Van Nostrand's SCIENTIFIC ENCYCLOPEDIA

Fifth Edition

H—Z

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HABIT. As used by the mineralogist, this term denotes the sum of the external characteristics of a mineral. It is also, but more rarely, applied to rocks.

HABITAT. Ecology.

HABIT PLANE. Many phenomena, such as twinning and martensite transformations, occur in metals where plate-like structures develop inside crystals. The crystallographic plane or planes of the parent phase parallel to the sides of these plates are called the habit plane or planes of the phenomena.

HACHURE. A short line drawn parallel to the slope as a means of illustrating topography on a map.

HACKBERRY TREES. Zelkova and Hackberry Trees.

HACKLY. A term used by mineralogists to describe a jagged fracture.

HADDOCK. Codfishes.

HADFIELD STEEL. Manganese.

HAFNIUM. Chemical element symbol Hf, at. no. 72, at. wt. 178.49, periodic table group 4b, mp $2220 \pm 10°C$, bp 5400°C, density 13.10–13.35 g/cm^3. The alpha form of elemental hafnium has a close-packed hexagonal crystal structure; the beta form, a body-centered cubic structure. Metallic hafnium, like zirconium, exhibits passivity in air due to formation of adherent coatings of oxide or nitride. Urbain reported evidence of the element in 1911, but hafnium was not fully identified until 1923 by D. Coster and G. C. de Hevesy. The remarkable similarity between hafnium and zirconium accounts mainly for its late isolation, as compared with the majority of elements. In terms of abundance, there is an average of about 4 ppm hafnium in the earth's crust. The element occurs with zirconium in certain varieties of zircon, including malacon, cyrtolite, and alvite. One mineral found in Scandanavia, thortveitite, contains more hafnium than zirconium. Pegmatite, monazite, baddeleyite, and zerkelite also contain hafnium. First ionization potential 5.5 eV. Oxidation potentials $Hf + H_2O \rightarrow HfO^{2+} + 2H^+ + 4e^-$, 1.68 V; $Hf + 4OH^- \rightarrow HfO(OH)_2 + H_2O + 4e^-$, 2.60 V. Electron configuration $1s^2 2s^2 2p^6 3s^2 4d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^2 6s^2$. Ionic radius Hf^{+4}, 0.75Å. Other important physical properties of hafnium are given under **Chemical Elements.**

Hafnium usually is extracted from ores along with zirconium. In one process, zircon sand is broken down by carbiding or carbonitriding, followed by chlorination. The mixture formed is dissolved with a complexing agent, after which it is introduced into a liquid-liquid extraction process. The final product is $HfCl_4$. Fractional crystallization of the fluorides of hafnium and zirconium also is practiced. Metallic hafnium is made by the Kroll process in which the $HfCl_4$ is reduced in an inert atmosphere by magnesium. The hafnium sponge and magnesium chloride resulting is vacuum-distilled to accomplish the final separation. In a modified Kroll process, sodium or sodium amalgam may be used. The latter requires less rigid temperature and pressure control during processing, costs less, and introduces fewer impurities into the process. For further purification of hafnium metal, a number of methods have been used, including electrorefining, arc and induction melting, zone refining, and the hot-wire or van Arkel-de Boer process.

Uses: Compared with most metals, the annual production of hafnium is low. Mainly produced in the United States, France, and the Soviet Union, the combined production is in the range of 100 tons annually, or less. Several uses have been found for hafnium: (1) as a control material in water-cooled nuclear reactors. Also hafnium is an effective flux-depressor in a reactor for absorbing neutrons to decrease the peaks in neutron flux; (2) as a filament in gas-filled incandescent light bulbs; (3) as an alloying ingredient to add strength to tungsten and molybdenum filaments and electrodes used in high-pressure discharge tubes; (4) as a cathode in x-ray tubes; (5) as a getter material in vacuum tubes and systems; (6) as a minor alloying ingredient in nichrome heating elements where hafnium appears to significantly increase the lifespan of the elements; and (7) usually with zirconium, as an ingredient of several alloys.

Chemistry and Compounds: Hafnium metal dissolves in HCl (warm) and slowly in H_2SO_4, more rapidly if fluoride ion F^- is present, forming compounds of HfO^{2+}, or fluoro complexes in the latter case. The metal resists the attack of weak acids and their salts.

Due to its $5d^2 6s^2$ electron configuration, hafnium forms tetravalent compounds readily, although the Hf^{4+} ion does not exist as such in aqueous solution except at very low pH values, the common cation being HfO^{2+} (or $Hf(OH)_2^{2+}$) and many of the tetravalent compounds are partly covalent. There are also less stable Hf(III) compounds. There is close similarity in chemical properties to those of zirconium due to the similar outer electron configuration ($4d^2 5s^2$ for zirconium) and the almost identical ionic radii (Zr^{4+} is 0.80Å) the relatively low value for Hf^{4+} being due to the Lanthanide contraction.

With improved means to separate the compounds of these two elements, future research will yield more details of specific hafnium compounds. The methods of separation used effectively include ion exchange techniques, a particularly effective one using a column of silica gel, with a solution of the tetrachlorides in methanol as feed and a 1.9 *N* HCl solution as eluant for zirconium. Separations also have been accomplished through the distillation of the phosphorus oxychloride addition products.

HAGFISHES (*Agnatha*). A jawless fish of the family *Myxinidae*, is an aggressive scavenger usually averaging less than 30 inches in length. The hagfish is characterized by the primitive features of jawless fishes—no scales, no sympathetic nervous system, a cartilage skeleton, and single nostril. The hagfish is elongate, rather wormlike, and blind. Because the fish can exude large quantities of a slimy mucus, it is sometimes called a "slime eel." The fish is equipped with sharp, triangular teeth which are effectively used to drill into valuable commercial fishes, such as cod, haddock, hake, mackerel, and flatfishes. Once inside another fish, the hagfish commences to eat and play the role of a termite. Among species of hagfishes are the Japanese *Paramyxine*, the *Eptatretus*, the Atlantic *Myxine glutinosa*, and the Pacific *Heptatretus stouti*. The latter species has been used in medical research, particularly in studies of the hag heart (no heart nerves or sympathetic nerves). Generally, hagfishes prefer cold to temperate marine waters from shallow levels down to about 3,000 feet. They cannot tolerate fresh or brackish waters.

HAIDINGER FRINGES. Optical interference fringes seen with thick, flat plates near normal incidence. The fringes of the Fabry-Perot interferometer are of this type. They are also known as constant angle or constant deviation fringes.

HAIL. Hydrometeors and Precipitation.

HAIR. There are several kinds of hair on the human body. The appearance depends on age and body location. The so-called *lanugo* is that hair which develops on the unborn child. Usually, it is shed before birth, or within the first few months after birth. The lanugo is immediately replaced by secondary hair which is fine and soft and is often called "baby hair." The coarser hair of later life is called *tertiary hair*. Hairs are continually lost from all parts of the body throughout life, and up to a certain age, those which replace them often are coarser than their predecessors.

There are about 125,000 hairs on the scalp of the average person. Darker persons usually have fewer scalp hairs than blonds. Scalp hair usually grows from 3 to 5 inches per year and, if permitted, can become as long as 2 to 3 feet, or even longer.

The hairs of the body originate from hair follicles embedded in the skin. The lower part of the follicle extends into the dermis where it is supplied with blood vessels. Generally, only one hair grows from a single follicle. That part of the hair beneath the surface of the skin is termed the *root*, while that part extending outward from the skin is called the *shaft*. The sebaceous glands of the skin have their openings in the hair follicles. These glands secrete a substance (sebum) which is responsible for the oily appearance of the skin or scalp. Persons with oily skin possess overactive sebaceous glands. When the hair follicle becomes plugged, the sebum collects within it, turns dark at the surface, and becomes a "blackhead."

Minute muscles (*erectors pilorum*) are connected to the hair follicle. When these muscles contract, they temporarily displace the entire follicle, causing the hair to "stand on end." The skin surrounding the hair is also elevated by the contraction of these muscles, giving the skin a prickled appearance, sometimes called "goose pimples." Contraction of the muscles also exerts pressure on the sebaceous glands, causing the emission of extra amounts of sebum. Thus, this set of reactions aids in protecting the body from sudden cold, the hairs forming better insulation when standing erect, and the sebum coats the skin with a further barrier against the cold.

Some skin diseases affect the condition (and existence) of the hair. See also **Alopecia.**

The structural protein of hair is keratin, which is also the protein found in wool, nails, horn, hoofs, claws, beaks and feathers. See also **Keratin.**

Hair can be an important item in identifying suspected criminals. See also **Bertillon System.**

HAIR (Abnormal Growth in Females). Hirsutism.

HAIR HYGROMETER. Hygrometer.

HAIR (Identification). Bertillon System.

HAIRSTREAK (*Insecta, Lepidoptera*). Small butterflies, those of the temperate zone dull-colored and those of the tropics often brilliant. The hind wings of most species bear hairlike tails. With the coppers and blues they make up the family *Lycaenidae*.

HAIRTAILS. Cutlass Fishes and Hairtails.

HAIRWORM (*Nematomorpha* or *Gordiacea*; formerly placed in the phylum Nemathelminthes with the *Nematoda*). Long slender roundworms of small size, which live as parasites in the bodies of invertebrates, chiefly insects.

HAKES. Codfishes.

HALF-ADDER (Computer System). A circuit having two output points, S and C, representing sum and carry, and two input points, A and B, representing sum and carry, and two input points, A and B, representing addend and augend, such that the output is related to the input according to the following table:

INPUT		OUTPUT	
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

A and B are arbitrary input pulses, and S and C are sum without carry and carry, respectively. Two half-adders, properly connected, may be used for performing binary addition and form a full serial adder.

See also terms listed under **Data Processing.**

HALF-CELL. An electrochemical system consisting of a single electrode and an electrolytic solution, with usually a (reversible) ionization process in progress between electrode and electrolyte. See also **Galvanic Cell.**

HALF-LIFE (Biological). The time of survival of half the individual members of an unstable system. The half-life $t_{1/2}$ of the system is related to the decay constant λ and the mean life τ by the relation:

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} = 0.693\tau$$

The term half-life is most commonly applied to systems of radionuclides but may also be applied to other systems that decay.

The biological half-life of a substance is the time in which a living tissue, organ or individual eliminates, through biological processes, one-half of a given amount of a substance which has been introduced into it. The effective half-life is a term usually applied to a radioactive substance in a biological organism. It is defined in terms of the half-life of the radioactive substance itself, and its biological half-life in the organism, by the following expression:

$$\text{effective half-life} = \frac{\text{radioactive half-life} \times \text{biological half-life}}{\text{radioactive half-life} + \text{biological half-life}}$$

HALF-LIFE (Elements). Chemical Elements.

HALF-SHADE PLATE. A semicircular, half-wave plate of quartz set between the polarizer and analyzer and close to the former. Useful in making precision settings with a polariscope.

HALF-SILVERED SURFACE. A surface coated with a metallic film of such thickness that it transmits approximately half of the light falling on it at normal incidence and reflects approximately half.

HALF-THICKNESS (Absorber). The thickness of a particular absorber that will reduce the intensity of a beam of radiation to one-half its initial value. If the absorption is exponential, the half-thickness is related to the linear or mass absorption coefficient and the mean free path as follows:

$$d_{1/2} = \frac{\ln 2}{\mu} = \frac{0.693}{\mu} = 0.693l$$

where $d_{1/2}$ is the half-thickness, μ is the absorption coefficient and l is the mean free path.

HALFWIDTH OF A SPECTRAL LINE. The intensity within a spectral line may be expressed as $I(x)$, where x is a measure of wavelength, frequency or wave number, and where $I(x)\,dx$ is a measure of the contribution to the intensity between x and $x + dx$. The halfwidth of the line is the halfwidth of the function $I(x)$.

HALIBUT. Flatfishes.

HALIDES. A compound made up of a halogen (astatine, bromine, chlorine, fluorine, or iodine) and another element or radical may be termed a *halide*. Fundamentally, there are three classes: (1) the *ionic* (saline) halides, (2) the *covalent* (acid) halides, and (3) the *complex* halides. The ionic halides are most sharply characterized by the halides of the alkali and alkaline earth metals, plus those of certain Lanthanide and Actinide metals. They form ionic or semi-ionic crystals in the solid state, have high boiling points and melting points, and are soluble in polar solvents. Their bonding is electrovalent, varying in degree with the difference between the electronegativities of the halogen and the metal. Potassium iodide and silver fluoride are ionic, but silver iodide is essentially covalent. The fluorides exhibit a primarily ionic character for most of the metals, but the other halogens form fewer ionic compounds. The degree of ionicity varies down as well as across the periodic table.

The covalent (acid) halides have low boiling and melting points, are soluble in nonpolar solvents and insoluble in polar solvents, although they often react with the latter. The degree of covalence generally is greatest for the nonmetals. For a given nonmetal, the boiling point depends upon both the number of atoms of the halogen with which it is combined and the symmetry of the molecule. For example, the boiling points of bromine(I) fluoride, bromine(III) trifluoride, and bromine(V) pentafluoride, BrF, BrF_3 and BrF_5, are 20, 135, and 40.5°C, respectively.

The complex halides are very numerous, because of the readiness with which halide ions form coordination compounds with metals. In general, stability of these complexes depends upon the size and electronic structure of the metal ion—the smaller cations form their more stable compounds with the smaller halide ions, notably with fluoride, while with larger cations the order of stability is that of polarizability of the halide, i.e., decreasing from iodide to fluoride. The more electronegative transition elements form especially stable complexes; e.g., those of palladium, platinum, etc., $PdCl_4^{2-}$, PtF_6^{2-}, etc. The most common halo complexes have four or six halogen ions coordinated with the cation, although such complexes as those of copper, gold and mercury, e.g., CuI_2^-, $AuCl_2^-$, $HgCl_3^-$, etc., are notable exceptions.

See also **Bromine; Carbon; Chlorine; Chlorine Organics; Fluorine; Iodine.**

HALITE (Rock Salt). The mineral halite (rock salt) is naturally occurring sodium chloride, NaCl, common salt. It is isometric with cubic habit and cleavage. It is brittle; hardness, 2.5; specific gravity, 2.4–2.6; luster, vitreous; colorless when pure, but usually white, yellow, red, or blue. It is soluble. Halite occurs interbedded with sedimentary rocks in all parts of the world and in all but the very oldest rocks. It frequently occurs in association with anhydrite and gypsum. In the United States this type of "salt beds" has been exploited in Michigan, New York, Ohio, and Pennsylvania. Louisiana produces salt from great subsurface dome-shaped masses, often 2,000–4,000 feet thick. The salt domes of the Gulf Coastal Plain are particularly important as subsurface structures, on the flanks of which are apt to occur large and important pools of petroleum. Poland, Saxony, Austria, and France possess well-known deposits of salt, as well as the U.S.S.R., England, Algeria, India, and China. Salt is chiefly used in cooking and as a preservative; in the manufacture of soda ash for the glass industry; and as a source of many sodium compounds. It derives its name from the halogen group of elements to which chlorine belongs.

See also **Sodium Chloride.**

HALL EFFECT. In 1879, Hall, at Johns Hopkins University, discovered that if a strip of gold leaf, carrying an electric current longitudinally, was placed in a magnetic field with the plane of the strip perpendicular to the direction of the field, the points directly opposite each other on the edges of the strip acquired different electric potentials; and that if such points were joined through a sensitive galvanometer, a feeble current would be indicated. In other words, the equipotential lines, ordinarily running across at right angles to the edges, were skewed into an oblique position, and the electric lines of flow in the plane of the strip were deflected to one side.

If one looks along the strip in the direction of the current, with the magnetic field directed downward, then, with strips of antimony, cobalt, zinc, or iron, the electric potential drop is toward the right and the effect is said to be positive; while with gold, silver, platinum, nickel, bismuth, copper, and aluminum, it is toward the left, and the effect is called negative. The transverse electric potential gradient per unit magnetic field intensity per unit current density is called the "Hall coefficient" for the metal in question. Thus, the Hall coefficient R_H is defined as

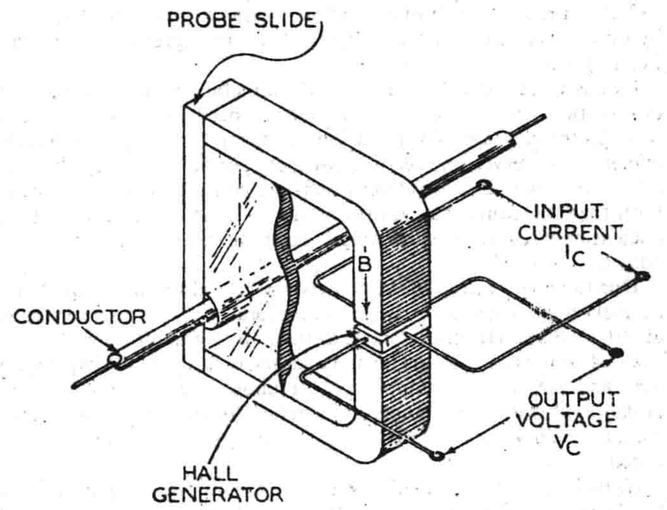
$$R_H = \frac{E_y}{j_x H_z}$$

where E_y is the electric field developed in the y direction when a current of current density j_x flows in the x direction through a magnetic field H_z in the z direction. According to the free electron theory of metals, the Hall coefficient should be given by

$$R_H = \frac{1}{Nce}$$

where N is the number of free electrons per unit volume, of charge e (in esu), and c is the velocity of light. The observed result that for some metals the carriers would seem to have positive charges is explained by the band theory of solids. In a nearly filled band, the wave functions of the electrons near the top of the band are so modified that it is the holes in the band that behave like particles. Since a hole represents the absence of negative charge, it behaves as if positively charged. The Hall angle is the ratio of E_y (defined above) to the field E_x, generating the current in the magnetic field H_z. The Hall mobility is the mobility of the electrons or holes in a semiconductor as measured by the Hall effect.

A number of transducers utilize the Hall effect. Shown in the accompanying diagram is a direct-current oscilloscope probe based



Direct-current oscilloscope probe based on Hall effect. (*Tektronix, Inc.*)

on the effect. A steady direct current I_c is applied to one axis of the Hall generator and a magnetic field B, proportional to the current through the conductor, is applied to a second axis. An output voltage V_c is taken across the third axis of the Hall generator. The output voltage can be calculated from:

$$V_c = \frac{10^{-5} R_H}{t} I_c B$$

where

V_c = Hall voltage, volts
R_H = Hall coefficient, cm³/coulomb
t = thickness, cm
B = magnetic field density, kilogauss

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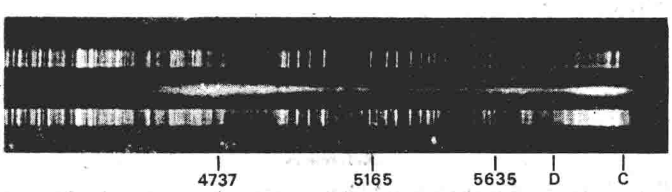
HÄLLEFLINTA. A Swedish term for hard, dense, metamorphic rocks composed chiefly of microscopic crystals of quartz and feldspar with occasional phenocrysts. Accessory minerals may be hornblende, chlorite, hematite or magnetite. The texture and composition of hälleflinta suggests that it is the metamorphosed equivalent of acid lava flows or tuffs.

HALLEY'S COMET. Probably the most famous of all the comets, and one that is especially interesting because of the fact that it was the first comet whose return was predicted. When Halley computed the orbit of the great comet observed in 1682, he found the elements to be almost identical with those of the prominent comets observed and studied by Kepler in 1607 and by Apian in 1531. He noticed that the interval between 1531 and 1607 was not exactly equal to the interval between 1607 and 1682, but suspected that the difference might be due to attractions by other planets. He was unable to predict just what effects the attractions of Jupiter might produce on the next return, but suspecting that they would retard it, he forecasted the return for the early part of 1759. In the meantime, mathematical astronomy had developed to such a point that Clairaut was able to predict the time of return as April, 1759. The comet actually came to perihelion on March 13th of that year. At the next return, in 1835, the predicted date of perihelion differed from the observed date by only 2 days, and for the return in 1910, the agreement was practically perfect.

Extensive calculations made by Crommelin and Cowell after the observations in 1910 carried the dates of perihelion passages back through the centuries. Examination of ancient records prove that the comet was observed and recorded at every perihelion passage back to 87 B.C. In some cases, the descriptions are complete enough to prove both that the comet has always been a striking object and that the ancient records were surprisingly accurate as to position of the comet.

Due to perturbations of the planets, the periods between successive perihelion passages have varied considerably, with an average of about 77 years. Historians have, at times, attempted to use observations of comets as a means for fixing dates, employing the hypothesis that any bright comet appearing at about the correct date was Halley's. This is a very dangerous practice, for there have been many comets as striking as Halley's, and their appearances were always noted.

At its return in 1910, Halley's comet was first picked up by Wolf at Heidelberg, on September 11, 1909, when it was 5×10^8 kilometers from the sun, and was followed photographically until July 1, 1911, when it was 8.3×10^8 kilometers from the sun. When close to perihelion, it was a magnificent object, particularly during the early part of May, when it was observed in the morning sky. On May 19th, about a month after perihelion passage, the comet passed directly between the earth and the sun, but no change in the brightness of the sun could be observed, even with the most delicate instruments. At one time, the tail of the comet extended across the sky for a distance of nearly 120°, appearing as a broad bright band much like the Milky Way. On May 21st, the earth was certainly grazed by the tail of the comet and probably passed through it.

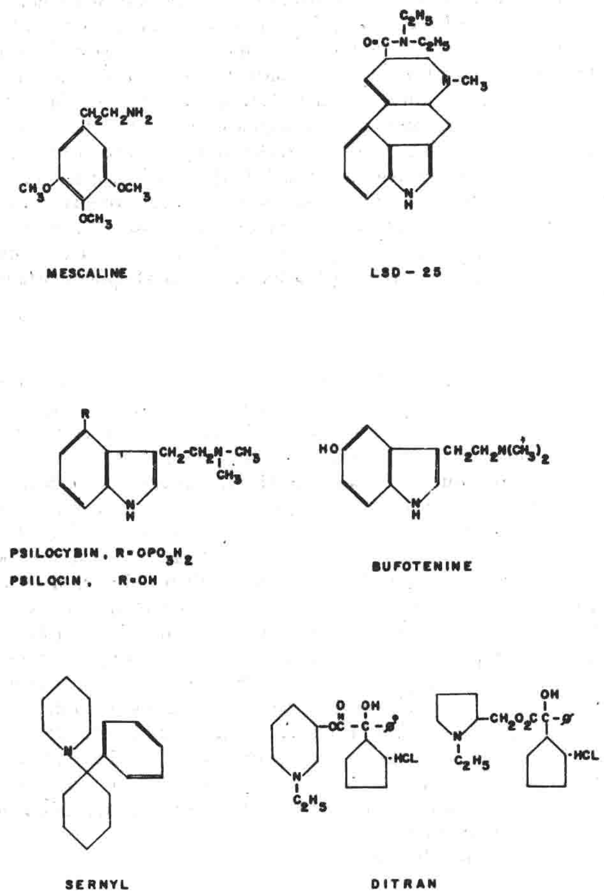


Spectrum of Halley's Comet, May 23, 1910. The bright-line spectrum shows the carbon bands, indicated by their wavelengths, and the D line of sodium, which lasted only a few days. In the spectrum of sunlight reflected by the comet's head, the dark Fraunhofer lines C and F are prominent. A comparison spectrum appears above and below. (*Lowell Observatory photograph*)

In 1949, the comet reached its greatest distance from the sun, being at that time more distant than the planet Neptune. It should return to perihelion on April 29, 1986.

HALLUCINOGENS. There are many substances which will, if taken in appropriate quantities, produce distortion of perception, vivid images, or hallucinations. Most of these substances will produce powerful peripheral as well as the central effects. Some few agents are characterized by the predominance of their actions on mental and psychic functions. This group of drugs has been called hallucinogens, psychotomimetics, psycholytics, and psychodelics, among several ambiguous terms. None of these names is adequately descriptive of these compounds.

Hallucinogens may be classified into five groups of chemically distinct compounds: (1) lysergic acid derivatives of which lysergic acid diethylamide (LSD-25) is the prototype; (2) phenylethylamines, such as mescaline; (3) indolealkylamines, which include psilocybin, psilocin, and bufotenin; (4) piperidyl benzilate esters, typified by Ditran (a 70 : 30 mixture of N-ethyl-2-pyrrolidymethyl phenylcyclopentylglycolate and N-ethyl-3-piperidyl phenylcyclopentylglycolate), and (5) phenylcyclohexyl piperidines (Sernyl). The chemical structures of these compounds is shown in the accompanying figure.



Structures of some hallucinogenic drugs.

Drugs from the first three groups have been isolated from naturally-occurring sources. LSD-25 is a molecular component of ergot, a fungus which infects cereal grains. Mescaline, historically the oldest hallucinogen, was isolated from a Mexican peyote cactus. Psilocybin and psilocin were isolated by A. Hoffman from the Mexican mushroom, *Psilocybe mexicana*. Bufotenin is found in some varieties of toadstools. The indole derivatives are chemically closely related to serotonin (5-hydroxytryptamine), a compound which plays an important, yet unknown role in the central nervous system.

The piperidyl benzilate esters and phenylcyclohexyl piperidines are synthetic compounds, and have not been shown to occur naturally. Some authorities do not consider them to be hallucinogens, but active researchers in the field include them among the most active psychotomimetics.

Clinical syndromes from LSD-25, mescaline, and the indoleamines are similar. Somatic symptoms are nausea, dizziness, loss of appetite, blurred vision, paresthesia, weakness, drowsiness, and trembling. These result frequently and are usually associated with sympathomimetic effects, such as increased pulse rate and slight temperature elevation. Perceptual and psychic changes are marked. Visual illusions and vivid hallucinations, decreased concentration, slow thinking, depersonalization, dreamy states, changes in mood, and often anxiety are commonly found.

The clinical syndromes from Ditran are different from those produced by the aforementioned drugs in some respects. Disorganization of thought, disorientation, confusion, mood changes, and visual and auditory hallucinations are observed. The piperidyl benzilate esters are central anticholinergics, and mental states produced by them are reminiscent of those from other anticholinergics, such as scopolamine.

The effects of phenylcyclohexyl derivatives are also distinctive. Comparatively minor somatic symptoms are evoked. Psychic effects predominate, being typically characterized by feelings of unreality, depression, anxiety, and delusional or illusional experiences. The effects of these drugs are said to be more analogous to natural psychoses than those of the other drugs; however, the same claim has been made for Ditran.

When LSD-25 was discovered by A. Hoffman, it was believed that the drug would provide an extremely useful tool in the investigation of psychoses and mental illness. However, therapeutically, the hallucinogens, including LSD-25, have been of little value to psychiatrists.

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HALO. **Atmospheric Optical Phenomena.**

HALOGENATED COMPOUNDS. **Chlorine Organics; Organic Chemistry.**

HALOGEN GROUP (The). The elements of group 7a of the periodic classification sometimes are referred to as the Halogen Group. The individual elements commonly are called *halogens*. In order of increasing atomic number, they are fluorine, chlorine, bromine, iodine, and astatine. The elements of this group are characterized by the presence of seven electrons in an outer shell, and hence have the ability to gain an electron to form negative ions with a completed octet of valence electrons. The halogens present striking similarities of chemical behavior, all being very reactive and, in particular, readily form substitution compounds with numerous organic compounds. Although these elements also have other valences all have a -1 valence in common.

HALOGENS (Budde Effect). **Budde Effect.**

HALOTHANE. **Anesthesia.**

HALTERE. The vestigial hind wing of a 2-winged fly. In this order the 2-winged condition is due to the loss of the hind wings as organs of flight. They persist, however, as small knobbed organs, in some species large enough to be seen with the naked eye just behind the bases of the functional wings. They contain sense organs, and both static and chordotonal functions have been attributed to them. The evidence seems inconclusive.

HALYS (*Reptilia, Sauria*). Asiatic vipers of several species, related to the copperhead and water moccasin of North America. One small species of Ceylon and India is called the carawila.

HAMMER FORGING. **Iron Metals, Alloys, and Steels; Forging.**

HAMMERHEAD SHARKS. **Sharks.**

HAMMER MILL. **Crushing (Size Reduction).**

HAMMETT ACIDITY FUNCTION. The function

$$H_0 = pK_{BH^+} - \log(C_{BH^+}/C_B)$$

where C_B is the concentration of an indicator C_{BH^+} is the concentration of its protonated form, of which K_{BH^+} is the ionization constant.

HAMILTONIAN (or Hamiltonian Function of a System). Generally denoted by the symbol H, the Hamiltonian is defined by the equation

$$H(q_k, p_k, t) = -L(q_k, p_k, t) + \sum_{l=1}^{3n} p_l \dot{q}_l(q_k, p_k, t)$$

L is the Lagrangian function of the system, expressed as a function of the coordinates, momenta and time. $\dot{q}_l$ stands for the generalized velocities, also expressed as functions of the coordinates, momenta and time, where q are the coordinates of position, p, those of momentum, and the dot means the derivative with respect to time. n is the number of particles of the system. If the time does not occur explicitly, the system is called conservative, and H is identical with the total energy of the system. See also terms listed under **Mathematics.**

HAMSTER. **Rodentia.**

HAND. The terminal portion of the pectoral appendage of mammals, developed for grasping and in some species largely freed from locomotor uses. True hands appear only in the primates.

The skeletal structure of the hand includes the series of five bones, the metacarpals, which attach it to the wrist, and the five divergent series of phalanges located in the digits. Of the digits, one, the thumb, is placed and articulated so that it can be opposed to the other four, which are fingers. As a result, the appendage can be used for grasping like a forceps, and also as a prehensile organ by folding the fingers back against the palm. In some of the monkeys, the prehensile method of grasping is more important in moving through the trees, and the thumb has shifted and become smaller so that it can no longer be opposed.

The human hand is the most versatile grasping organ in the animal kingdom.

HANDEDNESS (Right- and Left-). Defined in terms of the motion of a screw. A *right-handed* screw, when rotated in the sense of Fig. 1(a) (counterclockwise looking down at the page), will move out of the page; when rotated in the sense of Fig. 1(b), a right-handed

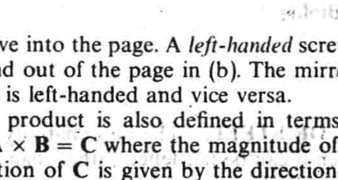


Fig. 1. Screw rotations.

screw will move into the page. A *left-handed* screw will move into the page in (a) and out of the page in (b). The mirror image of a right-handed screw is left-handed and vice versa.

The vector product is also defined in terms of a right-handed screw. Thus $\mathbf{A} \times \mathbf{B} = \mathbf{C}$ where the magnitude of $\mathbf{C}$ is $|\mathbf{A}|\,|\mathbf{B}| \sin\theta$, and the direction of $\mathbf{C}$ is given by the direction of progression of a right-handed screw rotating in the sense of rotating $\mathbf{A}$ into $\mathbf{B}$ through the smaller angle (θ). $\mathbf{C}$ is thus a vector pointing into the page in Fig. 2.

Coordinate systems are also classed as right or left handed. In Fig. 3, coordinate system (a) is right-handed, since rotation of the unit vector $\mathbf{i}$ into the unit vector $\mathbf{j}$ would make a right-handed screw progress in the direction of $\mathbf{k}$, $\mathbf{i} \times \mathbf{j} = \mathbf{k}$ and also $\mathbf{j} \times \mathbf{k} = \mathbf{i}$, $\mathbf{k} \times \mathbf{i} = \mathbf{j}$. Thus in a right-handed coordinate system, the above cyclic relations

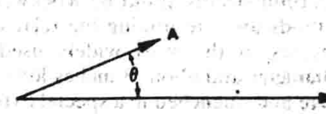


Fig. 2. Vector product.

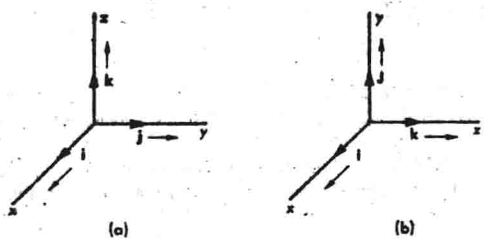


Fig. 3. Coordinate system.

among the unit vectors hold. Coordinate system (b), on the other hand, is left-handed, i.e., it would take a left-handed screw to carry the unit vectors into each other in cyclic order of vector multiplication.

Circular polarization of electromagnetic waves is described as right-handed or left-handed depending on whether the direction of rotation of the electric vector and the direction of progression of the electromagnetic wave are related to a right-handed or a left-handed screw.

HANDSET. This is the part of the modern telephone which contains the transmitter and receiver, i.e., the part which the user holds when talking. While this placing of the transmitter and receiver on the same handle seems a rather insignificant accomplishment, the necessity of avoiding feedback from the receiver into the transmitter makes very careful acoustical design necessary. In addition the electrical and mechanical construction of the transmitter must be such that it can be operated in almost any position as the user will hold the instrument in innumerable positions.

HANGING VALLEY. Under normal conditions a tributary stream enters the main stream at grade, that is, at the same level. Under certain circumstances the tributary valley may be at a greater elevation than the main valley into which the tributary stream will plunge, forming a waterfall. In such cases the tributary valley is called a hanging valley, and the stream in it is said to be out of adjustment with the main stream.

Hanging valleys originate in the following ways: by glacial action, the main glacier cutting down its valley faster than a tributary glacier; by river action, the main stream eroding its bed faster than the tributary stream; by faulting, the tributary stream flowing off the upthrown block. A fourth type of hanging valley, much less common, may result from a stream plunging over wave-cut cliffs or other escarpments into a lake or ocean basin.

HANKEL FUNCTION. **Mathieu Equation.**

HANTZSCH-WIDMAN NAME. **Organic Chemistry.**

HAPLOID. **Cell (Biology).**

HAPLOMI. **Fishes.**

HARDENABILITY OF STEEL. The hardenability of steel refers to the ease with which it can be hardened rather than the maximum hardness value attainable. For example, a 1-inch diameter bar of a certain 0.20% carbon alloy steel can be hardened to 50 Rockwell "C" in the center by quenching in oil. A similar bar of plain carbon steel requires a drastic quench in brine to attain the same hardness, and therefore, has a lower hardenability. Neither bar can be quenched to a greater hardness because 50 Rockwell "C" is the maximum attainable for a 0.20% carbon steel. A 0.40% carbon steel can be hardened to a maximum of about 60 Rockwell "C" and the maximum for high-carbon steel is about 65 Rockwell "C."

Of the several methods for determining the relative hardenability of steels, the Jominy test is the most widely used. A cylindrical specimen 1 inch in diameter and about 3 inches long is heated to the hardening temperature and quenched in a special fixture which holds the specimen in a vertical position and directs a stream of water on the bottom surface. The stream takes an "umbrella" shape and does not wet the sides. Cooling occurs progressively from the bottom to the top of the cylinder and the cooling rate at any distance from the bottom is known and reproducible from one sample to another. The hardness along the length of a quenched Jominy bar decreases from bottom to top. The distance from the bottom, expressed in sixteenths of an inch, to the point where the hardness is 50 Rockwell "C" is one method of reporting the hardenability.

One of the principal functions of alloying elements in steel, such as manganese, chromium, nickel, molybdenum, etc., is to increase the hardenability. Whereas prodigious amounts of expensive alloys were formerly used to insure full hardening, especially in medium and heavy sections, wartime shortages focused attention on the use of as little alloy as possible within the hardenability requirements. A large number of steels were developed containing relatively small additions of a number of elements, and a number of these steels have continued in use.

HARDENING OF METALS. There are three principal methods of hardening metals and alloys: cold working by (see **Cold-Worked Metal**) plastic deformation, precipitation hardening, and quench hardening as applied to steel. The last two methods involve heating and cooling operations. A pure metal may also be hardened through the addition of alloying elements. When a solid solution is formed it is normally harder than the pure metal. If additional phases are formed by alloying, these may also be harder than the pure metal and contribute to the hardness of the metal.

HARDENING OF THE ARTERIES. **Arteriosclerosis.**

HARDENING (Precipitation). **Precipitation Hardening.**

HARD FACING. Deposition of a hard wear-resistant alloy on a metal surface. The material to be deposited is generally in the form of a welding rod and may be applied by gas or arc welding. Such surfaces are usually finished by grinding.

While hard facing or hard surfacing is usually a maintenance operation, it is also used in new production. The surfacing material may be cemented carbides, nonferrous Stellite-type alloys, or iron-base alloys with alloying additions such as chromium, tungsten, manganese, silicon, nickel, and carbon. While hard facing is most often applied to steel, cast iron and some of the nonferrous alloys such as Monel metal can also be coated. Typical applications are metal-working dies, oil well drilling tools, excavating equipment, shafting, and rolling mill rolls.

HARDGROVE GRINDABILITY. **Coal.**

HARDNESS. The significance of this term as applied to solids has various interpretations. Commonly, it refers to the resistance of the substance to surface abrasion, so that of two solids, the one that will scratch the other, as diamond scratches glass, is the harder. Again, it may denote rigidity, or lack of plasticity, or even strength; in some cases a combination of several such properties. The original Mohs' Scale of Hardness is delineated in Table 1 and further described under **Mineralogy.**

In metallurgy and engineering, hardness is determined by methods based on resistance to penetration by an indenter of greater hardness than the material being tested. Aluminum, copper, lead, magnesium, tin, and their alloys, as well as plastics are generally indented by hardened steel balls ranging in size in the various tests from $\frac{1}{16}$ inch to 10 millimeters in diameter. The same methods may be used for soft steels and irons, but for heat-treated steels and all other alloys which develop high hardness special diamond indenters, or in some cases sintered tungsten carbide balls, are used. In all of the technological tests, the indenters are impressed into the test material under carefully regulated loads; thus, the relative size of the resulting indentation becomes a measure of hardness. (See Table 2.) The operating principles of the instruments most widely used in this country follow:

Brinell. The indenter is a 10-millimeter diameter hardened steel ball. A sintered tungsten-carbide ball is also coming into use, especially for testing hard metals. The load applied is generally 500

TABLE 1. HARDNESS SCALES

Mohs' Scale	Ridgway's Extension of Mohs' Scale	Metal Equivalent	Others
1. Talc			
2. Gypsum			
			2.5. Finger Nail
3. Calcite			
4. Fluorite			
5. Apatite			
			5.5. Window Glass
6. Feldspar (Orthoclase)	6. Orthoclase or Periclase		
			6.5. Steel (Knife Blade; File)
7. Quartz	7. Vitreous Pure Silica		
8. Topaz	8. Quartz	8. Stellite	
9. Corundum or Sapphire	9. Garnet		
	10. Topaz		
	11. Fused Zirconia	11. Tantalum Carbide	
	12. Fused Alumina	12. Tungsten Carbide	
	13. Silicon Carbide		
	14. Boron Carbide		
10. Diamond	15. Diamond		

1. In the above scales each abrasive is capable of scratching all others above it in each scale and may be scratched by all abrasives below it.

2. The gap between 9 and 10 in the original Mohs' scale is much greater than that between 1 and 9 in the same scale.

3. Various additional hardness scales have been devised by different investigators; in general, different materials maintain the same order of hardness in all these scales.

kilograms for soft metals and 3,000 kilograms for steels and hard metals. Brinell hardness is equal to the load (kilogram) divided by the surface area (square millimeter) of the impression made in the test material. Tables are available for direct conversion to hardness from the diameter of the indentation as measured with a calibrated magnifier after removal of the piece from the testing machine.

Rockwell. Indenter is $\frac{1}{16}$-, $\frac{1}{8}$-, or $\frac{1}{4}$-inch-diameter steel ball or a conical diamond having an apex angle of 120° and a slightly rounded point. The various scales used are designated by letters. Rockwell "B," for example, indicates a 100-kilogram load on a $\frac{1}{16}$-inch diameter ball. Rockwell "C" indicates a 150-kilogram load on the diamond indenter. Rockwell "30T" designates a load of 30 kilograms on a $\frac{1}{16}$-inch diameter ball. (An instrument of higher sensitivity known as the Rockwell Superficial Tester is used for loads of 15, 30, and 45 kilograms.) The size of the indentation is measured by a dial gauge as the final depth minus a small preliminary penetration produced by a minor preload of 10 kilograms. The Rockwell hardness values are arbitrary numbers having an inverse relationship to the depth of the indentation.

Vickers. Also known as Diamond Pyramid Hardness. Indenter is a square-based diamond pyramid with included angle between faces of 136°. Loads may vary from 1 to 120 kilograms with 10, 30, and 50 kilograms in common use. Hardness is equal to load (kilograms) divided by surface area (square millimeter) of the permanent indentation. It is determined directly from optical measurements of the diagonals of the indentation which appears square at the surface of the metal.

Tukon. A highly sensitive instrument for determining hardness under very light loads down to 25 grams. The small indentations are measured at high magnifications up to 1,000 times. The indenter is a diamond pyramid that makes an elongated impression, one diagonal being 7 times the other in length.

TABLE 2. TYPICAL HARDNESS VALUES

Material	Brinell 500 kg	Brinell 3000 kg	Rockwell	Vickers 50 kg
Aluminum, annealed	23		H 45	25
Magnesium alloy	63		B 21	63
Armco iron	66	73	B 31	71
Yellow brass, annealed	72	82	B 40	77
Copper, cold rolled	99	83	B 55	110
Mild steel, annealed	107	117	B 70	123
Aluminum alloy, 24st	130	144	B 78	146
Stainless steel, annealed	121	145	B 80	153
Yellow brass, cold rolled	174	178	B 91	189
Ni-Moly steel, quenched in water, tempered at 1200 F		241	C 23	255
Same, 1000 F		293	C 31	310
Same, 800 F		363	C 38	380
High-speed tool steel		684	C 62	740

Eberbach. Also used for very light loads. Consists of a spring-loaded, Vickers-type diamond pyramid indenter arranged for use on a metallurgical microscope.

Scleroscope. Depends on the height of rebound of a diamond-tipped body falling under the force of gravity from a fixed height. The instrument is relatively small and is portable. One type reads directly on a graduated dial.

While there is overlapping in the field of useful application of the various hardness tests, each has certain special qualifications. The Brinell test makes a large indentation, giving an average hardness value for several grains even in rather coarse-grained metals; however, it cannot be used on small or thin specimens. The various **Rockwell** tests are widely used, especially for rapid production inspection of parts. The Vickers test, which originated in England, is less rapid than the Rockwell but has the advantage of a single scale covering the hardness of all metals from lead to the hardest tool materials. The Tukon test makes it possible to determine the hardness of very thin sheets and of thin metallic coatings such as chromium plate, or zinc on galvanized steel. The Scleroscope test is used principally on heavy forgings or castings which cannot be placed in an indentation-type instrument, or for field tests where a portable instrument is required.

HARDNESS (Mineral). Mineralogy.

HARDNESS (Water). Feedwater (Boiler); Water Softening.

HARDPAN. The term which prospectors and miners give to the subsurface or basal layers of placer deposits in which the gold-bearing gravels have been cemented and hardened. The same term is also used to designate till or boulder clay which has been cemented by limonite.

HARDWARE (Computer System). The physical equipment or devices forming a computer and peripheral equipment. This is contrasted with the program, generally termed *software*. See also **Software (Computer System).**

HARDWOODS. Wood.

HARE. Rabbits and Hares.

HARELIP. A congenital deformity in which there is a failure of fusion of the maxillary and median nasal processes, resulting in a cleft in the upper lip. This is part of the same defect associated with cleft palate. In some cases, the harelip may be double, in which case there is a division on either side of the mid-line of the lip. Correction of the deformity must be by surgery, and this is best accomplished at a very early age. Usually, correction of the slip is done first, thus enabling the infant to suck. Surgery on the palate normally is undertaken just as soon as there is sufficient tissue to cover over the bony palate after repair. This usually occurs at the age of 18 to 24 months, well before abnormal speech habits are formed. In some cases, the operation must be performed in several stages. Cosmetically and functionally, the surgical results usually are excellent.

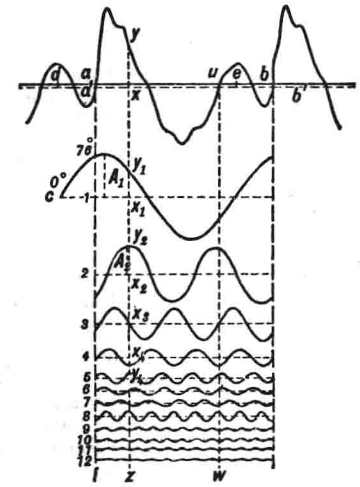
HARMONIC. A sinusoidal frequency component of a waveform. The harmonic has a frequency that is an integral multiple of the fundamental frequency. The frequency of the second harmonic will be double that of the fundamental frequency (first harmonic).

Harmonic distortion is nonlinear distortion characterized by the appearance in the output of harmonics other than the fundamental component when the input wave is sinusoidal. Harmonic distortion is sometimes called amplitude distortion.

HARMONIC ANALYSIS. Not only is it possible to combine two or more simple harmonic motions of different period, amplitude, and phase to form a complex motion, but there are also means of analyzing the resultant motion, when the latter is given, to find its component harmonics. For example, if the wave form of such a complex tone as that produced by a bell or a saxophone is accurately graphed by means of a phonodeik the equation of the vibratory motion can be deduced in such form as to show the separate components. Fourier showed that the same analysis is possible for any periodic motion, however complicated. The equation, called Fourier's series, may be written

$$y = a \sin 2\pi nt + b \cos 2\pi nt + c \sin 4\pi nt + d \cos 4\pi nt + e \sin 6\pi nt + f \cos 6\pi nt + \cdots$$

in which y is the displacement of the vibrating particle and t is the time. The fundamental frequency n and the constants a, b, c, d, etc., must be calculated from the given wave form or the data from which it is plotted. There is a type of instrument, called a "harmonic analyzer," which automatically computes the coefficients; or it may be done mathematically, though the process is very laborious. The accompanying figure shows the wave form and the twelve components of complex tone, analyzed by Professor D. C. Miller.



Records of a complex sound and twelve of its components.

See also **Musical Sound.**

HARMONIC MEAN. Average.

HARMONIC MOTION. A distinct type of periodic motion, or vibration, characteristic of elastic bodies; illustrated by a bird-cage bobbing up and down at the end of a spiral spring, or (approximately) by the piston of the steam engine. It may be either simple, with only one frequency and amplitude, or made up of two or more simple components and consequently of more complex character. The essential feature of simple harmonic motion is that, with its range extending to equal distances on both sides of an equilibrium position or origin, the acceleration is always toward the origin and directly proportional to the distance from it. With elastic vibrations this is easily seen to follow from Hooke's law, since the force tending to restore the deformed body to equilibrium is proportional to the deformation. See **Elasticity.** The motion is called "harmonic" undoubtedly because the vibrations of bodies emitting musical sounds are of this character. Any simple harmonic motion may be represented by the equation

$$y = a \cos(2\pi nt + \phi)$$

in which y is the distance at time, t, a is the amplitude, n is the frequency or number of vibrations per unit time, and ϕ is the phase constant, such that when $t = 0$, $y = a \cos \phi$.

It is interesting to note the relationship between harmonic and circular motion. If a peg is inserted in the face of a circular disk or wheel and the latter uniformly rotated, the motion of the peg, as viewed with the wheel seen edgewise, is simple harmonic. In fact, uniform circular motion is made up of two simple harmonic components of the same period and amplitude at right angles, one being a quarter-period ahead of the other in phase. If the two harmonic components have a phase difference other than a quarter-period, the resultant in general is motion in an ellipse; while if they have unequal periods, the path is one of a class of more or less complicated loci called "Lissajous' curves."

HARMONIC OPERATION. *Impeded* harmonic operation is constrained magnetization or forced magnetization. It is the type of operation which takes place in a magnetic amplifier in which the impedance of the control circuit and any circuit closely coupled to it is so great as to substantially prevent the flow of all harmonic currents in such circuits.

Unimpeded harmonic operation is natural magnetization or free magnetization. It is the type of operation that takes place in a magnetic amplifier in which the impedance of the control circuit or any circuit closely coupled to it is so small as to permit substantially unimpeded flow of all harmonic currents in such circuit.

See also **Amplifier.**

HARMONIC PROGRESSION. **Progression.**

HARMONIC SYNTHESIZER. A machine which combines elementary harmonic constituents into a single periodic function. A machine performing the opposite function is called a harmonic analyzer.

HARMOTOME. The mineral harmotome is a zeolite, composition approximately (Ba, K)(Al, Si)$_2$Si$_6$O$_{16}$·6H$_2$O; it is monoclinic but often forms double twins giving the effect of a square prism. It is a brittle mineral; hardness, 4.5; specific gravity, 2.44–2.50; luster, vitreous; color, white to gray or perhaps yellow, red or brown; white streak; translucent. Harmotome like other zeolites is found in cavities in basalts and similar rocks, sometimes in trachytes or in gneisses, occasionally as a gangue mineral in veins of metallic minerals. Some well-known localities are in Bavaria; the Harz Mountains; Norway; and Scotland. Harmotome occurs in the United States with stilbite, near Port Arthur, Lake Superior. The name harmotome comes from the Greek meaning joint and to cut, referring to the division of the pyramid formed by the prismatic faces of the mineral when in the twinned position.

HARPY. **Eagle.**

HARRIER. **Eagle.**

HARTEBEEST. **Antelope.**

HARTLEY. A unit of information generally defined as being equal to 3.219 bits.

HARTLEY OSCILLATOR. **Oscillator.**

HARTLEY PRINCIPLES (Transmission). The amount of information that can be transmitted is proportional to the width of the frequency range, and the time it is available. Information content is equated to the total number of code elements, multiplied by the logarithm of the number of possible values a code element may assume. Information content is independent of how the code elements are grouped. By quantizing, the continuous magnitude-time function used in ordinary telephony may be transmitted by a succession of code symbols such as are employed in telegraphy. To obtain the maximum rate of transmission of information, the signal elements need to be spaced uniformly.

Time-Frequency Duality. As implied by the Fourier integral, a time function cannot be confined within a small region on the time scale when the steady-state transmission characteristic is confined to a narrow range on the time scale. For example, it is well known that, if a telegraph dot is made narrower and narrower, its corresponding significant-frequency spectrum becomes broader and broader until, in the limit when the dot becomes an impulse, its significant-frequency spectrum is of infinite intent.

HARTMANN TEST. Hartmann devised various optical tests, including the following: (1) Hartmann test for telescope mirrors. For a perfect mirror, light from all points on the mirror should come to the same focus. By covering the mirror with a screen, in which regularly spaced holes have been cut, and then permitting the reflected light to strike a photographic plate placed near the focus, the failure of dots on the plate to be regularly spaced indicates a fault of the mirror. (2) Hartmann test for spectrometers. Light is passed through different parts of the entrance slit. Any change in the spectrum as different parts of the slit are used indicates a fault of the instrument. A "Hartmann diaphragm" is one device for using only one part of the entrance slit at a time.

HARTREE-FOCK APPROXIMATION. Also called Hartree-Fock-Slater approximation. A method for the solution of a many electron problem, e.g., that which arises in considering the band theory of solids or an atom with more than one electron. The antisymmetric wave function for the N-electron system is expanded as a linear combination of determinants of order N, having as elements one electron wave functions. This procedure introduces exchange terms in the Hamiltonian, of the form:

$$e^2 \int \left[\frac{\psi_i(r_1)\psi_j^*(r_2)}{r_{12}} d\tau_2\right] \psi_j(r_1)$$

where r_{12} is the separation of the points defined by the vectors r_1 and r_2.

HARVESTMAN (*Arachnida, Phalangida*). Spider-like animals, most species with small oval bodies and extremely long slender legs. Those with shorter legs are more easily confused with the true spiders but all may be recognized by the segmented abdomen. Daddy longlegs.

HASHIMOTO'S STRUMA. **Thyroid Gland.**

HASHISH. **Drug Addiction; Marijuana.**

HASTELLOY. **Nickel.**

HATCHET FISHES (*Osteichthyes*). Of the order *Isospondyli*, family *Sternoptychidae*, hatchet fishes are small, rarely exceeding 3½ inches in length. They are silvery and are so named because of their hatched-head appearance. They possess photophores (light organs) on their sides and undersurfaces. The genus *Argyroplecus* features telescopic eyes which are aimed in an upward direction. They are a food source for tuna, but are not nearly so abundant as their relatives, the bristlemouths. Some species of hatchet fishes have been favorites among tropical-fish fanciers.

The flying hatchet fishes of South America of the order *Ostariophysi*, family *Characidae* are the only fishes credited with performing true flight. See also **Characids (Osteichthyes).**

HAUSDORFF SPACE. **Topological Space.**

HAVERSINE. **Trigonometric Function.**

HAWK (*Aves, Falconiformes*). Birds of prey with hooked beaks and large curved claws, closely related to the eagles, falcons, harriers, and others and not sharply distinguished as a group. Hawks are found on all continents. North America has many species, including buzzards, harriers, goshawks and other forms. Most of them are beneficial as destroyers of vermin but the sharp-shinned (*Accipiter velox*), and Cooper (*A. cooperi*) hawks destroy too many birds, including poultry, to be regarded as friends.

Cooper's hawk. (*American Museum of Natural History*)

There are numerous species of hawks, at least 25 of these occurring in North America, particularly north of Mexico. The hawks are swift in flight, seek their prey by day, have remarkable vision, and eat only what they kill. They are very bold, pouncing upon their prey in a rapid swoop, using claws and talons, firmly clinching the victim. The hawk prefers to take its victim to a private location for consumption.

In the African rain forest, three species are known as darters.

The osprey is a large bird of prey of almost worldwide distribution. It is a skillful fisher and is known in North America as the fish hawk, *Pandion haliaëtus.*

Buzzards are birds of prey of several species that belong to the genus *Buteo.* The North American representatives are commonly called hawks, as Swainson's hawk. The same may be said of the nearly related rough-legged buzzards; American representatives of the genus are the rough-legged hawks. The name is incorrectly, although commonly, applied to the turkey buzzard, which is a vulture.

HAWK MOTH (*Insecta, Lepidoptera*). Large moths composing the family *Sphingidae*, one of the largest of the order. These moths have a long, rather stout body projecting beyond the narrow wings. The front wings are much longer than the hinder pair, and because of their limited surface they are vibrated rapidly in flight. The moths have long tongues and visit deep-throated flowers. From their habit of hovering as they probe the flower for nectar they are also called hummingbird moths. Another common name is sphinx moth.

HAWTHORN TREES AND SHRUBS. **Rose Family.**

HAY BRIDGE. **Bridge Circuits (Electrical).**

HAY FEVER. **Allergy.**

HAZE. **Hydrometeors and Precipitation.**

HAZELNUT SHRUBS. Of the family *Corylaceae*, genus *Corylus*, hazelnut shrubs (rarely trees) are deciduous, and characterized by male catkins that hang from the tree during most of the winter months, and by their edible and tasty fruit, an ovoid nut in a toothed container, simply known as the hazelnut of commerce. The term *filbert* is generally reserved for use with reference to the fruits of two European hazelnut plants, *Corylus avellana pontica* and *C. maxima.* The American hazelnut (*C. americana*) is a shrub ranging from 3 to 8 feet in height. It is commonly found in thickets and hedgerows. The leaves are narrow, heart-shaped or sometimes ovate, with abrupt points. They are of a lackluster dark green color and from 3 to 5 inches in length. The stems are short. The staminate catkins are from 3 to 4 inches in length. This shrub ranges from Maine westward to Alberta and Kansas and southward to Florida. The beaked hazelnut (*C. rostrata*) ranges from 3 to 8 feet in height and commonly occurs along the road in thickets, ranging throughout Canada from Quebec westward to the Pacific slopes and south into the United States to Missouri, Michigan, and Ohio, and Delaware in the east. It is found in the mountains as far south as northern Georgia. The fruit is edible and sweet and in the form of an ovoid nut. The nut is enclosed in a bristly cup which has a beak-like termination, hence the name. The California hazelnut (*C. cornuta* or *californica*) is well known for its velvety leaves and makes an attractive garden shrub. For purple coloration in gardens, the purple hazel (*C. maxima purpurea*) is sometimes used. The Turkish hazel (*C. colurna*) can be classified as a tree, in that it can attain a height up to 75 feet, but in most respects it is similar to the lesser hazelnut shrubs. Another species is the corkscrew hazel or Harry Lauder's walking stick, a shrub which attains a height up to 10 feet. It makes an attractive shrub, particularly in winter months when the catkins are on display.

Selected as a champion shrub by The American Forestry Association in this class in 1972 is the *C. cornuta*, located in the Siuslaw National Forest, Oregon. This shrub/tree has a circumference (at 4½ feet) of 1 foot, 9 inches, a height of 22 feet, and a spread of 20 feet.

HEADACHE. Head pain and ache is a symptom and not a disease. Headache is one of the most common symptoms of a disorder, not only of the nervous system, but other parts of the body as well. Consequently, discovery of the primary cause of headache is often difficult. The degree of pain associated with headache does not necessarily correlate with seriousness of cause, a violent headache sometimes being associated with a relatively minor injury. Diagnosis of headache complaint can be facilitated by providing accurate information to the physician—events occuring before the headache, such as emotional stress, exertion, eating, and so on; the time of day or night when headache usually occurs; and other symptoms that may accompany headache, such as nausea, flashes of light, ringing in the ears, rapid or slow onset of the headache, as well as how the headache usually ceases.

The large veins (venous sinuses) and their tributaries that drain the surface of the brain are sensitive to pain, as are the arteries. The brain substance itself apparently is not sensitive to pain, but the coverings of the brain are. The sinuses, teeth, ears, and muscles in the area of the head may be affected so that pain from them, at first local, later covers a wider area.

At least eight pain mechanisms have been identified as causative factors in headache: (1) dilation of the cranial arteries; (2) pulling or traction upon pain-sensitive intracranial structures; (3) traction on and dilation of intracranial blood vessels; (4) inflammation of structures within the skull; (5) contraction of skeletal muscles over the head and neck; (6) spread of pain from stimulation elsewhere in the head; (7) pain from allergenic reaction; and (8) mentally-produced (*psychogenic*) pain. The majority of headaches for which medical attention is sought arise either from dilation of the cranial arteries or contraction of the muscles of the head and neck, or by combinations of these factors. Fortunately, headaches of this type arise from conditions that usually are easy to correct.

Vascular headache is the term applied to the condition caused by dilation of the cranial arteries. It is associated with general infections, migraine headaches, or those resulting from taking certain drugs; and is largely responsible for so-called hunger and hangover headaches. The headaches of suddenly increased blood pressure are in this group, as well as headaches which follow convulsive seizures or head injury. Headaches of this type usually have a throbbing quality, but this may not be present if the headache is prolonged.

Treatment of vascular headache is generally directed to the underlying cause. The inhalation of high concentrations of oxygen are particularly helpful to persons whose headaches are caused by lack of oxygen. Headaches caused by traction or pressure on intracranial structures are associated with expanding intracranial masses, with brain tumors, abscesses, and hematomas, as examples. Such headaches are aggravated by coughing or straining and are not relieved by drugs which constrict the ateries. Headache associated with brain tumor may be intermittent and mild to moderate in severity and usually does not interfere with sleep.

The headache produced by a hematoma (swelling or tumor filled with blood) is dull, steady, and felt throughout the head. The pain from brain abscess is similar to that of tumor. However, the abscess must be of sufficient size to cause traction before pain is felt.

Headaches caused by traction upon and dilation of the intracranial vessels are typified by the headache which frequently follows lumbar spinal puncture. Despite precautions, at times there may be slow leakage of the spinal fluid through the hole made by the needle. This results in headaches which are ordinarily mild, but can be severe. Once the headache develops, bed rest is about all that is required. The condition heals spontaneously.

Headaches resulting from inflammation of cranial structures are experienced if the patient has any infection within the skull, such as meningitis or encephalitis. Such a headache also occurs as a result of the inflammation that follows brain hemorrhages. These headaches may be intense and require narcotics.

Typical of the headache which may occur secondary to pain arising elsewhere is that associated with sinusitis. Certain diseases of the eye, or eye strain resulting from long use, or excessive attempts at accommodation of eyes that require glasses, also cause this type of headache. Infections which involve muscles, especially rheumatic fever, cause this type of head pain. Arthritis of the upper part of the neck or tumors in this area also produce this type of headache.

Headaches also may be caused by sustained contraction of the muscles of the head and neck. The contraction may result from local muscle or nerve injury. Muscle contraction sometimes is associated with emotional tension.

Headaches resulting from muscle contraction are located frequently over the back and lower part of the head and upper part of the neck. The pain is a steady, deep ache often associated with a feeling of pulling or tightness. The headache may be aggravated by movements of the head. The muscles themselves may be tender and tight. Massaging the muscles and application of heat often relieve the pain.

Headaches caused by allergy often go unrecognized because they are not distinguished from other types by location and duration of pain. See **Allergy.**

Headache caused by emotional stress is not well understood. This type of headache can be bizarre. The patient may experience a wide variety of unusual sensations. While the headache may be described as being terribly intense, it ordinarily is of moderate severity and usually does not respond to medications which relieve other forms of headache. In many cases, the treatment needed is primarily psychiatric.

Migraine headaches have been reported since ancient times. Migraine has been termed one of the most common complaints of civilized people. The onset of migraine headaches usually occurs between the ages of 12 to 25, but they can begin at any age. Persons who perform mental work are more likely to be affected than blue collar workers. Also, urban dwellers seem to be more affected than people in rural areas. Often, the migraine victim will be an ambitious, hard driving, meticulous, and exceptionally intelligent individual.

An outstanding feature of migraine headache, thus differentiating it from other types, is that it affects one side of the head. Other distinctions are the periodic recurrence. There is some evidence that migraine may be hereditary. In most instances, the headaches occur about once every two weeks. In women, it may be associated with the menstrual period. Attacks in some persons, however, do not show this regularity, with headaches being separated by months or even years. A migraine headache may last from a few hours to more than a week. In any individual, the characteristic pain, accompanying symptoms, and length of time are usually about the same for each attack. Some sufferers can generally predict such experiences.

The typical migraine headache commences in the temple, eyeball, or forehead, and soon spreads to include either the left- or right-half of the head. The pain may involve the face and neck and sometimes the arms. Sometimes the headache is preceded by disturbances of vision (dullness of vision, blinding flashes of light, sensitivity to light or sound, or dizziness). As the attack begins, the patient may notice a blind spot, that is, several words in a printed sentence may not be seen. This spot, in rare instances, increases in size until vision in one field is fully gone. The patient may regain the ability to see in the later stages of the attack, but he may still be troubled with dazzling black and white flashes of light. During the attack, the victim's face usually is pale and sallow and the skin may be sweaty and clammy. The arms and legs may feel cool to the patient, even though there may be fever. Nausea and violent vomiting often mark the climax of the attack. After the attack has run its course, if there has been no vomiting, the patient usually feels relaxed and relieved and may be filled with energy and tend to be overactive, although a dull headache may persist for a day or two.

Many migraine sufferers report that attacks seem to occur in relation to periods of let-down or of exhilaration. Many have noted that their headaches commence on weekends, the first day of a holiday, or on days of planned social engagements or travel. Often, on the eve of onset, the victim may be in high spirits, with an unusually increased appetite. However, on the following morning, the victim may arise with a very depressed or melancholic attitude. The victim may become restless, irritable, and confused, with an inability to concentrate on routine tasks, or to make decisions. There may be a tendency to absent-mindedness.

Many theories have been offered as to the cause of migraine headaches. Most authorities agree that distention of the cranial arteries in the scalp is the immediate cause, but the causes of such distension are not well understood. There appears to be a relation between the personality traits of migraine patients with those having high blood pressure. It has been noted that about 50% of the children of migraine patients also suffer from migraine.

Some investigators believe that migraine headaches occur as the result of allergy, probably to certain protein-containing foods. According to some patients, chocolate has been an offender. In some patients, migraine may be akin to asthma. However, in other patients, the headaches are thought to occur because of eyestrain; and in others, to an imbalance of the endocrine system.

Generally, the patient should be left alone in a quiet, darkened room because most migraine patients are extremely sensitive to light and odors. An ice bag on the head and hot water bottle at the feet may provide some relief from pain. In some patients, sitting in an upright position rather than lying down reduces the intensity of the pain. Ergotamine tartrate, to be prescribed only by a physician, has been found helpful in terminating the headache in many instances, if given at the beginning of an attack. Inhalation of 100% oxygen may alleviate pain. Strong drugs should not be taken for a migraine attack unless prescribed by a physician, for it is too easy for migraine sufferers to develop a drug habit. The victim should make every effort to determine the factors associated with attacks and to avoid wherever possible such factors. Avoidance of fatigue, late hours, strain, and worry tend to reduce frequency or severity of migraine attacks. In most persons, physical or mental tension is often the immediate cause of an attack.

Women who suffer attacks of migraine usually do not have any episodes during pregnancy; and the attacks may disappear entirely after the change of life. The disease may disappear in men and women at all ages, but most frequently attacks cease at around 50 years of age, when the elasticity of the blood vessels has diminished, so that the dilation previously described in the etiology of migraine has decreased.

HEAD (Data Processing). A device that reads, records, or erases information in a storage medium, usually a small electromagnet used to read, write or erase information on a magnetic drum or tape or the set of perforating or reading fingers and block assembly for punching or reading holes in paper tape or cards.

HEADER. Any pipe, conduit, duct, or channel which acts as a central point of distribution of a fluid flow to several branch lines, is a header.

HEAD FLOWMETERS. Flow Measurement (Fluids).

HEAD (Hydrostatic). Hydrostatic Pressure.

HEADING. The direction of the forward end of the keel of a ship (either airborne or seaborne) is known as the heading of the ship. Unless a qualifying adjective is used with the term heading, it means direction with reference to true north. Compass heading, or magnetic heading, may be converted to heading by applying the compass corrections.

See also **Compass (Navigation); Course;** and **Navigation.**

HEAD WIND. Jet Streams.

HEAD (Zoology). The region of a bilaterally symmetrical animal body lying at the front end in relation to the ordinary direction of locomotion, or, in bipedal vertebrates like man and some of the birds, at the highest level.

The development of a head is indicated in animals which are without sharply separated body regions, such as the flatworms. This process of cephalization is closely correlated with bilateral symmetry. The portion of a bilateral animal which goes first inevitably is the first to encounter new sources of stimuli, and shows some concentration of sense organs. Usually the chief nerve center, a cerebral ganglion or brain, also develops here. The concentration of sense organs and nervous control in the head remains characteristic of the region throughout the animal kingdom and in most groups is accompanied by the location of the mouth in the head, together with associated structures for securing food.

HEALTH SAFEGUARDS (Mining). Coal.

HEARING AND THE EAR. The role of the sense organ of hearing (the ear) is to code acoustic disturbances into neural signals suitable for transmission to the brain. The study of this process necessarily involves anatomy and physiology of the ear, the nature of auditory pathways and central nervous system activity in hearing, properties of acoustic signals that elicit auditory responses, and observed phenomena of auditory behavior. These aspects serve to

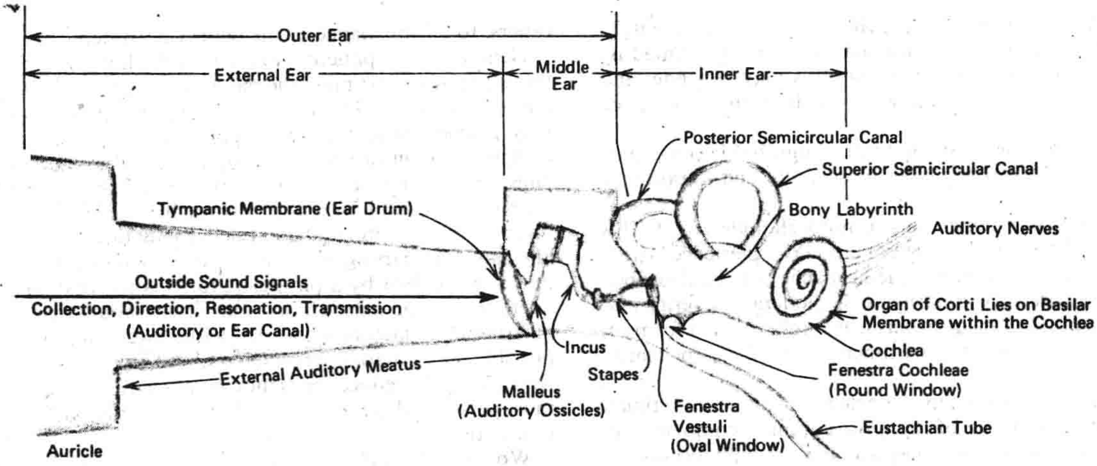


Fig. 1. Highly schematic representation of human auditory system.

define and delineate areas for investigations of hearing.

The ear is a highly complex, intricate organ and, because of the several phenomena taking place in the chain of actions from the outer ear through the middle ear to the inner ear and hence to the brain, it is difficult and cumbersome to construct one or more analogs of its function so as to relate ear function to known, mechanical, electrical, or hydraulic systems to assist in the understanding of the total hearing system. Further, not all of the phenomena occurring in the ear are yet fully understood in a highly detailed fashion.

Although physiological functions may correspond in a general way to anatomical sequences, several physiological functions may occur in the same anatomical structure, or a single function may require several anatomical units. In a similar manner, psychological functions cannot usually be identified with specific physiological functions, and it is recognized that the central nervous system, as well as the auditory system, is involved in any auditory response. The correlations between and knowledge about structure and functions are best developed for peripheral, rather than central, parts of the auditory system because the ear is more accessible for examination and study than are the more central parts of the auditory system.

Traditional theories of hearing have been largely concerned with pitch perception or loudness of pure tones. However, within the last few decades, there has been an increased awareness that any comprehensive theory of hearing needs to encompass various experimental phenomena of hearing. In this regard, increased attention has been given to auditory processing of complex signals, to the examination of binaural inputs to the system, and to the study of pathological hearing conditions.

Structure of the Ear. When the structure of the ear is examined, it is convenient to consider the (1) external, (2) middle, and (3) inner ear separately. However, from a functional standpoint, the ear may be divided into an outer and an inner part. Some of the terms used here are indicated by the highly schematic representation of Fig. 1. The term *external* as used in connection with the ear encompasses the auricle (that part of the ear which can be seen) as well as the auditory or ear canal which extends to the *tympanic membrane* (eardrum). The outer ear is concerned with the transformation of acoustic energy into mechanical energy. The inner ear is concerned with the transduction of mechanical energy into neural impulses.

The auricle and *external auditory meatus* constitute the external ear. The meatus is an irregularly-shaped tube approximately 27 millimeters long with a diameter of about 7 millimeters, terminated by the tympanic membrane. The ear canal is an acoustic resonator, and frequencies in the range of 3,000 to 4,000 Hz are increased in pressure at the eardrum, as compared to the pressure at the entrance to the canal. The eardrum is in a protected position at the end of the canal, and humidity and temperature conditions at the drum are relatively independent of those external to the ear.

The middle ear is an irregular, air-filled space in the pestrous portion of the temporal bone. The three auditory ossicles of the middle ear (a) the *malleus*, (b) the *incus*, and (c) the *stapes* provide mechanical linkage between the tympanic membrane and the *fenestra vestuli*, an opening in the vestibule of the inner ear, commonly referred to as

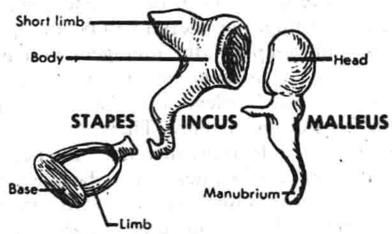


Fig. 2. Greatly enlarged sketches of the malleus, incus, and stapes. (*Anatomy of the Ear . . . Grace Hewitt*)

the oval window. The auditory ossicles are shown greatly enlarged in Fig. 2. The handle of the malleus attaches to the tympanic membrane, and the footplate of the stapes attaches to the oval window. Two important functions are provided by the middle ear. The first is to amplify and deliver sound vibrations from the drum to the inner ear, and the second is that of protecting the inner ear from very loud sounds. The amplification of sound waves is accomplished by apparent lever action of the ossicles that produces a greater force at the oval window than the force at the drum, and because of the gain in force that results from the relationship between the larger drum area to the smaller stapedial footplate area. The area of the drum is approximately 25 times that of the oval window. The amplification gain of these two factors is approximately 25 dB. The effectiveness of the middle ear action in increasing hearing sensitivity is evidenced in middle ear pathologies where the ossicular chain is disrupted. A hearing loss of 25 dB or more occurs. The second function of the middle ear, that of protecting the inner ear

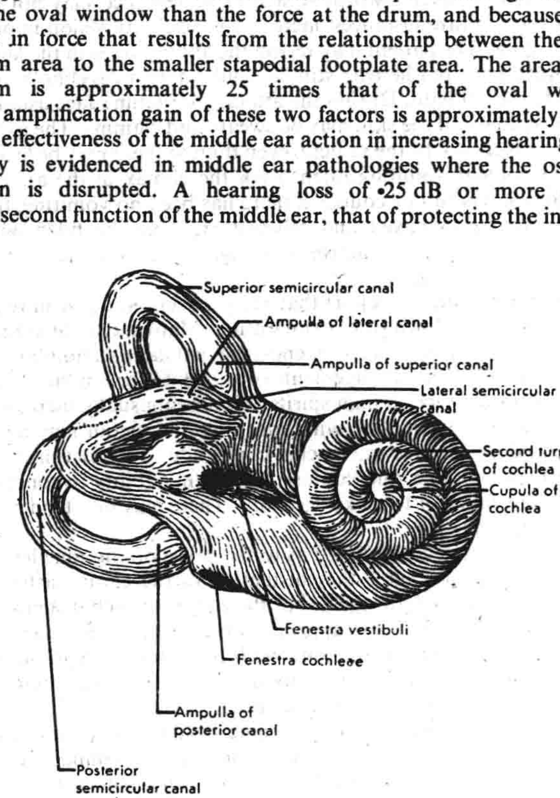


Fig. 3. The bony labyrinth. (*Anatomy of the Ear . . . Grace Hewitt*)

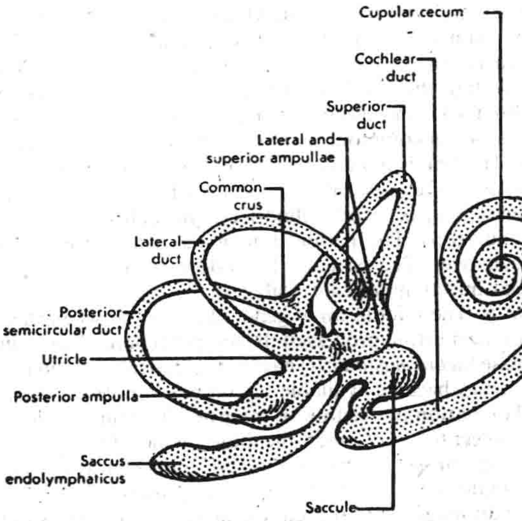


Fig. 4. The membranous labyrinth. (*Anatomy of the Ear . . . Grace Hewitt*)

from loud sounds, is accomplished by reflex action of the middle ear musculature, the tensor tympani, and the stapedius. The action of the muscles is to retract the eardrum, draw the stapes away from the oval window, and change ossicle vibrations in such a way as to decrease the transmitted pressure. Latency of muscle contraction and possible muscle fatigue limit protection of the inner ear by these mechanisms. Middle ear air pressure is equalized by virtue of the Eustachian tube which connects the middle ear and the nasopharynx. The pressure equalization is necessary for normal ear drum movement.

The inner ear is a system of cavities in the dense petrous portion of the temporal bone. One of the cavities is the cochlea, a bony labyrinth that is approximately 35 millimeters in length coiled around a central core for two and three-quarters turns. The spiral-shaped cochlea is divided into three ducts, two bony and one membraneous. (See Figs. 3 and 4.) The upper bony duct, the scala vestibuli and the lower bony duct, the scala tympani, are separated from each other by a membranous labyrinth, the cochlear duct. The cochlear duct is bound on top by Reissner's membrane and is bound below by the basilar membrane. The cochlear duct is filled with a viscous fluid called endolymph, and the duct is surrounded by a fluid called perilymph that has about twice the viscosity of water. The scala vestibuli and the scala tympani join at the apical end of the cochlea at a passage called the helicotrema. The scala tympani terminates at the basal end at the round window, a membrane-covered opening into the middle ear. The scala vestibuli is continuous with the vestibule; the oval window opens into the vestibule. Vibrations at the footplace of the stapes are transmitted into the fluid adjacent to the oval window. Vibration of the stapes and resultant disturbances in cochlear fluids results in movement of the basilar membrane. The cochlear duct contains the sensory receptors, specifically the organ of Corti, which lies upon the basilar membrane. There are about 25,000 hair cells; one end of each rests on the basilar membrane. The other ends of the hair cells are the cilia, very fine hairline processes, which make contact with the tectorial membrane, a membrane that overlaps the organ of Corti and that functionally behaves as if it were hinged at the cochlear wall. There are three rows of outer, and one row of inner, hair cells along most of the length of the basilar membrane. When vibrations are introduced into the inner and cause displacement of the basilar membrane, a shearing of the action of the cilia occurs that results in neural activity. It is assumed that amplification occurs in the inner ear in that small pressures on the basilar membrane result in a shearing force of considerably greater magnitude that distorts the hair cells. The result is increased sensitivity of the hearing system. Physical properties of the cochlea are such that different frequencies tend to localize at different points along the basilar membrane. The basilar membrane is narrowest and stiffest at the basal end, and most lax and widest at the apical end of the cochlea. High-frequency sounds result in the greatest disturbances near the basal end, and low-frequency sounds tend to localize near the apical end. When the role of the cochlea in pitch and loudness analyses is considered it is now realized that more is involved in pitch perception than the place of localization on the basilar membrane, although the particular neural fibers involved are probably relevant. Loudness is probably related to the total number of neural impulses per unit time.

The auditory pathways provide for the neural impulses from the ear to be transmitted to the cerebral centers of the auditory cortex. Processing of the neural signals probably occurs at synaptic connections as well as in the cortex. The cell bodies of the receptor neurons are located in the spiral ganglion. Neurons of the auditory nerve make synaptic connections with the hair cells of the cochlea. Nerve fibers typically innervate many hair cells, and more than one nerve fiber may make a connection with the same hair cell. There is recent evidence to indicate that there are also descending neural pathways as well as ascending ones. The central nervous system may thus be involved in auditory processing at the cochlea. Spiral ganglion axons make synaptic connections with cells of the central nervous system at the cochlear nucleus. At this point, there is interconnection between the pathways for the two ears. Other synaptic stations between this point and the auditory cortex include the inferior colliculus and the medial geniculate body. Evidence from pathological auditory systems is of particular interest with respect to the auditory pathways. An impaired cochlea, for example, may result in a better than normal response to small amplitude changes in a sound. A lesion of the VIIIth Nerve is frequently manifested by a rapid decrease in the ability to respond under sustained stimulation. The ability to process speech is markedly affected when there is an involvement of the lower central nervous system. Cortical involvement does not affect usual speech or pure tone inputs.

Sound involves a disturbance in the air that is a forward and backward, rarefaction and compresion, movement of air particles. The unit of force usually used in acoustics is the dyne. Sound pressure is frequently expressed in dynes per square centimeter. Intensities of sounds are usually measured on a decibel scale, a logarithmic ratio scale. The tremendous loudness range of the ear is exemplified by the fact that the most intense sound that can be tolerated is a million million times greater in intensity than a sound that is just audible. This is a range of approximately 120 dB. The frequency range of hearing is frequently given as 16 to 20,000 Hz. The ear is most sensitive in the middle frequency range of 1,000 to 6,000 Hz. In terms of discrimination of frequency and intensity, it is possible for about 1,400 pitches and 280 intensity levels to be distinguished.

The truly phenomenal aspects of hearing can be observed in such behavior as localization of sounds, speech perception and particularly the understanding of one voice in the noisy environment of many, and the recognition of acoustic events that only last a few milliseconds. These and other behavioral phenomena remain to be fully accounted for in theories of hearing.

Disorders of the Ear. Common earache may arise from many causes and occur in numerous forms. The most usual cause of pain in the ear, aside from mechanical injuries, is some type of bacterial infection. Each form of earache is characterized by a somewhat different type of pain and is accompanied by distinct symptoms. Although painful, most forms of earache are not dangerous, but because some types can become fatal, a physician should be consulted whenever symptoms arise.

Infection of the Outer Ear. Earache may be caused by a foreign body that has become trapped in the ear. Removal of any such object should be done by a physician to avoid injury to the delicate parts of the ear. Hardened wax in the ear may cause aching.

Boils or Furnucles. When present in the external ear, these often produce severe pain because the skin in this region normally adheres closely to the underlying cartilage and bone. If infection is allowed to persist, perforations of the eardrum may occur. Through them, infection may spread to the middle ear, the inner ear, or the mastoid area. An x-ray will assist in determining the nature of any secondary complication.

Fungus Infection. Otomycosis is a fungus infection of the outer ear and canal. The inside of the ear appears dirty and crusty, and fluid seeps out continually. When the crusts and scales are removed, the skin beneath is raw and bleeds easily. Itching causes much discomfort. Pain is usually present because of the swelling of the canal; hearing may be impaired. Treatment is by specific solutions and ointments. Home remedies are not recommended.

Aero-Otitis Media. In this disorder, the structures of the middle ear are affected by changes of pressure which occur during airplane flights. In milder cases, there is a sensation of stuffiness in the ears, with a slight inflammation of the eardrum, and perhaps some minor hearing impairment. Excruciating pain and hemorrhages in the tympanic membrane may occur in more severe cases. Although the condition still may occur among sensitive individuals, pressurized aircraft cabins have greatly alleviated the problem. If one senses this developing, chewing gum or moving the lower jaw with the mouth open will usually prevent it by opening the Eustachian tube which will equalize the pressure. The problem is more common with persons who have upper respiratory infection or severe nasal allergy.

Nondraining Infection of the Middle Ear. Many disorders, both inflammatory and noninflammatory, may affect the middle ear. Often, bacteria from respiratory infections invade the middle ear by way of the Eustachian tube, which opens into the cavity (*nasopharynx*) behind the nose. Bacteria may also enter the middle ear cavity through a perforation in the eardrum. Blowing the nose incorrectly is sometimes responsible for middle ear infections. Both nostrils should be blown at the same time. Blowing only one side at a time may force purulent material into the sinuses or the Eustachian tube.

Disturbances in the middle ear often are caused by infections in other nearby organs, such as the tonsils or nasopharynx. In so-called "catarrhal" disorders of the middle ear, the primary problem is that the Eustachian tube is partially or completely closed.

Otitis Media is an acute middle ear infection. Sharp stabbing pains may shoot through the ear, and a heavy feeling is noticed on that side of the head. Momentary relief is achieved by yawning or blowing the nose. This type of middle ear infection may last for several days or a few weeks, with healing usually slower in damp climates. Often, removal of the tonsils and adenoids may be recommended after recovery as a preventive measure against further attacks.

Sulfonamide drugs, broad-spectrum antibiotics, or anihistamines are used effectively to clear up the disorder and the underlying infection or allergy. After the inflammation subsidides, it is sometimes necessary to remove or add air to the middle air chamber in order to attain the correct pressure.

Chronic infection of the middle ear may develop as a result of persistent ear infections or from respiratory diseases. It may also be caused by diseases, such as tuberculosis, measles, and syphilis. One of the main symptoms of chronic middle ear infection is a ringing sensation in the affected ear. It comes at intervals at first, then gradually the ringing becomes constant. The sounds vary both in pitch and intensity. Hearing is usually affected, but total deafness seldom occurs. Complete recovery requires early treatment. Draining of the middle ear can be accomplished successfully and safely by a surgical procedure by which a small incision is made in the eardrum. Eardrums that rupture spontaneously may become infected chronically, with a possibility of mastoid complication. Surgery of the drum membrane does not benefit most advanced cases. More radical surgery is required to clear up the disease.

Secretory Otitis Media also called *serous otitis media* is characterized by the collection of fluid in the middle ear. This fluid may be either clear (serous) or gluelike (mucous). The predominant symptom is impaired hearing, which varies from slight to almost total loss. Children who have secretory otitis media may be subject to frequent upper respiratory infections and often have enlarged lymphoid tissue in the nasopharynx. If there is an underlying allergy or infection, appropriate antihistamines, antibiotics, or sulfonamides may be prescribed. Draining the fluid through an incision in the eardrum may relieve the condition. When there are repeated attacks, tiny plastic tubes can be inserted into the middle ear to provide adequate aeration. These tubes may be left in place for as long as 3 to 4 months.

Many cases of severely impaired hearing in adults can be attributed to middle ear infections in childhood. In infants and children, the Eustachian tube is shorter and more nearly horizontal than in adults. Thus, the tube is more likely to become an avenue of infection.

Acute Draining Middle Ear Infection. Known as *acute suppurative otitis media*, this disorder originates from the same causes as all middle ear infections, but it differs in the type of inflammation and the changes that occur in the tissues. A head cold may precede the infection. The attack of inflammation is sudden and causes congestion in the linings of the ear spaces, Eustachian tube, and mastoid cells. The ear itself fills with fluid, which gradually becomes puslike. Pain is the main symptom. It is severe, radiating, and throbbing. In children, early symptoms may include refusal to eat, nausea and vomiting, rolling the head, or tugging at the ear. The temperature rises to about 100° in adults, but may reach 105° in children, with convulsions not uncommon. A ringing sensation and dizziness may be present. Hearing is impaired as long as pus remains in the middle ear. Untreated, after several days, the eardrum ruptures spontaneously. For as long as 3 weeks, fluid seeps through the canal and then subsides and stops. The perforation in the drum usually, but not always, heals over. The parts of the middle ear are so intricate and delicate that infections spread easily.

Mastoiditis. The middle ear is generally involved when there is an infection of the mastoid process of the temporal bone. The acute form of this disease (*acute mastoiditis*) has been practically eliminated since antibiotic drugs became available to combat middle ear infections.

The inflammation in mastoiditis involves the lining of the mastoid cells. The infection may enter the bone, which becomes soft and decayed. The causes of mastoiditis include respiratory infection, abnormal anatomy of the ear in infants and children, improper channels for ear drainage, and lowered resistance to infection. Mastoiditis may occur as a secondary infection to various diseases. The predominating symptom is pain, which may be either continuous or intermittent. If the patient is not treated, the intense pain could persist for 6 or more days, which may not be true for middle ear infection. Also unlike middle ear infection, mastoiditis is characterized by a definite, localized tenderness over the mastoid process.

In *chronic mastoiditis*, which now occurs far more often than the acute type, drainage from the ear (*otorrhea*) is the principal symptom. Fever may or may not be present. If acute mastoiditis should occur, the physician may perform a *mastoidectomy*. In this operation, the infected mastoid cells are removed through an incision in the area behind the ear, or in the external auditory meatus.

Tinnitus. Most persons, at one time or another, experience this disorder, a sensation of ear noise which is more noticeable in a quiet environment. Such sounds may seem to be in the head rather than the ear, and may affect one or both ears. The symptom is associated with many conditions, including middle ear infection, Ménière's syndrome, exposure to intense noise, circulatory diseases, otosclerosis, and neutritis of the auditory nerve. The symptom also may be caused by excessive amounts of coffee, tobacco, or alcohol. Quinine, certain antibiotics, or large doses of aspirin also may produce tinnitus. Such sounds occur most often in persons between ages 50 and 70. The reason for the sensation has not been established. Inasmuch as the symptom could be an early warning of hearing damage, it should be investigated.

Punctured Eardrum. The most common cause of a punctured eardrum is the insertion of a sharp object into the ear. Violent explosions near the ear may cause the drum to tear or rupture. Decreased air pressure during or after descent from high altitudes, severe sneezing, diving, and increased pressure frequently are responsible for damaged membranes. Sometimes, diagnosis is difficult. The pain accompanying a puncture is sharp and intermittent. Blood may ooze from the injury, but this is not positive proof of a drum tear, because the same symptom may be present in a skull fracture. Dizziness, ringing sounds, and headaches also are significant symptoms. A tear in the eardrum may heal without treatment within a period of a few weeks, but there may be aftereffects which may not be noticed, even for as long as a year. A grafting operation known as *tympanoplasty* can be employed in cases in which the tear does not close.

Growth on the Eardrum. Following rupture or perforation of the eardrum, small chalky (lime) deposits may form at the site of healing as a result of repeated attacks of middle ear infection. If they form from a healed perforation, they mark the path of least resistance for a future rupture. It is the general opinion of physicians that such deposits do not affect normal hearing. There is no successful way of removing the chalk deposits without injuring the eardrum seriously or depressing the hearing. Hence, it is rarely attempted.

Ménière's Syndrome. Prosper Ménière described this malady in 1861 and correctly attributed its origin to the inner ear. Its characteristic symptoms are sudden severe episodes of *vertigo* (dizziness), tinnitus, and fluctuating hearing loss. The term syndrome continues to be used because the exact causes of the disorder have not been fully established. Persons in the middle age group are more commonly affected by the syndrome. The vertigo associated with an attack may be so severe that the simplest activities become impossible. Usually, the patient has a sensation that objects are whirling about. The same type of dizziness occurs with certain cardiovascular disorders and middle ear infections. Attacks may last for minutes or weeks. The tinnitus, usually a roaring noise, sometimes persists between attacks. Nausea and vomiting are also usual symptoms.

The course of the syndrome is unpredictable. Remissions of up to several years often occur. About two-thirds of the patients improve or recover regardless of treatment. No single form of therapy has been fully successful. Certain drugs, such as Dramamine, often help control the vertigo. Sedatives or tranquilizers are occasionally helpful. If the condition is disabling and unilateral, the diseased parts of the labyrinth may be surgically removed. The procedure stops the vertigo, but balance is impaired and hearing loss in the affected ear is total. Ultrasonic radiation has been used to irradiate the labyrinth with the objective of destroying the diseased portions. For relief of severe vertigo, some surgeons recommend the Tack operation to drain the saccule, which contains endolymph. A tack, a small pointed piece of metal, is placed through the footplate into the sac, thus allowing drainage. According to one theory, this syndrome is related to an imbalance of pressure between the perilymph and the endolymph. Another innovation has been the use of surgical instruments which are maintained at temperatures as low as −140°C. With these instruments, a surgical procedure should be less likely to damage the cochlea.

Cauliflower Ear. Known as *hematoma of the auricle*, this disorder has long been recognized as the badge of the prizefighter. It is caused by injury to the external ear. A hard blow may cause bleeding below the skin. If this accumulation of blood remains for sometime, it become fibrous tissue and eventually will be converted into a bone-like or cartilaginous substance. Thus, the ear will be deformed by this irregular mass of extra tissue. For prevention, the blood should be removed before it clots. Plastic surgery also is used for restoration of affected ears.

Congenital Malformations. These occur rather frequently, but generally they are not gross enough to impair hearing. They may be unsightly. Absence of the lobe or the outer rim of the ear (*helix*), large protruding ears, and irregular shapes are among the more common malformations. Plastic surgery can restore most of these conditions to normal appearance. Occasionally, a congenital defect, such as an obstruction in the canal, may have to be removed before hearing improves. In rare instances, the ears may be displaced on the head, and in some extreme cases when the lower jaw is grossly misshapen, they may even be fused together (*synotia* or *otocephaly*).

Disturbances of Equilibrium. The semicircular canals of the inner ear are responsible for adjusting the body to changes in motion. The rate of these changes normally allows sufficient time for the canals to maintain bodily equilibrium. When rapid, irregular, and continuous waves of motion persist, the canals are not able to function properly, and *motion sickness* results.

Seasickness, airsickness, and elevator sickness are forms of motion sickness. The usual symptoms are dizziness, nausea, vomiting, and thirst. Despite the extreme unpleasantness experienced, motion sickness is often thought of as a trifling ailment. However, the number of deaths that occur from this disturbance is greater than would be expected. Death does not occur as a result of motion sickness itself, but rather from exciting a preexisting disorder.

Deafness

Deafness means nearly complete or total loss of hearing. There are two types: (1) congenital, and (2) acquired. In the congenital type, the person is born deaf or later becomes deaf because of an inborn defect. Hard of hearing is a term that applies to those who lose some of the ability to hear later in life, but who have learned how to speak before the loss occurred.

Causes of deafness are many. Some conditions which may cause deafness or milder hearing difficulties include (1) temporary or chronic infections in one or both ears; (2) secondary complications of disease elsewhere in the body; (3) direct damage or defect in some part of the hearing system; (4) aging; (5) occlusion of the auditory canal; (6) aerotitis media; (7) Ménières syndrome; (8) ostosclerosis; (9) noise; and (10) certain toxic drugs.

Conductive deafness results when sound waves are not transmitted properly through the outer and the middle ear. If the damage is to the inner ear or the nerve pathway to the brain, a *sensorineural* (also called *nerve* or *perceptive*) *deafness* occurs. The latter type is generally a greater handicap and usually cannot be reversed. In *mixed hearing loss*, there are elements of both conductive and sensorineural types of loss. Some deafness is caused by a disorder in the central nervous system.

If a woman develops German measles (rubella) during the first three months of her pregnancy, the baby will, in about 50% of the cases, be born with at least a partial hearing defect. This congenital deafness may be masked by even more severe birth defects. Outbreaks of rubella occurred in 1964 and 1969 and many children suffered hearing loss as the result.

Otosclerosis. Usually first detected during early adulthood, *otosclerosis* can cause a conductive type of hearing loss. Bony growths form just inside the inner ear where the middle ear's stirrup (*stapes*) enters it. Eventually, the footplate of the stapes becomes anchored and no longer conducts sound waves to the inner ear. About 10% of the population is affected to some extent in this way, although they may have no hearing loss for many years. Experience indicates that the disorder may become arrested at any stage. Heredity appears to be an important factor. Middle ear infections are not a cause. The disorder occurs about twice as often in females as in males.

Since 1952, an operation in the tiny stapes itself has been used for many patients with advanced otosclerosis. In this *stapedectomy*, all or part of the fixed stapes is removed and replaced with an artificial device. The operation has since been modified in which only part of the stapes is removed.

Noise. During wartime, military personnel often suffer partial or total hearing loss after exposure to noises such as blasts or gunfire. More than 58,000 veterans of World War II received some ear damage. Prolonged exposure to certain industrial noises also can cause partial or total deafness. See also **Acoustics**. In addition to industrial noise, which ultimately can be reduced to safe levels through industry coöperation and government regulation, there are various societal situations less difficult to control. For example, overamplification of music will often exceed levels considered safe for hearing, and persons repeatedly exposed to such conditions can develop either temporary or permanent hearing loss, dependent upon the ability of the individual's auditory system to withstand such conditions.

Instrumental Measurements of the Ear

The most common measurement of hearing function is the pure-tone audiogram in which a frequency from 125 to 8,000 Hz is plotted against hearing loss in decibels. The audiogram displays the ability of the ear to hear a pure sine-wave tone at a given frequency compared with a "normal" ear. The unit of loudness is the decibel, defined as $10 \times \log_{10}(P_1/P_2)$, where P_1 is the power of the sound being applied and P_2 is the just-audible power required at the given frequency for the "normal" ear to hear. The standard audiometer contains a frequency-selection knob, an attenuator calibrated in 5-dB increments, and a key which connects the output of the instrument to the earphones placed on the subject's head. The procedure is to increase the amplitude slowly while depressing the key in short pulses until the subject reports that the sound can just be detected.

In addition to pure tones, speech sounds are also used as test signals. Using +9 dB (referred to 0.0002 dyne/square centimeter) as a 0-dB threshold level, it is possible to determine the extent of the hearing loss for speech using specially selected two-syllable words having approximately equal stress on each syllable (called "spondaic" words). The equipment used for this measurement consists of a microphone, audio amplifier, and a pair of headsets, the system having a float frequency response between 125 Hz and 8 kHz. Sensitivity, or gain, of the amplifier is controlled by a step attenuator calibrated in 1-dB steps, and the output is arranged to go into either ear separately, or both ears simultaneously.

In the von Békésy pure-tone audiometer, the amplitude control is run up and down by a motor while the subject operates a key. The amplitude is slowly increased until the subject hears the sound, which reverses the motor. The frequency is similarly increased slowly and automatically. The resulting curve is somewhat sawtooth in form and more accurately brackets the threshold values.

In designing and using audiometers, great care must be given to the elimination of background noise and hum. If more than one tone is presented at a time, "masking effects" may occur, giving different results than would be obtained with each sound separately.

Hearing losses are generally greatest at the higher frequencies (above 2 kHz). Thus, the sibilants and percussives in speech are the most difficult to perceive. In addition, there usually is a loss in dynamic range so that not only must sound be louder to be perceived, but the range between threshold of perception and threshold of pain is much narrower. Thus, the ear cannot accommodate in many cases to an undue amount of amplification. This condition is known as "recruitment." Any hearing aid should take these two factors into account and hence should not be a simple audio amplifier if best results are to be achieved. Furthermore, stereophonic sound location is lost with a single-channel hearing aid. Thus, some patients find that binaural hearing aids are of much value. In some cases, the user can discriminate a desired conversation from background noise in a dramatic fashion.

As a further aid in helping the profoundly deaf, whose hearing may be cut off as low as 1,000 Hz, a device known as a transposer may be used. This translates sounds at the upper frequencies made by sibilants and percussives into the lower-frequency region where they can be amplified sufficiently to be audible. There are several variations on the basic scheme, but in principle the devices contain filters which detect only the upper frequencies and then trigger sound generators below 1,000 Hz which indicate to the user the presence of the high frequencies.

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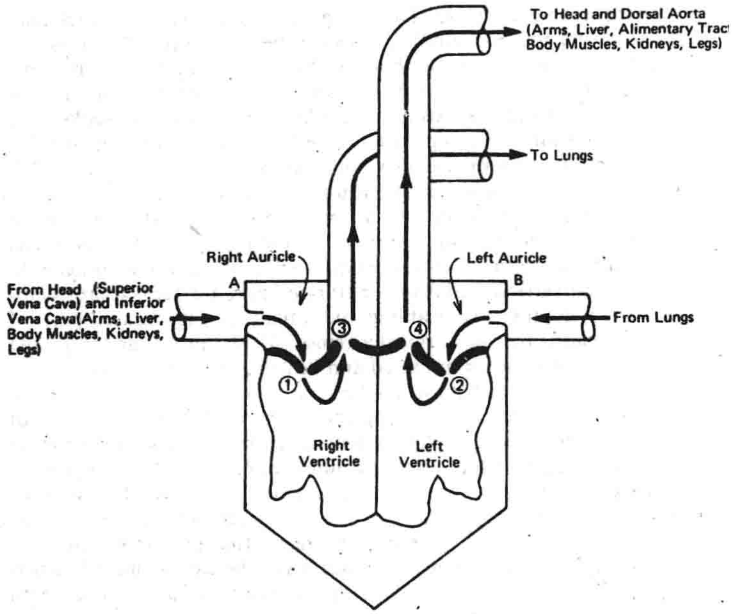
HEARING ORGANS. **Hearing and the Ear; Sensory Organs.**

HEART. The muscular organ that pumps the blood. Depending upon the size of the individual, the human heart weighs somewhat less than three-quarters of a pound. The organ essentially is a hollow muscle capable of contraction like other muscles. A contraction is designated a "heartbeat." The rate of the heartbeats can be changed by two different sets of nerves: (1) The accelerating nerves are connected to the spinal cord and are a part of the sympathetic nervous system; (2) the *vagus nerve* depresses the rate and is connected to the brain stem. The beating of the heart commences long before birth and must continue as long as life continues. Beats occur at the rate of 70 to 80 times per minute in adults, but may increase to more than 100 beats per minute during exertion, or in the presence of emotional upsets. During a 70-year life span, it is estimated that the heart beats some 3 billion times, an average of about 42 million beats per year. Each contraction of the heart moves slightly more than two fluid ounces of blood out into the arteries, providing a change of blood over the body about once every minute. During a lifetime of 70 years, a total of 250 million quarts of blood are moved, almost enough to fill a large football stadium. There are only a little over 6 quarts of blood in the average human body, so that this blood requires not only rapid circulation, but also a fine adjustment of controls to assure the proper and effective distribution required by the body.

The role of the heart in the total circulatory system is described under **Circulatory System (Human).**

The accompanying highly schematic diagram of the heart indicates the principal components of the heart structure. The heart is divided into four chambers—two auricles, referred to as the right and the left



Highly schematic diagram of major components of human heart. (A) Entrance of blood from venae cavae to right auricle; (B) entrance of blood from lungs; (1) tricuspid valve; (2) mitral valve; (3) pulmonic valve; (4) aortic valve.

auricle; and two ventricles, referred to as the right and the left ventricle. The flow of blood through these chambers is controlled by four valves, as numbered in the diagram (1) the tricuspid valve; (2) the mitral valve; (3) the pulmonic valve; and (4) the aortic valve. The schematic diagram, of course, is not to scale.

Blood coming from over the body through the large veins (venae cavae) enters the right auricle at A. This blood has been partially depleted of its oxygen. As the lower, thick-muscled ventricles expand, this blood enters the right ventricle through the tricuspid valve. Then, the ventricle contracts and forces the blood into the pulmonary artery toward the capillaries of the lungs and is prevented from running back into the heart by the closure of the pulmonic valve. In the meantime, the purified blood in the left auricle has just arrived from the lungs through the pulmonary veins, at B. From here it passes into the thick-walled left ventricle through the mitral valve. When the right ventricle forces blood out into the pulmonary artery, the left ventricle at the same time contracts and sends blood out into the arteries of the body, passing through the aortic valve into the aorta. The auricles thus act as collecting chambers, while the ventricles serve as pumps. The right side of the heart collects the blood and forces it through the lungs; while the left side collects it from the lungs and forces it through the body as a whole. The four valves between the various chambers of the heart prevent the blood from flowing backward and maintain the pressure betwen heartbeats because of the closed system that results.

In order that blood can be moved forward in an orderly manner, it is important that the heart muscles expand and contract at just the right time and that all the valves open and close completely at the proper time during the cycle. This control is accomplished by a special structure known as the *sino-auricular node*. This is the pacemaker of the heart. It is not entirely dependent upon the general nervous system, and it has been known to function for some time after breathing has ceased. Sudden changes in temperature, unusual nervous stimuli, fright, a sense of impending danger, or a happy thought can affect this heart center and, thereby cause speeding or slowing of the heart action. All warm-blooded animals have such a fine adjustment that acceleration or retardation may occur within 1/100th second.

The sino-auricular node lies in the wall of the right auricle, embedded within the muscular tissue. A heavy partition extends between the left and right side of the heart, so that there is no direct connection between them except for a group of structures consisting of the auriculo-ventricular node, the *common bundle* and its left and right branches. The auriculo-ventricular node transmits impulses from the common bundle, also known as the *bundle of His*, thence to