mediated *immune responses (*see* T CELL). In mammals it is a bilobed organ in the region of the lower neck, above and in front of the heart. In humans it undergoes progressive shrinkage throughout life, starting after the first 12 months of age.

thyratron A thermionic valve (usually a triode) that functions as a gas-filled relay. A positive pulse fed to a correctly biased thyratron causes a discharge to start and to continue until the anode voltage has been reduced. It has now been replaced by its solid-state counterpart, the silicon-controlled rectifier.

thyristor A silicon-controlled rectifier whose anode–cathode current is controlled by a signal applied to a third electrode (the gate) in much the same way as in a thyratron valve. It consists usually of a four-layer chip comprising three *p*–*n* junctions.

thyrocalcitonin *See* CALCITONIN.

thyroglobulin (TGB) A glycoprotein, made in the thyroid gland, that consists of about 5000 amino acids, some of which are tyrosine residues. TGB is the precursor of the thyroid hormones, thyroxine and triiodothyronine. Iodine binds to the tyrosine residues in thyroglobulin, which is then hydrolysed into **iodotyrosines** that combine to form triiodothyronine (T_3) or thyroxine (tetraiodothyronine or T_4).

thyroid gland A bilobed endocrine gland

t

in vertebrates, situated in the base of the neck. It secretes two iodine-containing **thyroid hormones**, **thyroxine** (T_4) and **triiodothyronine** (T_3), which are formed in the gland from *thyroglobulin; they control the rate of all metabolic processes in the body and influence physical development and activity of the nervous system. Growth and activity of the thyroid is controlled by *thyroid-stimulating hormone, secreted by the anterior *pituitary gland.

thyroid-stimulating hormone (TSH; thyrotrophin) A hormone, secreted by the anterior pituitary gland, that controls the synthesis and secretion of the two thyroid hormones, thyroxine and triiodothyronine, in the *thyroid gland. The secretion of thyroid-stimulating hormone is controlled by **thyrotrophin-releasing hormone** (**TRH**) from the hypothalamus. The release of TRH depends on many factors, including the levels of TSH, glucose, and thyroxine in the blood and the rate of metabolism in the body.

thyrotrophin-releasing hormone (TRH) *See* THYROID-STIMULATING HORMONE.

thyroxine (T_4) The principal hormone secreted by the *thyroid gland. *See also* THYROGLOBULIN.

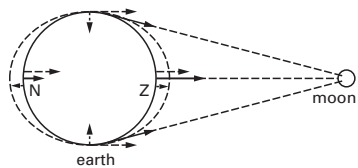
tibia **1.** The larger of the two bones of the lower hindlimb of terrestrial vertebrates (*compare* FIBULA). It articulates with the *femur at the knee and with the *tarsus at the ankle. The tibia is the major load-bearing bone of the lower leg. **2.** The fourth segment of an insect's leg, which is attached to the femur.

tidal energy *See* TIDES.

tidal volume The volume of air taken in or expelled by an animal breathing normally at rest during each cycle of *ventilation. The average human has a tidal volume of approximately 500 cm^3.

tides The regular rise and fall of the water level in the earth's oceans as a result of the gravitational forces between the earth, moon, and sun. The forces involved are complex, but the moon is approximately twice as effective as the sun in causing tides. In illustration (a) the resultant gravitational forces between the moon and various points on the earth (solid lines) are shown as the vector sums of the tide-generating forces (broken lines) and a constant force (dotted lines) that is the same at all points on the earth and is equal to the moon's attraction on the earth's centre. The resultant force when the moon is in zenith (Z in the illustration) is greater than that at nadir (N) because Z is closer to the moon than N and the force is inversely proportional to the square of the distance according to *Newton's law of gravitation. Illustration (b) shows how at full and new moon the sun and moon act together to produce the high-range **spring tides**, while at quarter moon the forces are at right angles to each other causing the low-range **neap tides**.

The use of **tidal energy**, estimated at some 4×10^{18} J per annum at known tidal sites, dates back to medieval tidal mills. Modern tidal power stations use specially designed turbines, operated by tidal waters, to drive generators.



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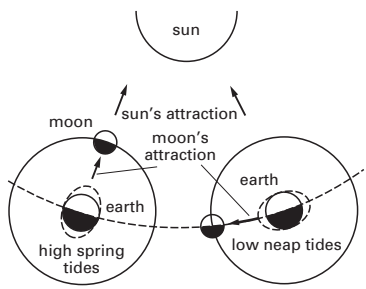


(b)

Tides.

timbre *See* QUALITY OF SOUND.

time A dimension that enables two otherwise identical events that occur at the same point in space to be distinguished (*see* SPACE–TIME). The interval between two such events forms the basis of time measurement. For general purposes, the earth's rotation on its axis provides the units of the clock (*see*

DAY) and the earth's orbit round the sun (*see* YEAR) provides the units of the calendar. For scientific purposes, intervals of time are now defined in terms of the frequency of a specified electromagnetic radiation (*see* SECOND). *See also* TIME DILATION; TIME REVERSAL.

timebase A voltage applied to the electron beam in a *cathode-ray tube at regular intervals so that the luminous spot on the screen is deflected in a predetermined manner. The timebase is usually designed to make the beam sweep the screen horizontally, the period during which the spot returns to its starting point (the **flyback**) being suppressed in some contexts (e.g. in television) although in a *cathode-ray oscilloscope the timebase can be put to more complicated uses.

time dependence of fundamental constants The possible variation with time in the values of the fundamental constants of nature, such as the speed of light. Such a variation has been proposed in various theories but there is no conclusive evidence at present for any such variation.

time dilation (time dilatation) The principle, predicted by Einstein's special theory of *relativity, that intervals of time are not absolute but are relative to the motion of the observers. If two identical clocks are synchronized and placed side by side in an inertial frame of reference they will read the same time for as long as they both remain side by side. However, if one of the clocks has a velocity relative to the other, which remains beside a stationary observer, the travelling clock will show, to that observer, that less time has elapsed than the stationary clock. In general, the travelling clock goes more slowly by a factor $\sqrt{(1 - v^2/c^2)}$, when measured in a frame of reference travelling at a velocity v relative to another frame of reference; c is the speed of light. The principle has been verified in a number of ways; for example, by comparing the lifetimes of fast muons, which increase with the speed of the particles to an extent predicted by this factor.

time-lapse photography A form of photography used to record a slow process, such as plant growth. A series of single exposures of the object is made on film at predetermined regular intervals. The film produced can then be projected at normal cine speeds and the process appears to be taking place at an extremely high rate.

time-of-flight mass spectrometer *See* MASS SPECTROMETRY.

time reversal Symbol T. The operation of replacing time t by time $-t$. The *symmetry of time reversal is known as **T invariance**. As with CP violation, **T violation** occurs in certain weak interactions, notably kaon decay, and in processes involving mesons with bottom quarks. *See also* CP INVARIANCE; CPT THEOREM.

time sharing A means by which several jobs – data plus the programs to manipulate the data – share the processing time and other resources of a computer. A brief period is allocated to each job by the computer's operating system, and the computer switches rapidly between jobs. A *multiaccess system relies on time sharing.

tin Symbol Sn. A silvery malleable metallic element belonging to *group 14 (formerly IVB) of the periodic table; a.n. 50; r.a.m. 118.69; r.d. 7.28; m.p. 231.88°C; b.p. 2260°C. It is found as tin(IV) oxide in ores, such as cassiterite, and is extracted by reduction with carbon. The metal (called **white tin**) has a powdery nonmetallic allotrope **grey tin**, into which it changes below 18°C. The formation of this allotrope is called **tin plague**; it can be reversed by heating to 100°C. The natural element has 21 isotopes (the largest number of any element); five radioactive isotopes are also known. The metal is used as a thin protective coating for steel plate and is a constituent of a number of alloys (e.g. phosphor bronze, gun metal, solder, Babbitt metal, and pewter). Chemically it is reactive. It combines directly with chlorine and oxygen and displaces hydrogen from dilute acids. It also dissolves in alkalis to form *stannates. There are two series of compounds with tin in the +2 and +4 oxidation states.

SEE WEB LINKS

- Information from the WebElements site

Tinbergen, Niko(laas) (1907–88) Dutch-born British zoologist and ethologist. Working first at Leiden University, he moved to Oxford in 1947, becoming professor of animal behaviour in 1966. With Konrad *Lorenz he was a pioneer of ethology, working with animals in their natural setting. In later years Tinbergen attempted to apply ethological principles to human beings, especially autistic children. He shared the Nobel Prize for

physiology or medicine with Lorenz and Karl von Frisch (1886–1982).

tin(II) chloride A white solid, $SnCl_2$, soluble in water and ethanol. It exists in the anhydrous form (rhombic; r.d. 3.95; m.p. 246°C; b.p. 652°C) and as a dihydrate, $SnCl_2.2H_2O$ (monoclinic; r.d. 2.71; m.p. 37.7°C). The compound is made by dissolving metallic tin in hydrochloric acid and is partially hydrolysed in solution.

$$Sn^{2+} + H_2O \rightleftharpoons SnOH^+ + H^+$$

Excess acid must be present to prevent the precipitation of basic salts. In the presence of additional chloride ions the pyramidal ion $[SnCl_3]^-$ is formed; in the gas phase the $SnCl_2$ molecule is bent. It is a reducing agent in acid solutions and oxidizes slowly in air:

$$Sn^{2+} \rightarrow Sn^{4+} + 2e$$

tin(IV) chloride A colourless fuming liquid, $SnCl_4$, hydrolysed in cold water, decomposed by hot water, and soluble in ethers; r.d. 2.226; m.p. –33°C; b.p. 114°C. Tin(IV) chloride is a covalent compound, which may be prepared directly from the elements. It dissolves sulphur, phosphorus, bromine, and iodine, and there is evidence for the presence of species such as $SnCl_2I_2$. In hydrochloric acid and in chloride solutions the coordination is extended from four to six by the formation of the $SnCl_6^{2-}$ ion.

tincture A solution with alcohol as the solvent (e.g. tincture of iodine).

tin(IV) hydride (stannane) A highly reactive and volatile gas (b.p. –53°), SnH_4, which decomposes on moderate heating (150°C). It is prepared by the reduction of tin chlorides using lithium tetrahydridoaluminate(III) and is used in the synthesis of some organo-tin compounds. The compound has reducing properties.

tin(IV) oxide (tin dioxide) A white solid, SnO_2, insoluble in water; tetrahedral; r.d. 6.95; m.p. 1127°C; sublimes between 1800°C and 1900°C. Tin(IV) oxide is trimorphic: the common form, which occurs naturally as the ore *cassiterite, has a rutile lattice but hexagonal and rhombic forms are also known. There are also two so-called dihydrates, $SnO_2.2H_2O$, known as α- and β-stannic acid. These are essentially tin hydroxides. Tin(IV) oxide is amphoteric, dissolving in molten alkalis to form *stannates; in the presence of sulphur, thiostannates are produced.

tin plague *See* TIN.

tin(II) sulphide A grey-black cubic or monoclinic solid, SnS, virtually insoluble in water; r.d. 5.22; m.p. 882°C; b.p. 1230°C. It has a layer structure similar to that of black phosphorus. Its heat of formation is low and it can be made by heating the elements together. Above 265°C it slowly decomposes (disproportionates) to tin(IV) sulphide and tin metal. The compound reacts with hydrochloric acid to give tin(II) chloride and hydrogen sulphide.

tin(IV) sulphide (mosaic gold) A bronze or golden yellow crystalline compound, SnS_2, insoluble in water and in ethanol; hexagonal; r.d. 4.5; decomposes at 600°C. It is prepared by the reaction of hydrogen sulphide with a soluble tin(IV) salt or by the action of heat on thiostannic acid, H_2SnS_3. The golden-yellow form used for producing a gilded effect on wood is prepared by heating tin, sulphur, and ammonium chloride.

T invariance *See* TIME REVERSAL.

tissue A collection of similar cells organized to carry out one or more particular functions. For example, in animals nervous tissue is specialized to perceive and transmit stimuli. An organ, such as a lung or kidney, contains many different types of tissues.

tissue culture The growth of the tissues of living organisms outside the body in a suitable culture medium. Culture (or nutrient) media contain a mixture of nutrients either in solid form (e.g. in *agar) or in liquid form (e.g. in *physiological saline). Tissue culture has proved to be invaluable for gaining information about factors that control the growth and differentiation of cells. Culture of plant tissues has resulted in the regeneration of complete plants, enabling commercial propagation (e.g. of orchids) and – through culture of meristem tissues – the production of virus-free crop plants. *See also* EXPLANTATION; TISSUE ENGINEERING.

tissue engineering The creation of synthetic or semisynthetic tissue that can be used instead of human tissue in surgery. Different kinds of tissue have been developed or are currently being researched, including skin, bone, cartilage, cornea, and spinal tissue. For example, the first such product to gain approval for clinical use was a form of artificial skin consisting of a thin sheet of collagen gel infiltrated with two layers of cultured human cells – keratinocytes on the outer surface to form the 'epidermis', and

fibroblasts on the inner surface to form the 'dermis'. More rigid tissues, such as synthetic bone and cartilage, are typically based on a biopolymer scaffold, which is treated with growth factors and seeded with cultured bone cells or cartilage cells to secrete the natural tissue material.

tissue fluid The fluid, consisting of water, ions, and dissolved gases and food substances, that is formed when blood is ultrafiltered (*see* ULTRAFILTRATION) from the capillaries into the intercellular spaces. The pressure in the arterial capillaries causes most components of the blood to pass across the capillary walls; blood cells and most of the plasma proteins are retained in the capillaries. The tissue fluid surrounds the body cells, facilitating the exchange of nutrients and waste materials. At the venous end of the capillaries, the tissue fluid is drawn into the capillaries by *osmosis.

Titan The largest satellite of *Saturn and the only one to possess a thick planet-like atmosphere. With a mean diameter of 5152 km and a mass of 1.345×10^{23} kg, it is the second largest satellite in the solar system after Ganymede (*see* GALILEAN SATELLITES). Titan orbits Saturn in synchronous rotation at a distance of 1 221 900 km once every 15.95 days. Titan's disc appears reddish-orange, due to the photochemically produced fog that obscures its surface. The atmosphere is composed almost entirely of nitrogen. It exerts a pressure at the surface that is equal to about 1.6 times that of the earth's atmosphere. In January 2005 the space probe Huygens landed on Titan. It found a world littered with ice boulders, where liquid methane falls like rain and forms lakes and channels of standing liquid hydrocarbons.

titania *See* TITANIUM(IV) OXIDE.

titanium Symbol Ti. A white metallic *transition element; a.n. 22; r.a.m. 47.9; r.d. 4.5; m.p. 1660±10°C; b.p. 3287°C. The main sources are rutile (TiO_2) and, to a lesser extent, ilmenite ($FeTiO_3$). The element also occurs in numerous other minerals. It is obtained by heating the oxide with carbon and chlorine to give $TiCl_4$, which is reduced by the *Kroll process. The main use is in a large number of strong light corrosion-resistant alloys for aircraft, ships, chemical plant, etc. The element forms a passive oxide coating in air. At higher temperatures it reacts with oxygen, nitrogen, chlorine, and other nonmetals. It dissolves in dilute acids. The main compounds are titanium(IV) salts and complexes; titanium(II) and titanium(III) compounds are also known. The element was first discovered by William Gregor (1761–1817) in 1789.

SEE WEB LINKS

- Information from the WebElements site

titanium dioxide *See* TITANIUM(IV) OXIDE.

titanium(IV) oxide (titania; titanium dioxide) A white oxide, TiO_2, occurring naturally in various forms, particularly the mineral rutile. It is used as a white pigment and as a filler for plastics, rubber, etc.

Titius–Bode law *See* BODE, JOHANN ELERT.

titration A method of volumetric analysis in which a volume of one reagent (the **titrant**) is added to a known volume of another reagent slowly from a burette until an end point is reached (*see* INDICATOR). The volume added before the end point is reached is noted. If one of the solutions has a known concentration, that of the other can be calculated.

titre **1.** The number of infectious virus particles present in a suspension. **2.** A measure of the amount of *antibody present in a sample of serum, given by the highest dilution of the sample that results in the formation of visible clumps with the appropriate antigen (*see* AGGLUTINATION). **3.** The concentration of a solution as measured by *titration. **4.** The minimum quantity of solution required to complete a reaction in a titration.

T lymphocyte *See* T CELL.

TNT *See* TRINITROTOLUENE.

toads *See* AMPHIBIA.

tobacco mosaic virus (TMV) A rigid rod-shaped RNA-containing virus that causes distortion and blistering of leaves in a wide range of plants, especially the tobacco plant. It is transmitted by insects when they feed on plant tissue. TMV was the first virus to be discovered.

tocopherol *See* VITAMIN E.

TOE *See* THEORY OF EVERYTHING.

tokamak *See* THERMONUCLEAR REACTOR.

Tollens reagent A reagent used in testing for aldehydes. It is made by adding sodium hydroxide to silver nitrate to give silver(I) oxide, which is dissolved in aqueous ammonia (giving the complex ion $[Ag(NH_3)_2]^+$).

t

The sample is warmed with the reagent in a test tube. Aldehydes reduce the complex Ag^+ ion to metallic silver, forming a bright silver mirror on the inside of the tube (hence the name **silver-mirror test**). Ketones give a negative result. It is named after Bernhard Tollens (1841–1918).

toluene *See* METHYLBENZENE.

tomography The use of X-rays to photograph a selected plane of a human body with other planes eliminated. The **CT** (**computerized tomography**) **scanner** is a ring-shaped X-ray machine that rotates through 180° around the horizontal patient, making numerous X-ray measurements every few degrees. The vast amount of information acquired is built into a three-dimensional image of the tissues under examination by the scanner's own computer. The patient is exposed to a dose of X-rays only some 20% of that used in a normal diagnostic X-ray.

Tomonaga–Luttinger liquid *See* LUTTINGER LIQUID.

tone (tonus) The state of sustained tension in muscles that is necessary for the maintenance of posture. In a tonic muscle contraction, only a certain proportion of the muscle fibres are contracting at any given time; the rest are relaxed and recovering for subsequent contractions. The fibres involved in tone contract more slowly than the fast fibres used for rapid responses by the same muscle. The proportions of slow and fast fibres depend on the function of the muscle.

tongue A muscular organ of vertebrates that in most species is attached to the floor of the mouth. It plays an important role in manipulating food during chewing and swallowing and in terrestrial species it bears numerous *taste buds on its upper surface. In some advanced vertebrates the tongue is used in the articulation of sounds, particularly in human speech.

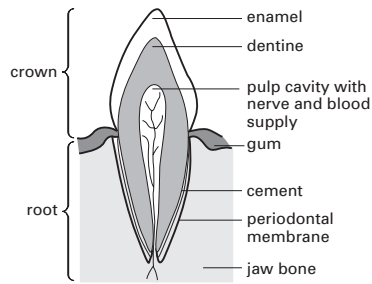
tonoplast (vacuole membrane) The single membrane that bounds the *vacuole of plant cells.

tonsil A mass of *lymphoid tissue, several of which are situated at the back of the mouth and throat in higher vertebrates. In humans there are the **palatine tonsils** at the back of the mouth, **lingual tonsils** below the tongue, and **pharyngeal tonsils** (or **adenoids**) in the pharynx. They are concerned with the production of *lymphocytes and therefore with defence against infection.

tonus *See* TONE.

tooth Any of the hard structures in vertebrates that are used principally for biting and chewing food but also for attack, grooming, and other functions. In fish and amphibians the teeth occur all over the palate, but in higher vertebrates they are concentrated on the jaws. They evolved in cartilaginous fish as modified placoid *scales, and this is reflected in their structure: a body of bony *dentine with a central *pulp cavity and an outer covering of *enamel on the exposed surface (**crown**). The portion of the tooth embedded in the jawbone is the **root** (see illustration).

In mammals there are four different types of teeth, specialized for different functions (*see* CANINE TOOTH; INCISOR; MOLAR; PREMOLAR). Their number varies with the species (*see* DENTAL FORMULA). *See also* DECIDUOUS TEETH; PERMANENT TEETH.



Tooth. Section through an incisor tooth.

topaz A variably coloured aluminium silicate mineral, $Al_2(SiO_4)(OH,F)_2$, that forms orthorhombic crystals. It occurs chiefly in acid igneous rocks, such as granites and pegmatites. Topaz is valued as a gemstone because of its transparency, variety of colours (the wine-yellow variety being most highly prized), and great hardness (8 on the Mohs' scale). When heated, yellow or brownish topaz often becomes a rose-pink colour. The main sources of topaz are Brazil, Russia, and the USA.

top carnivore *See* CONSUMER.

topography The relief and position of the natural and cultural features of the earth's surface.

topological defect A stable configuration of a system that results from topologically distinct solutions to differential equations describing the system. A number of different phenomena are identifiable as topological defects, including screw dislocations in crystals, *solitons, and *skyrmions. In some cosmological theories, topological defects are thought to have formed in the early universe.

topological insulator An insulator in which there is an excitation gap due to *spin–orbit coupling. It is so named because such an insulator is associated with topology.

topology The branch of geometry concerned with the properties of geometrical objects that are unchanged by continuous deformations, such as twisting or stretching. Mathematical approaches employing topology are of great importance in modern theories of the *fundamental interactions.

topsoil *See* SOIL.

tornado A violently rotating column of air, 10–100 m in diameter, usually made visible by a funnel cloud, that extends below cloud, usually cumulonimbus, and is in contact with the ground surface. Wind speeds of up to 100 metres per second may occur, but the damage to meteorological instruments caused by the passage of tornadoes makes exact measurement difficult. Tornadoes frequently occur in groups and are most common in the central USA and Australia, where they cause considerable destruction.

torque (moment of a force or couple) The product of a force and its perpendicular distance from a point about which it causes rotation or *torsion. The unit of torque is the newton metre, a vector product, unlike the joule, also equal to a newton metre, which is a scalar product. A turbine produces a torque on its central rotating shaft. *See also* COUPLE.

torr A unit of pressure, used in high-vacuum technology, defined as 1 mmHg. 1 torr is equal to 133.322 pascals. The unit is named after Evangelista Torricelli (1609–47).

Torricellian vacuum The vacuum formed when a long tube, closed at one end and filled with mercury, is inverted into a mercury reservoir so that the open end of the tube is below the surface of the mercury. The pressure inside the Torricellian vacuum is the vapour pressure of mercury, about 10^{-3} torr.

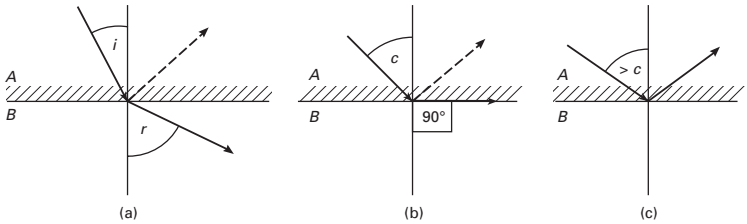
torsion A twisting deformation produced by a *torque or *couple. A **torsion bar** is a form of spring in which one end of a bar is fixed and a torque is applied to the other end. Torsion bars are used in the suspension systems of motor vehicles.

torsion balance An instrument for measuring very weak forces. It consists of a horizontal rod fixed to the end of a vertical wire or fibre or to the centre of a taut horizontal wire. The forces to be measured are applied to the end or ends of the rod. The turning of the rod may be measured by the displacement of a beam of light reflected from a plane mirror attached to it. The best-known form is that used by Henry Cavendish (1731–1810) and later by Sir Charles Boys (1855–1944) to determine the *gravitational constant; in this form the balance is calibrated by determining the torsional coefficient of the suspension by treating the device as a torsional pendulum.

torus **1.** (in mathematics) A solid generated by rotating a circle about an external line in its plane, also called an **anchor ring**. It has the shape of the inner tube of a tyre. If r is the radius of the rotating circle and R the distance between the centre of the circle and the axis of rotation, the volume of the torus is $2\pi^2Rr^2$ and the surface area is $4\pi^2Rr$. In Cartesian coordinates, if the z-axis is the axis of rotation, the equation of the torus is $[\sqrt{(x^2 + y^2)} - R]^2 + z^2 = r^2$. **2.** (in botany) *See* RECEPTACLE.

total internal reflection The total reflection of a beam of light at the interface of one medium and another medium of lower refractive index, when the angle of incidence to the second medium exceeds a specific **critical angle**.

If a beam of light passing through a medium A (say glass) strikes the boundary to a medium B of lower refractive index (say air) with a small angle of incidence i, part will be refracted, with an angle of refraction r, and part will be reflected (see illustration a overleaf). If i is increased it will reach a critical angle c, at which $r = 90°$ (see illustration b overleaf). If i is now increased further, no refraction can occur and all the light energy is reflected by the interface (see illustration c overleaf). This total internal reflection occurs when c (given by $n\sin c = 1$) is exceeded (n is the refractive index of A relative to B). The



Total internal reflection.

critical angle of optical glass is usually about 40° and total internal reflection is made use of by incorporating prisms in some optical instruments instead of mirrors.

totality The period during a total *eclipse of the sun in which the view of the sun's surface from a point on the earth is totally obscured by the moon. The maximum duration of totality is 7.67 minutes, but it is usually less.

total-radiation pyrometer *See* PYROMETRY.

touch The sense that enables the texture of objects and substances to be perceived. Touch receptors occur in the *skin, being concentrated in the tips of the finger in humans.

tourmaline A group of minerals composed of complex cyclosilicates containing boron with the general formula $NaR_3^{2+}Al_6B_3Si_6O_{27}(H,F)_4$, where R = Fe^{2+}, Mg, or (Al + Li). The crystals are trigonal, elongated, and variably coloured, the two ends of the crystals often having different colours. Tourmaline is used as a gemstone and because of its double refraction and piezoelectric properties is also used in polarizers and some pressure gauges.

Townes, Charles *See* BASOV, NIKOLAI GENNEDIYEVITCH.

toxicogenomics The study of the toxic effects of drugs or other substances on patterns of gene expression in particular cells or tissues. It is thus a synthesis of toxicology and genomics, and is aimed at identifying potential new drugs more efficiently and revealing the genetic basis of toxic reactions to compounds.

toxicology The science of the study of poisons. Originally developed by Paracelsus (1493–1541), toxicology is concerned with the investigation of the deleterious effects of all foreign substances (*xenobiotics) on living organisms.

toxin A poison produced by a living organism, especially a bacterium. An **endotoxin** is released only when the bacterial cell dies or disintegrates. An **exotoxin** is secreted by a bacterial cell into the surrounding medium. In the body a toxin acts as an *antigen, producing an *immune response.

trace element *See* ESSENTIAL ELEMENT.

trace fossil *See* FOSSIL.

trachea **1. (windpipe)** The tube in air-breathing vertebrates that conducts air from the throat to the *bronchi. It is strengthened with incomplete rings of cartilage. **2.** An air channel in insects and most other terrestrial arthropods. Tracheae occur as ingrowths of the body wall. They open to the exterior by **spiracles** and branch into finer channels (**tracheoles**) that terminate in the tissues (*see also* AIR SAC). Pumping movements of the abdominal muscles cause air to be drawn into and out of the tracheae.

tracheid A type of cell occurring within the *xylem of conifers, ferns, and related plants. Tracheids are elongated and their walls are usually extensively thickened by deposits of lignin. Water flows from one tracheid to another through unthickened regions (pits) in the cell walls. *Compare* VESSEL ELEMENT.

tracheophyte Any plant that has elaborate tissues, including *vascular tissue; a conspicuous *sporophyte generation; and complex leaves with waterproof cuticles. Tracheophytes include plants of the phyla *Lycophyta, *Sphenophyta, *Filicinophyta, *Coniferophyta, and *Anthophyta. In traditional classification systems these were regarded as classes of the division Tracheophyta.

tracing (radioactive tracing) *See* LABELLING.

trajectory *See* PHASE SPACE.

transactinide elements Elements with an atomic number greater than 103, i.e. elements above lawrencium in the *periodic table. So far, elements up to 112 have been detected. Because of the highly radioactive and transient nature of these elements, there has been much dispute about priority of discovery and, consequently, naming of the elements. The International Union of Pure and Applied Chemistry (IUPAC) introduced a set of systematic temporary names based on affixes, as shown in the table.

Affix	Number	Symbol
nil	0	n
un	1	u
bi	2	b
tri	3	t
quad	4	q
pent	5	p
hex	6	h
sept	7	s
oct	8	o
enn	9	e

Transactinide elements.

All these element names end in -ium. So, for example, element 109 in this system is called un + nil + enn + ium, i.e. unnilennium, and given the symbol u+n+e, i.e. Une.

One long-standing dispute was about the element 104 (rutherfordium), which has also been called kurchatovium (Ku). There have also been disputes between IUPAC and the American Chemical Union about element names.

In 1994 IUPAC suggested the following list:
mendelevium (Md, 101)
nobelium (No, 102)
lawrencium (Lr, 103)
dubnium (Db, 104)
joliotium (Jl, 105)
rutherfordium (Rf, 106)
bohrium (Bh, 107)
hahnium (Hn, 108)
meitnerium (Mt, 109)

The ACU favoured a different set of names:
mendelevium (Md, 101)
nobelium (No, 102)
lawrencium (Lr, 103)
rutherfordium (Rf, 104)
hahnium (Ha, 105)
seaborgium (Sg, 106)
nielsbohrium (Ns, 107)
hassium (Hs, 108)
meitnerium (Mt, 109)

A compromise list was adopted by IUPAC in 1997 and is generally accepted:
mendelevium (Md, 101)
nobelium (No, 102)
lawrencium (Lr, 103)
rutherfordium (Rf, 104)
dubnium (Db, 105)
seaborgium (Sg, 106)
bohrium (Bh, 107)
hassium (Hs, 108)
meitnerium (Mt, 109)

Element 110 was named as darmstadtium in 2003 and element 111 was named roentgenium in 2004. So far elements 112 (ununbium, Uub), 113 (ununtrium, Uut), 114 (ununquadium, Uuq), 115 (ununpentium, Uup), and 116 (ununhexium, Uuh) are not officially named. All these elements are unstable and have very short half-lives.

transamination A biochemical reaction in amino acid metabolism in which an amine group is transferred from an amino acid to a keto acid to form a new amino acid and keto acid. The coenzyme required for this reaction is pyridoxal phosphate.

transcendental number A number that is not algebraic, such as π or e. A **transcendental function** is also nonalgebraic, such as a^x, $\sin x$, or $\log x$.

transcriptase *See* REVERSE TRANSCRIPTASE.

transcription The process in living cells in which the genetic information of *DNA is transferred to a molecule of messenger *RNA (mRNA) as the first step in *protein synthesis (*see also* GENETIC CODE). Transcription takes place in the cell nucleus or nuclear region. It involves the action of RNA *polymerase enzymes in assembling the nucleotides necessary to form a complementary strand of mRNA from the DNA template, and (in eukaryote cells) the subsequent removal of the noncoding sequences from this primary transcript (*see* GENE SPLICING) to form a functional mRNA molecule. *See also* REVERSE TRANSCRIPTASE. *Compare* TRANSLATION.

transcription factor Any of a group of proteins that work synergistically to regulate gene activity by increasing or decreasing the binding of RNA *polymerases to the DNA

molecule during the process of *transcription. This is achieved by the ability of the transcription factors to bind to the DNA molecule.

transcriptome The full complement of RNA transcripts of the genes of a cell or organism. The types and relative abundance of different transcripts, i.e. the messenger RNAs (mRNAs), can be obtained by analysing cell contents using oligonucleotide *DNA microarrays. Such an analysis provides a 'snapshot' of the expression pattern of the cell's genes. *See* TRANSCRIPTOMICS.

transcriptomics The study of the RNA transcripts of a cell, tissue, or organism (i.e. the *transcriptome). Transcriptomics is concerned with determining how the transcriptome, and hence pattern of gene expression, changes with respect to various factors, such as type of tissue, stage of development, hormones, drugs, or disease. It complements and overlaps with *proteomics.

transducer A device for converting a non-electrical signal, such as sound, light, heat, etc., into an electrical signal, or vice versa. Thus microphones and loudspeakers are **electroacoustic transducers**. An **active transducer** is one that can itself introduce a power gain and has its own power source. A **passive transducer** has no power source other than the actuating signal and cannot introduce gain.

transduction **1.** The transfer of genetic material from one bacterial cell to another by means of a *bacteriophage. **2.** The conversion of stimuli detected in sensory *receptor cells into electric impulses, which are transmitted to the brain by the nervous system. **3. (signal transduction)** (in cell biology) Any mechanism by which binding of a *signal molecule to a cell-surface receptor triggers a response inside the cell. It often involves *second messengers.

transect A straight line across an expanse of ground along which ecological measurements are taken, continuously or at regular intervals. Thus an ecologist wishing to study the numbers and types of organisms at different distances above the low-tide line might sample at five-metre intervals along a number of transects perpendicular to the shore.

trans effect An effect in the substitution of inorganic square-planar complexes, in which certain ligands in the original complex are able to direct the incoming ligand into the trans position. The order of ligands in decreasing trans-directing power is: $CN^- > NO_2 > I^- > Br^- > Cl^- > NH_3 > H_2O$.

transferase Any of a class of enzymes that catalyse the transfer of a group of atoms from one molecule to another.

transfer RNA *See* RNA.

transformer A device for transferring electrical energy from one alternating-current circuit to another with a change of voltage, current, phase, or impedance. It consists of a primary winding of N_p turns magnetically linked by a ferromagnetic core or by proximity to the secondary winding of N_s turns. The **turns ratio** (N_s/N_p) is approximately equal to V_s/V_p and to I_p/I_s, where V_p and I_p are the voltage and current fed to the primary winding and V_s and I_s are the voltage and current induced in the secondary winding, assuming that there are no power losses in the core. In practice, however, there are *eddy-current and *hysteresis losses in the core, incomplete magnetic linkage between the coils, and heating losses in the coils themselves. By the use of a *laminated core and careful design, transformers with 98% efficiency can be achieved.

transgene A gene that is taken from one organism and inserted into the germ line of another organism so that it is replicated as part of the genome and present in all the recipient's cells. *See* TRANSGENIC.

transgenic Describing an organism whose genome incorporates and expresses genes from another species (*transgenes). *See* GENETICALLY MODIFIED ORGANISMS (Feature).

transient A brief disturbance or oscillation in a circuit caused by a sudden rise in the current or e.m.f.

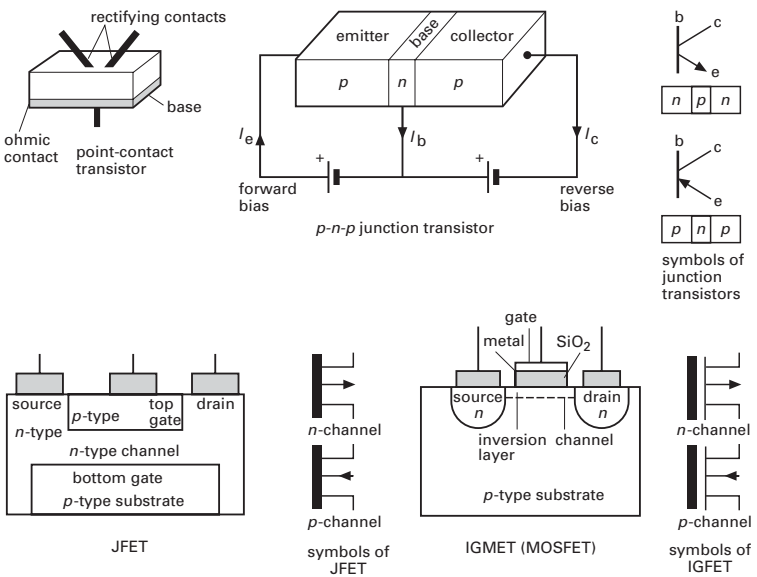
trans-isomer *See* ISOMERISM.

transistor A *semiconductor device capable of amplification in addition to rectification. It is the basic unit in radio, television, and computer circuits, having almost completely replaced the *thermionic valve. The **point-contact transistor**, which is now obsolete, was invented in 1948. It consists of a small germanium crystal with two rectifying point contacts attached to it; a third contact, called the **base**, makes a low-resistance non-rectifying (ohmic) connection with the crystal. Current flowing through the device between the point contacts is modulated by

the signal fed to the base. This type of transistor was replaced by the **junction transistor**, which was developed in 1949–50. The **field-effect transistor** (**FET**) was a later invention. **Bipolar transistors**, such as the junction transistor, depend on the flow of both majority and minority carriers, whereas in **unipolar transistors**, such as the FET, the current is carried by majority carriers only.

In the bipolar junction transistor, two *p*-type semiconductor regions are separated by a thin *n*-type region, making a *p*–*n*–*p* structure. Alternatively, an *n*–*p*–*n* structure can also be used. In both cases the thin central region is called the base and one outer region of the sandwich is called the **emitter**, the other the **collector**. The emitter–base junction is forward-biased and the collector–base junction is reverse-biased. In the *p*–*n*–*p* transistor, the forward bias causes holes in the emitter region to flow across the junction into the base; as the base is thin, the majority of holes are swept right across it (helped by the reverse bias), into the collector. The minority of holes that do not flow from the base to the collector combine with electrons in the *n*-type base. This recombination is balanced by a small electron flow in the base circuit. The diagram illustrates the (conventional) current flow using the **common-base** type of connection. If the emitter, base, and collector currents are I_e, I_b, and I_c, respectively, then $I_e = I_b + I_c$ and the current gain is I_c/I_b.

Field-effect transistors are of two kinds, the **junction FET** (**JFET** or **JUGFET**) and the **insulated-gate FET** (**IGFET**; also known as a **MOSFET**, i.e. metal-oxide-semiconductor FET). Both are unipolar devices and in both the current flows through a narrow **channel** between two electrodes (the **gate**) from one region, called the **source**, to another, called the **drain**. The modulating signal is applied to the gate. In the JFET, the channel consists of a semiconductor material of relatively low conductivity sandwiched between two regions of high conductivity of the opposite polarity. When the junctions between these regions are reverse-biased, *depletion layers form, which narrow the channel. At high bias the depletion layers meet and pinch-off the channel completely. Thus the voltage applied to the two gates controls the thickness of the channel and thus its conductivity.



Transistors.

JFETs are made with both *n*-type and *p*-type channels.

In the IGFET, a wafer of semiconductor material has two highly doped regions of opposite polarity diffused into it, to form the source and drain regions. An insulating layer of silicon dioxide is formed on the surface between these regions and a metal conductor is evaporated on to the top of this layer to form the gate. When a positive voltage is applied to the gate, electrons move along the surface of the *p*-type substrate below the gate, producing a thin surface of *n*-type material, which forms the channel between the source and drain. This surface layer is called an **inversion layer**, as it has opposite conductivity to that of the substrate. The number of induced electrons is directly proportional to the gate voltage, thus the conductivity of the channel increases with gate voltage. IGFETs are also made with both *p*-type and *n*-type channels. Because MOS devices cannot be formed on gallium arsenide (there are no stable native oxides of GaAs), metal semiconductor FETs (MESFET) devices are used. This makes use of Schottky barrier (*see* SCHOTTKY EFFECT) as the gate electrode rather than a semiconductor junction.

transit (in astronomy) **1.** The passage of a planet across the face of a star, especially the passage of Mercury or Venus across the face of the sun as viewed from earth. **2.** The passage of a planetary satellite and its shadow across the disc of the parent planet. **3.** The passage of a celestial object across an observer's meridian as near as possible to the observer's zenith.

transition A change of a system from one quantum state to another.

transition elements A set of elements in the *periodic table in which filling of electrons in an inner *d*- or *f*-level occurs. With increasing proton number, electrons fill atomic levels up to argon, which has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6$. In this shell, there are 5 *d*-orbitals, which can each contain 2 electrons. However, at this point the subshell of lowest energy is not the 3*d* but the 4*s*. The next two elements, potassium and calcium, have the configurations $[Ar]4s^1$ and $[Ar]4s^2$ respectively. For the next element, scandium, the 3*d* level is of lower energy than the 4*p* level, and scandium has the configuration $[Ar]3d^1 4s^2$. This filling of the inner *d*-level continues up to zinc $[Ar]3d^{10} 4s^2$, giving the first transition series. There is a further series of this type in the next period of the table: between yttrium ($[Kr]4d5s^2$) and cadmium ($[Kr]4d^{10}5s^2$). This is the second transition series. In the next period of the table the situation is rather more complicated. Lanthanum has the configuration $[Xe]5d^1 6s^2$. The level of lowest energy then becomes the 4*f* level and the next element, cerium, has the configuration $[Xe]4f^1 5d^1 6s^2$. There are 7 of these *f*-orbitals, each of which can contain 2 electrons, and filling of the *f*-levels continues up to lutetium ($[Xe]4f^{14}5d^1 6s^2$). Then the filling of the 5*d* levels continues from hafnium to mercury. The series of 14 elements from cerium to lutetium is a 'series within a series' called an **inner transition series**. This one is the *lanthanoid series. In the next period there is a similar inner transition series, the *actinoid series, from thorium to lawrencium. Then filling of the *d*-level continues from element 104 onwards.

In fact, the classification of chemical elements is valuable only in so far as it illustrates chemical behaviour, and it is conventional to use the term 'transition elements' in a more restricted sense. The elements in the inner transition series from cerium (58) to lutetium (71) are called the lanthanoids; those in the series from thorium (90) to lawrencium (103) are the actinoids. These two series together make up the *f*-block in the periodic table. It is also common to include scandium, yttrium, and lanthanum with the lanthanoids (because of chemical similarity) and to include actinium with the actinoids. Of the remaining transition elements, it is usual to speak of three **main transition series**: from titanium to copper; from zirconium to silver; and from hafnium to gold. All these elements have similar chemical properties that result from the presence of unfilled *d*-orbitals in the element or (in the case of copper, silver, and gold) in the ions. The elements from 104 to 109 and the undiscovered elements 110 and 111 make up a fourth transition series. The elements zinc, cadmium, and mercury have filled *d*-orbitals both in the elements and in compounds, and are usually regarded as nontransition elements forming group 12 of the periodic table.

The elements of the three main transition series are all typical metals (in the nonchemical sense), i.e. most are strong hard materials that are good conductors of heat and electricity and have high melting and boiling

points. Chemically, their behaviour depends on the existence of unfilled *d*-orbitals. They exhibit variable valency, have coloured compounds, and form *coordination compounds. Many of their compounds are paramagnetic as a result of the presence of unpaired electrons. Many of them are good catalysts. They are less reactive than the *s*- and *p*-block metals.

transition point (transition temperature) **1.** The temperature at which one crystalline form of a substance changes to another form. **2.** The temperature at which a substance changes phase. **3.** The temperature at which a substance becomes superconducting (*see* SUPERCONDUCTIVITY). **4.** The temperature at which some other change, such as a change of magnetic properties (*see also* CURIE POINT), takes place.

transition state (activated complex) The association of atoms of highest energy formed during a chemical reaction. The transition state can be regarded as a short-lived intermediate that breaks down to give the products. For example, in a S_N2 substitution reaction, one atom or group approaches the molecule as the other leaves. The transition state is an intermediate state in which both attacking and leaving groups are partly bound to the molecule, e.g.

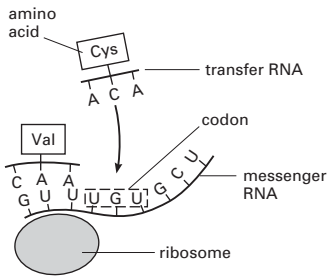
$$B + RA \rightarrow B\text{—-}R\text{—-}A \rightarrow BR + A$$

In the theory of reaction rates, the reactants are assumed to be in equilibrium with this activated complex, which decomposes to the products.

transition zone *See* HYPOCOTYL.

translation **1.** (in biochemistry) The process in living cells in which the genetic information encoded in messenger *RNA (mRNA) in the form of a sequence of nucleotide triplets (*codons) is translated into a sequence of amino acids in a polypeptide chain during *protein synthesis (see illustration). Translation takes place on *ribosomes in the cell cytoplasm. The ribosomes move along the mRNA 'reading' each codon in turn. Molecules of transfer RNA (tRNA), each bearing a particular amino acid, are brought to their correct positions along the mRNA molecule: base pairing occurs between the bases of the codons and the complementary base triplets of tRNA (*see* ANTICODON). In this way amino acids are assembled in the correct sequence to form the polypeptide chain. **2.** (in physics) Motion of a body in which all the points in the body follow parallel paths.

translocation **1.** (in botany) The movement of minerals and chemical compounds within a plant. There are two main processes. The first is the uptake of soluble



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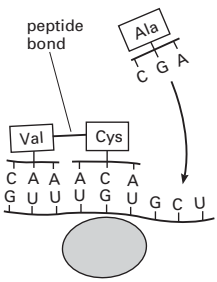

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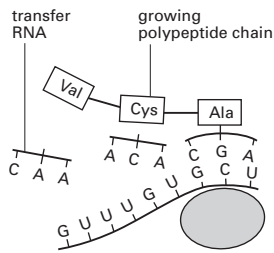


(c)

Translation. The stages of translation in protein synthesis.

minerals from the soil and their passage upwards from the roots to various organs by means of the water-conducting vessels (*xylem). The second is the transfer of organic compounds, synthesized by the leaves, both upwards and downwards to various organs, particularly the growing points. This movement occurs within the *phloem tubes. *See also* MASS FLOW. **2.** (in genetics) A type of *chromosome mutation in which a section of one chromosome is broken off and becomes attached to another chromosome, resulting in a loss of genetic information from the first chromosome.

translucent Permitting the passage of radiation but not without some scattering or diffusion. For example, frosted glass allows light to pass through it but an object cannot be seen clearly through it because the light rays are scattered by it. *Compare* TRANSPARENT.

transmission **1.** (in neurophysiology) The one-way transfer of a nerve *impulse from one neuron to another across a *synapse. *See also* NEUROTRANSMITTER. *Compare* PROPAGATION. **2.** (in medicine) The spread of an *infection from person to person. This can occur in various ways, such as close contact with an infected person, including sexual contact (*see* SEXUALLY TRANSMITTED DISEASE); contact with a *vector or a *carrier of the disease; consuming food or drink contaminated with the infecting microorganism; and breathing in contaminated droplets of moisture, produced by coughing and sneezing. **3.** (in radio) *See* TRANSMITTER.

transmission coefficient *See* TRANSMITTANCE.

transmission electron microscope *See* ELECTRON MICROSCOPE.

transmittance (transmission coefficient) The ratio of the energy of some form of radiation transmitted through a surface to the energy falling on it. The reciprocal of the transmittance is the **opacity**.

transmitter **1.** The equipment used to generate and broadcast radio-frequency electromagnetic waves for communication purposes. In **transmitted-carrier transmission** it consists of a carrier-wave generator, a device for modulating the carrier wave in accordance with the information to be broadcast, amplifiers, and an aerial system. In **suppressed-carrier transmission**, the carrier component of the carrier wave is not transmitted; one *sideband (**single-sideband transmission**) or both sidebands (**double-sideband transmission**) are transmitted and a local oscillator in the receiver regenerates the carrier frequency and mixes it with the received signal to detect the modulating wave. **2.** The part of a telephone system that converts sound into electrical signals. **3.** *See* NEUROTRANSMITTER.

transmutation The transformation of one element into another by bombardment of nuclei with particles. For example, plutonium is obtained by the neutron bombardment of uranium.

trans-Neptunian object (TNO) Any of the large number of objects orbiting the sun out beyond the planet *Neptune. They include the objects of the *Kuiper belt and the *scattered disc.

transparent Permitting the passage of radiation without significant deviation or absorption. *Compare* TRANSLUCENT. A substance may be transparent to radiation of one wavelength but not to radiation of another wavelength. For example, some forms of glass are transparent to light but not to ultraviolet radiation, while other forms of glass may be transparent to all visible radiation except red light. *See also* RADIOTRANSPARENT.

transpiration The loss of water vapour by plants to the atmosphere. It occurs mainly from the leaves through pores (stomata) whose primary function is gas exchange. The water is replaced by a continuous column of water (and dissolved nutrients) moving upwards from the roots within the *xylem vessels. The flow of this column of water is known as the **transpiration stream**, which is maintained by *root pressure and a combination of cohesive and adhesive forces in the xylem vessels according to the **cohesion–tension theory** (*see* COHESION). *See also* POTOMETER.

transplantation *See* GRAFT.

transport coefficients Quantities that characterize transport in a system. Examples of transport coefficients include electrical and thermal *conductivity. One of the main purposes of non-equilibrium *statistical mechanics is to calculate such coefficients from first principles. It is difficult to calculate transport coefficients exactly for non-interacting systems and it is therefore necessary to use *approximation techniques and/or *model systems. A transport coeffi-

cient gives a measure for flow in a system. An **inverse transport coefficient** gives a measure of resistance to flow in a system. An example of an inverse transport coefficient is *resistivity.

transport number Symbol *t*. The fraction of the total charge carried by a particular type of ion in the conduction of electricity through electrolytes.

transport protein A protein that penetrates or spans a cell membrane to permit the passage of a substance through the membrane. Some transport proteins form pores, or *channels, through which particular ions or molecules can pass. Other types of transport protein bind the substance on one face of the membrane, then change shape so that the substance is carried by the protein through the membrane to be released at the other face. Transport proteins often require energy to drive the transport process; this is provided by hydrolysis of ATP or by an existing concentration gradient. *See* ACTIVE TRANSPORT.

transport theory The theory of phenomena involving the transfer of matter or heat. The calculation of *transport coefficients and inverse transport coefficients, such as *conductivity and *viscosity, is an aim of transport theory. Calculations from first principles in transport theory start from *non-equilibrium statistical mechanics. Because of the difficulties involved in calculations in non-equilibrium statistical mechanics, transport theory uses approximate methods, including the *kinetic theory of gases and *kinetic equations, such as the *Boltzmann equation.

transposon (transposable genetic element) A mobile genetic element, known informally as a 'jumping gene', that can become integrated at many different sites along a chromosome. The simplest types of transposon are known as **insertion sequences**, typically found in bacteria and consisting of some 700–2500 base pairs and with numerous short repeated nucleotide sequences at either end. Larger and more complex are the **composite transposons**, which consist of a central portion, possibly containing functional genes, flanked by insertion sequences at either end. Transposons were first discovered by Barbara McClintock in maize in the 1940s and have since been found in other eukaryotes and in bacteria. They can disrupt gene expression or cause deletions and inversions, and hence affect both the genotype and phenotype of the organisms concerned. Most eukaryotic transposons are *retrotransposons. Transposons account for a sizable proportion of the *repetitive DNA in eukaryotes.

transuranic elements Elements with an atomic number greater than 92, i.e. elements above uranium in the *periodic table. Most of these elements are unstable and have short half-lives. *See also* TRANSACTINIDE ELEMENTS.

transverse wave *See* WAVE.

travelling wave *See* WAVE.

travelling-wave accelerator *See* LINEAR ACCELERATOR.

Travers, Morris *See* RAMSAY, SIR WILLIAM.

Trematoda A class of parasitic flatworms (*see* PLATYHELMINTHES) comprising the flukes, such as *Fasciola* (liver fluke). Flukes have suckers and hooks to anchor themselves to the host and their body surface is covered by a protective cuticle. The whole life cycle may either occur within one host or require one or more intermediate hosts to transmit the infective eggs or larvae. *Fasciola hepatica*, for example, undergoes larval development in a land snail (the intermediate host) and infects sheep (the primary host) when contaminated grass containing the larvae is swallowed.

triacetone triperoxide (TATP) An organic peroxide, $C_9H_{18}O_6$, derived from acetone; r.d. 1.18; m.p. 91°C. It is a highly explosive white crystalline substance, very sensitive to heat and shock. It is favoured by some terrorist groups because it can easily be made from commonly available compounds. For example, it is probable that it was used in the London bombings of 7 July 2005.

triacylglycerol *See* TRIGLYCERIDE.

trial-and-error learning *See* LEARNING.

triangle of vectors A triangle constructed so that each of its sides represents one of three coplanar *vectors acting at a point with no resultant. If the triangle is completed, with the sides representing the vectors in both magnitude and direction, so that there are no gaps between the sides, then the vectors are in equilibrium. If the three vectors are forces, the figure is called a

triangle of forces; if they are velocities, it is a **triangle of velocities**.

Triassic The earliest period of the Mesozoic era. It began about 251 million years ago, following the Permian, the last period of the Palaeozoic era, and extended until about 200 million years ago when it was succeeded by the Jurassic. It was named, by F. von Alberti in 1834, after the sequence of three divisions of strata that he studied in central Germany – Bunter, Muschelkalk, and Keuper. The Triassic rocks are frequently difficult to distinguish from the underlying Permian strata and the term **New Red Sandstone** is often applied to rocks of the Permo-Triassic. During the period marine animals diversified: molluscs were the dominant invertebrates – ammonites were abundant and bivalves replaced the declining brachiopods. Reptiles were the dominant vertebrates and included turtles, phytosaurs, dinosaurs, and the marine ichthyosaurs.

triatomic molecule A molecule formed from three atoms (e.g. H_2O or CO_2).

triazine *See* AZINE.

tribe A category used in the *classification of plants and animals that consists of several similar or closely related genera within a family. For example the Bambuseae, Oryzeae, Paniceae, and Aveneae are tribes of grasses.

triboelectricity *Static electricity produced as a result of friction.

tribology The study of friction, lubrication, and lubricants.

triboluminescence *Luminescence caused by friction; for example, some crystalline substances emit light when they are crushed as a result of static electric charges generated by the friction.

tribromomethane (bromoform) A colourless liquid *haloform, $CHBr_3$; r.d. 2.9; m.p. 8°C; b.p. 150°C.

tricarbon dioxide (carbon suboxide) A colourless gas, C_3O_2, with an unpleasant odour; r.d. 1.114 (liquid at 0°C); m.p. –111.3°C; b.p. 7°C. It is the acid anhydride of malonic acid, from which it can be prepared by dehydration using phosphorus(V) oxide. The molecule is linear (O:C:C:C:O).

tricarboxylic acid cycle *See* KREBS CYCLE.

trichloroethanal (chloral) A liquid aldehyde, CCl_3CHO; r.d. 1.51; m.p. –57.5°C; b.p. 97.8°C. It is made by chlorinating ethanal and used in making DDT. *See also* 2,2,2-TRICHLOROETHANEDIOL.

2,2,2-trichloroethanediol (chloral hydrate) A colourless crystalline solid, $CCl_3CH(OH)_2$; r.d. 1.91; m.p. 57°C; b.p. 96.3°C. It is made by the hydrolysis of trichloroethanal and is unusual in having two –OH groups on the same carbon atom. Gem diols of this type are usually unstable; in this case the compound is stabilized by the presence of the three Cl atoms. It is used as a sedative.

trichloroethene (trichlorethylene) A colourless liquid, CCl_2=CHCl, b.p. 87°C. It is toxic and nonflammable, with a smell resembling that of chloroform (trichloromethane). It is widely used as a solvent in dry cleaning and degreasing. It is also used to extract oils from nuts and fruit, as an anaesthetic, and as a fire extinguisher.

trichloromethane (chloroform) A colourless volatile sweet-smelling liquid *haloform, $CHCl_3$; r.d. 1.48; m.p. –63.5°C; b.p. 61.7°C. It can be made by chlorination of methane (followed by separation of the mixture of products) or by the haloform reaction. It is an effective anaesthetic but can cause liver damage and it has now been replaced by other halogenated hydrocarbons. Chloroform is used as a solvent and raw material for making other compounds.

trichome A hairlike projection from a plant epidermal cell. Examples include root hairs and the stinging hairs of nettle leaves.

triclinic *See* CRYSTAL SYSTEM.

tricuspid valve A valve, consisting of three flaps, situated between the right atrium and the right ventricle of the mammalian heart. When the right ventricle contracts, forcing blood into the pulmonary artery, the tricuspid valve closes the aperture to the atrium, thereby preventing any backflow of blood. The valve reopens to allow blood to flow from the atrium into the ventricle. *Compare* BICUSPID VALVE.

tridymite A mineral form of *silicon(IV) oxide, SiO_2.

triglyceride (triacylglycerol) An ester of glycerol (propane-1,2,3-triol) in which all three hydroxyl groups are esterified with a fatty acid. Triglycerides are the major constituent of fats and oils and provide a con-

centrated food energy store in living organisms as well as cooking fats and oils, margarines, etc. Their physical and chemical properties depend on the nature of their constituent fatty acids. In **simple triglycerides** all three fatty acids are identical; in **mixed triglycerides** two or three different fatty acids are present.

trigonal bipyramid *See illustration at* COMPLEX.

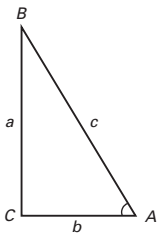
trigonometric functions Functions defined in terms of a right-angled triangle (see diagram) and widely used in the solution of many mathematical problems. They are defined as:

tangent of angle *A*, written $\tan A = a/b$
sine of angle *A*, written $\sin A = a/c$
cosine of angle *A*, written $\cos A = b/c$,

where *a* is the length of the side opposite the angle *A*, *b* is the length of the side opposite the angle *B*, and *c* is the hypotenuse of the triangle.

The reciprocal functions are:

cotangent of angle *A*, written $\cot A = 1/\tan A = b/a$
secant of angle *A*, written $\sec A = 1/\cos A = c/b$
cosecant of angle *A*, written $\mathrm{cosec} A = 1/\sin A = c/a$.



Trigonometric functions.

trihydrate A crystalline hydrate that contains three moles of water per mole of compound.

trihydric alcohol *See* TRIOL.

triiodomethane (iodoform) A yellow volatile solid sweet-smelling *haloform, CHI_3; r.d. 4.1; m.p. 115°C. It is made by the haloform reaction.

triiodothyronine (T_3) A hormone secreted by the *thyroid gland. *See also* THYROGLOBULIN.

triiron tetroxide (ferrosoferric oxide) A black magnetic oxide, Fe_3O_4; r.d. 5.2. It is formed when iron is heated in steam and also occurs naturally as the mineral *magnetite. The oxide dissolves in acids to give a mixture of iron(II) and iron(III) salts.

trilobite An extinct marine arthropod belonging to the class Trilobita (some 4000 species), fossils of which are found in deposits dating from the Precambrian to the Permian period (590–280 million years ago). Trilobites were typically small (1–7 cm long); the oval flattened body comprised a head (covered by a semicircular dorsal shield) and a thorax and abdomen, which were protected by overlapping dorsal plates with a raised central part and flattened lateral portions, presenting a three-lobed appearance. The head bore a pair of antenna-like appendages and a pair of compound eyes; nearly all body segments bore a pair of Y-shaped (biramous) appendages – one branch for locomotion and the other fringed for respiratory exchange. Trilobites were bottom-dwelling scavengers.

trimethylaluminium (aluminium trimethyl) A colourless liquid, $Al(CH_3)_3$, which ignites in air and reacts with water to give aluminium hydroxide and methane, usually with extreme vigour; r.d. 0.752; m.p. 0°C; b.p. 130°C. Like other aluminium alkyls it may be prepared by reacting a Grignard reagent with aluminium trichloride. Aluminium alkyls are used in the *Ziegler process for the manufacture of high-density polyethene (polythene).

2,4,6-trinitrophenol *See* PICRIC ACID.

trinitrotoluene (TNT) A yellow highly explosive crystalline solid, $CH_3C_6H_2(NO_2)_3$; r.d. 1.65; m.p. 82°C. It is made by nitrating toluene (methylbenzene), the systematic name being 1-methyl-2,4,6-trinitrobenzene.

triode A *thermionic valve with three electrodes. Electrons produced by the heated cathode flow to the anode after passing through the negatively biased *control grid. Small voltage fluctuations superimposed on the grid bias cause large fluctuations in the anode current. The triode was thus the first electronic device capable of amplification. Its role has now been taken over by the transistor, except where high power (radio-frequency transmitters producing more than 1 kW in power) is required.

t

triol (trihydric alcohol) An *alcohol containing three hydroxyl groups per molecule.

triose A sugar molecule that contains three carbon atoms. *See* MONOSACCHARIDE.

trioxoboric(III) acid *See* BORIC ACID.

trioxosulphuric(IV) acid *See* SULPHUROUS ACID.

trioxygen *See* OZONE.

triple bond *See* CHEMICAL BOND.

triple point The temperature and pressure at which the vapour, liquid, and solid phases of a substance are in equilibrium. For water the triple point occurs at 273.16 K and 611.2 Pa. This value forms the basis of the definition of the *kelvin and the thermodynamic *temperature scale.

triple product Either a *scalar product or a *vector product each having three components. A **scalar triple product** is obtained by multiplying three *vectors $\boldsymbol{a}$, $\boldsymbol{b}$ and $\boldsymbol{c}$ in the manner $\boldsymbol{a}.(\boldsymbol{b}\times\boldsymbol{c})$; the result is a scalar. If the three vectors represent the positions of three points with respect to the origin, the magnitude of the scalar triple product is the volume of the parallelepiped with corners at the three points and the origin. A **vector triple product** is obtained by multiplying three vectors $\boldsymbol{a}$, $\boldsymbol{b}$ and $\boldsymbol{c}$ in the manner $\boldsymbol{a}\times(\boldsymbol{b}\times\boldsymbol{c})$; the result is a vector. It also equals $(\boldsymbol{a}.\boldsymbol{c})\boldsymbol{b}-(\boldsymbol{a}.\boldsymbol{b})\boldsymbol{c}$ (but note it does not equal $(\boldsymbol{a}\times\boldsymbol{b})\times\boldsymbol{c}$).

triplet code *See* CODON; GENETIC CODE.

triploblastic Describing an animal having a body composed of three embryonic cell layers: the *ectoderm, *mesoderm, and *endoderm. Most multicellular animals are triploblastic; the coelenterates, which are *diploblastic, are an exception.

triploid Describing a nucleus, cell, or organism that has three times ($3n$) the haploid number (n) of chromosomes (*see also* POLYPLOID). Triploid organisms are normally sterile as their lack of *homologous chromosomes prevents pairing during meiosis. This can be useful to plant breeders, for example in banana cultivation: sterile triploid bananas can be propagated asexually and will not contain any seeds.

trisilane *See* SILANE.

trisodium phosphate(V) (sodium orthophosphate) A colourless crystalline compound, Na_3PO_4, soluble in water and insoluble in ethanol. It is known both as the decahydrate (octagonal; r.d. 2.54) and the dodecahydrate (trigonal; r.d. 1.62) The dodecahydrate loses water at about 76°C and the decahydrate melts at 100°C. Trisodium phosphate may be prepared by boiling sodium carbonate with the stoichiometric amount of phosphoric acid and subsequently adding sodium hydroxide to the disodium salt thus formed. It is useful as an additive for high-pressure boiler feed water (for removal of calcium and magnesium as phosphates), in emulsifiers, as a water-softening agent, and as a component in detergents and cleaning agents. Sodium phosphate labelled with the radioactive isotope ^{32}P is used in the study of the role of phosphate in biological processes and is also used (intravenously) in the treatment of polycythaemia.

trisomy The condition of a nucleus, cell, or organism in which one of the pairs of homologous chromosomes has gained an additional chromosome, resulting in a chromosome number of $2n + 1$. Trisomy is the cause of a number of human genetic abnormalities, including *Down's syndrome; Patau's syndrome, in which there is an extra chromosome 13 (**trisomy 13**); and Edwards' syndrome, in which there is an extra chromosome 18 (**trisomy 18**).

tritiated compound *See* LABELLING.

tritium Symbol T. An isotope of hydrogen with mass number 3; i.e. the nucleus contains 2 neutrons and 1 proton. It is radioactive (half-life 12.3 years), undergoing beta decay to helium–3. Tritium is used in *labelling.

triton The nucleus of a tritium atom.

trivalent (tervalent) Having a valency of three.

tRNA *See* RNA.

trochanter **1.** Any of several bony knobs on the femur of vertebrates to which muscles are attached. **2.** The second segment of an insect's leg, between the *coxa and the *femur.

trona A mineral form of sodium sesquicarbonate, consisting of a mixed hydrated sodium carbonate and sodium hydrogencarbonate, $Na_2CO_3.NaHCO_3.2H_2O$.

trophic level The position that an organism occupies in a *food chain. For example, green plants (which obtain their energy di-

rectly from sunlight) are the primary *producers; herbivores are primary *consumers (and secondary producers). A carnivore that eats only herbivores is a secondary consumer and a tertiary producer. Many animals feed at several different trophic levels.

tropical cyclone A *cyclone that develops over tropical or subtropical waters, in which sea temperatures are above 27°C and at least 5° of latitude away from the equator. The term encompasses tropical depression, with wind speeds of 33 knots (62 km/h) or less, and tropical storm, with wind speeds of 34–63 knots (63–117 km/h). A tropical cyclone with wind speeds of over 64 knots (117 km/h) is known as a *hurricane where it occurs in the North Atlantic Ocean, Caribbean Sea, Gulf of Mexico, and the east and central North Pacific Ocean (east of the dateline); as a typhoon where it occurs in the North Pacific Ocean; and as a severe tropical cyclone where it occurs in the southwest Pacific Ocean (west of 160°E) and southeast Indian Ocean (east of 90°E).

tropical year *See* YEAR.

tropism The directional growth of a plant organ in response to an external stimulus, such as light, touch, or gravity. Growth towards the stimulus is a **positive tropism**; growth away from the stimulus is a **negative tropism**. *See also* GEOTROPISM; HYDROTROPISM; ORTHOTROPISM; PHOTOTROPISM; PLAGIOTROPISM; THIGMOTROPISM. *Compare* NASTIC MOVEMENTS; TAXIS.

tropomyosin A protein found in the *actin filaments in muscles. The molecule consists of two elongated strands that run along the length of the filament. When the muscle is at rest, the tropomyosin molecule covers the region of the actin molecule where interaction with myosin occurs. On contraction of the muscle, the tropomyosin is displaced by another protein, *troponin, allowing the interaction of actin with myosin.

troponin A complex of three polypeptide chains that are found at regular intervals along the length of an *actin filament. During muscle contraction, troponin binds to calcium ions, displacing *tropomyosin and exposing the active site on the actin filament. This allows the interaction of actin and myosin to occur.

troposphere *See* EARTH'S ATMOSPHERE.

tropylium ion The positive ion $C_7H_7^+$, having a ring of seven carbon atoms. The ion is symmetrical and has characteristic properties of *aromatic compounds.

truth table A table that summarizes all possible outcomes of a logical operation. For example, for an AND *gate with inputs A and B and output C, the truth table is

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

This indicates that the output will be 0 unless both inputs are 1.

trypsin An enzyme that digests proteins (*see* ENDOPEPTIDASE; PROTEASE). It is secreted in an inactive form (**trypsinogen**) by the pancreas into the duodenum. There, trypsinogen is acted on by an enzyme (**enterokinase**) produced in the duodenum to yield trypsin. The active enzyme plays an important role in the digestion of proteins in the anterior portion of the small intestine. It also activates other proteases in the pancreatic juice (*see* CARBOXYPEPTIDASE; CHYMOTRYPSIN).

trypsinogen *See* TRYPSIN.

tryptamine A naturally occurring alkaloid, $C_{10}H_{12}N_2$, having an indole ring system with a $–CH_2–CH_2–NH_2$ side chain in the 3-position of the nitrogen-containing ring. Derivatives of tryptamine have hallucinogenic effects. An example in *psilocybin.

tryptophan *See* AMINO ACID.

TSH *See* THYROID-STIMULATING HORMONE.

tsunami A large sea wave usually generated by a submarine earthquake or volcanic eruption. It may aso be caused by a mass underwater mudslide. The waves, which can be over 10 m high, spread in concentric circles from the focus of the earthquake, often travelling hundreds of kilometres and reaching speeds of 700 km/h. A tsunami can be extremely destructive when it breaks on the shore. A devasting tsunami followed a powerful earthquake of magnitude 9.0 (*see* RICHTER SCALE) off the west coast of N Sumatra, Indonesia, on 26 December 2004. It swept over land causing widespread destruction in Indonesia, Sri Lanka, Thailand, Malaysia, Myanmar, S India, and the Mal-

dives, with lesser effects as faraway as E Africa, and resulted in over 283 100 deaths.

T Tauri star An unstable young variable star in its pre-main sequence phase (*see* HERTZSPRUNG–RUSSELL DIAGRAM). The instability, brought about by the beginning of nuclear fusion in the core of the star, causes pulsations and stellar winds, possibly with *bipolar outflows. Groups of such stars, often associated with *Herbig–Haro objects, are called T Tauri associations.

tuber A swollen underground stem or root in certain plants. It enables the plant to survive the winter or dry season and is also a means of propagation. A **stem tuber**, such as the potato, forms at the end of an underground stem. Each tuber represents several nodes and internodes. The following season several new plants develop from the terminal and axillary buds (eyes). **Root tubers**, such as those of the dahlia, are modified food-storing adventitious roots and may also give rise to new plants.

tubulin A protein of which the *microtubules of cells are formed.

Tullgren funnel A device used to remove and collect small animals, such as insects, from a sample of soil or leaf litter. The sample is placed on a coarse sieve fixed across the wide end of a funnel and a 100-watt light bulb, in a metal reflector, is placed about 25 cm above the funnel. The heat from the bulb dries and warms the sample, causing the animals to move downwards and fall through the sieve into the funnel, which directs them into a collecting dish or tube below. The dish can contain water or alcohol to prevent the animals from escaping.

tumour *See* NEOPLASM.

tundra A terrestrial *biome characterized by a lack of trees and a permanently frozen subsoil. Tundra lies to the north of the *taiga in North America and Eurasia; the vegetation is dominated by grasses, sedges, lichens, mosses, heathers, and low shrubs. The growing season, which occurs during the warmest part of the year when the average daily mean temperature is about 10°C, lasts only 2–4 months, during which the topsoil thaws to a depth of 30 cm, allowing roots to penetrate it. However, below this level the soil is permanently frozen (**permafrost**); water cannot filter through the soil and may lie in surface depressions during the growing season. Global warming is now affecting the ecology and economy of tundra regions dramatically. By the mid-21st century, the area of permafrost is predicted to decline by around 20–35%. *Compare* TAIGA.

tuneable laser *See* DYE LASER.

tungsten Symbol W. A white or grey metallic *transition element (formerly called **wolfram**); a.n. 74; r.a.m. 183.85; r.d. 19.3; m.p. 3410°C; b.p. 5660°C. It is found in a number of ores, including the oxides wolframite, $(Fe,Mn)WO_4$, and scheelite, $CaWO_4$. The ore is heated with concentrated sodium hydroxide solution to form a soluble **tungstate**. The oxide WO_3 is precipitated from this by adding acid, and is reduced to the metal using hydrogen. It is used in various alloys, especially high-speed steels (for cutting tools) and in lamp filaments. Tungsten forms a protective oxide in air and can be oxidized at high temperature. It does not dissolve in dilute acids. It forms compounds in which the oxidation state ranges from +2 to +6. The metal was first isolated by Juan and Fausto d'Elhuyer in 1783.

SEE WEB LINKS

- Information from the WebElements site

tungsten carbide A black powder, WC, made by heating powdered tungsten metal with lamp black at 1600°C. It is extremely hard (9.5 on Mohs' scale) and is used in dies and cutting tools. A ditungsten carbide, W_2C, also exists.

tuning fork A metal two-pronged fork that when struck produces an almost pure tone of a predetermined frequency. It is used for tuning musical instruments and in experiments in acoustics.

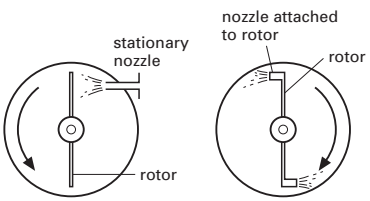
tunnel diode (Esaki diode) A semiconductor diode, discovered in 1957 by L. Esaki (1925–), based on the *tunnel effect. It consists of a highly doped *p*–*n* semiconductor junction, which short circuits with negative bias and has negative resistance over part of its range when forward biased. Its fast speed of operation makes it a useful device in many electronic fields.

tunnel effect An effect in which electrons are able to tunnel through a narrow *potential barrier that would constitute a forbidden region if the electrons were treated as classical particles. That there is a finite probability of an electron tunnelling from one classically allowed region to another arises as a conse-

quence of *quantum mechanics. The effect is made use of in the *tunnel diode. Alpha decay (*see* ALPHA PARTICLE) is an example of a tunnelling process.

Turbellaria A class of free-living flatworms (*see* PLATYHELMINTHES) comprising the planarians, which occur in wet soils, fresh water, and marine environments. Their undersurface is covered with cilia, used for gliding over stones and weeds. Planarians can also swim by means of undulations of the body.

turbine A machine in which a fluid is used to produce rotational motion. The most widely used turbines are the **steam turbines** and **water turbines** that provide some 95% of the world's electric power (in the form of *turbogenerators) and the **gas turbines** that power all the world's jet-propelled aircraft. In the **impulse turbine** a high-pressure low-velocity fluid is expanded through stationary nozzles, producing low-pressure high-velocity jets, which are directed onto the blades of a rotor. The rotor blades reduce the speed of the jets and thus convert some of the fluid's kinetic energy into rotational kinetic energy of the rotor shaft. In the **reaction turbine** the discharge nozzles are themselves attached to the rotor. The acceleration of the fluid leaving the nozzles produces a force of reaction on the pipes, causing the rotor to move in the opposite direction to that of the fluid. (See illustrations.) Many turbines work on a combination of the impulse and reaction principles.



Turbine.

turbogenerator A steam turbine driving an electric generator. This is the normal method of generating electricity in power stations. In a conventional power station the steam is raised by burning a fossil fuel (coal, oil, or natural gas); in a nuclear power station the steam is raised by heat transfer from a nuclear reactor.

turbojet *See* JET PROPULSION.

turbulence A form of fluid flow in which the particles of the fluid move in a disordered manner in irregular paths, resulting in an exchange of momentum from one portion of a fluid to another. Turbulent flow takes over from *laminar flow when high values of the *Reynolds number are reached.

turgor The condition in a plant cell when its *vacuole is distended with water, pushing the protoplast against the cell wall. In this condition the force causing water to enter the cell by *osmosis is balanced by the hydrostatic pressure of the protoplast against the cell wall (*see also* WATER POTENTIAL). Turgidity assists in maintaining the rigidity of plants; a decrease in turgidity leads to *wilting. *Compare* PLASMOLYSIS.

Turing, Alan Mathison (1912–54) British mathematician, who after studying at Cambridge University went to Princeton, where in 1937 he published his most important work on computable numbers, which contained a description of the hypothetical *Turing machine. He returned to Britain at the outbreak of World War II and worked on cracking German codes. This led to his involvement in the development of computers. He committed suicide after being convicted of indecency (as a homosexual).

Turing machine A hypothetical machine that determines whether or not a problem is computable. It has an infinite memory represented by an infinitely long ribbon of paper tape passing through the machine, which can be in several discrete internal states. The tape is divided into cells that can each hold one of a given number of symbols. The machine can move left or right along the tape, acting on one cell at a time. It is programmed by a set of instructions that make it change symbols, change state, and move one cell left or right (or remain at the same cell). If an operation can be performed by using an algorithm (i.e. if it is computable), a Turing machine can do it. It was devised by Alan Turing.

turion **1.** A winter bud, covered with scale leaves and mucilage, that is produced by certain aquatic plants, such as frogbit. Turions become detached and remain dormant on the pond or lake bottom during the winter before developing into new plants the following season. **2.** *See* SUCKER.

Turner's syndrome A genetic disorder of

women caused by the absence of the second *sex chromosome (such women are XO, rather than the normal XX). It is characterized by a lack of ovaries and menstrual cycle. Affected women are sterile and lack secondary sexual characteristics, although the external genitalia are present. The syndrome is named after the US endocrinologist Henry Turner (1892–1970), who first described it.

turns ratio *See* TRANSFORMER.

turpentine An oily liquid extracted from pine resin. It contains pinene, $C_{10}H_{16}$, and other terpenes and is mainly used as a solvent.

turquoise A mineral consisting of a hydrated phosphate of aluminium and copper, $CuAl_6(PO_4)_4(OH)_8.4H_2O$, that is prized as a semiprecious stone. It crystallizes in the triclinic system and is generally blue in colour, the 'robin's egg' blue variety being the most sought after. It usually occurs in veinlets and as masses and is formed by the action of surface waters on aluminium-rich rocks. The finest specimens are obtained from Iran.

T violation *See* TIME REVERSAL.

tweeter A small loudspeaker capable of reproducing sounds of relatively high frequency, i.e. 5 kilohertz upwards. In high-fidelity equipment a tweeter is used in conjunction with a *woofer.

twinning A process in which two crystals of the same material form with orientations such that the two crystals are related to each other by a symmetry operation. This may be either reflection in a plane (the **twinning plane**) or rotation about an axis (the **twinning axis**). The plane or axis is common to the two crystals.

twins Two individuals born to the same mother at the same time. Twins can develop from the same egg (*see* IDENTICAL TWINS) or from two separately fertilized eggs (*see* FRATERNAL TWINS).

twistor A generalization of the concept of a *spinor that involves the use of complex numbers in an essential way. Twistors were invented by Roger *Penrose in the hope that they would be a key concept in unifying the general theory of relativity and quantum mechanics. It has not done so yet, although some very intriguing relations have been established between twistors and noncommutative geometry, *supergravity theory, *superstring theory, and supersymmetry. Twistors have also proved useful for finding *soliton solutions to gauge theories.

tympanic cavity *See* MIDDLE EAR.

tympanum (tympanic membrane; eardrum) The membrane that separates the *outer ear from the *middle ear. It vibrates in response to sound waves and transmits these vibrations via the *ear ossicles of the middle ear to the site of hearing (the *cochlea of the *inner ear). In amphibians and some reptiles there is no external ear and the tympanum is exposed at the skin surface.

Tyndall effect The scattering of light as it passes through a medium containing small particles. If a polychromatic beam of light is passed through a medium containing particles with diameters less than about one-twentieth of the wavelength of the light, the scattered light appears blue. This accounts for the blue appearance of tobacco smoke. At higher particle diameters, the scattered light remains polychromatic. It is named after John Tyndall (1820–93). *See also* SCATTERING OF ELECTROMAGNETIC RADIATION.

type A and B metals A classification of metal ions according to the stability of their complexes for a given ligand. **Type A metal** cations include the ions of group 1 (Li^+ to Cs^+), the ions of group 2 (Be^{2+} to Ba^{2+}), and ions of lighter transition metals in high oxidation states (e.g. Co^{3+}, Ti^{4+}, Fe^{3+}). The **type B metal** cations are those of heavier transition metals in lower oxidation states (e.g. Ag^+, Cu^+, Ni^{2+}, Pd^{2+}, Pt^{2+}). Certain ligands tend to form more stable complexes with type A metals; others form more stable complexes with type B. For example, the tendency of halide anions to complex with type A metals is in the sequence

$$F^- > Cl^- > Br^- > I^-.$$

Their tendency to complex with type B metals is the opposite sequence. This led to a classification of ligands into type A ligands (e.g. F^-), which tend to complex with type A metals, and type B ligands (e.g. I^-), which tend to complex with type B metals. The classification was introduced by Ahrland in 1958. *See also* HSAB PRINCIPLE.

type A metal *See* TYPE A AND B METALS.

type B metal *See* TYPE A AND B METALS.

type specimen The specimen used for naming and describing a *species or subspecies. If this is the original specimen col-

lected by the author who named the species it is termed a **holotype**. The type specimen is not necessarily the most characteristic representative of the species. The term **type** is also applied to any taxon selected as being representative of the rank to which it belongs. For example, the genus *Solanum* (potato) is said to be the type genus of the family Solanaceae.

typhoon A *tropical cyclone or *hurricane that occurs in the W and N Pacific Ocean and the South China Sea.

tyrosine *See* AMINO ACID.

tyrosine kinase Any of a large family of proteins that catalyse the phosphorylation of a tyrosine residue of a protein by ATP (*see* PROTEIN KINASE). They are components of numerous signalling pathways inside cells, notably ones regulating cell growth and differentiation.