struck, which, as it advances, constantly increases in size and diminishes in force.

73. Somewhat resembling this, is the undulation, or sound-wave, which is imparted by a sonorous vibration to the surrounding atmosphere. The rate of motion of this spherical wave of air is about 1050 feet per second, or one mile in five seconds. In water, sound travels four times as fast as in air, and still more rapidly through solid bodies; along an iron rod, its velocity is equal to two miles per second.

74. The earth, likewise, is a good conductor of sound. It is said that the Indian of our western prairies can, by listening at the surface of the ground, hear the advance of a troop of cavalry, while they are still out of sight, and can even discriminate between their tread and that of a herd of buffaloes. Solid substances also convey sounds with greater power than air. If the ear be pressed against one end of a long beam, the scratching of a pin at the other extremity may be distinctly heard, which will not be at all audible when the ear is removed from the beam. Although air is not the best medium for conveying sound, it is necessary for its production. Sound cannot be produced in a vacuum, as is shown by ringing a bell in the exhausted receiver of an air-pump, for it is then entirely inaudible. But let the air be readmitted gradually, then the tones become more and more distinct, and when the receiver is again full of air, they will be as clear as usual.

75. All sonorous bodies do not vibrate with the same degree of rapidity, and upon this fact depends the *pitch* of the sounds that they respectively produce. The more frequent the number of vibrations within a given time, the higher will be the pitch; and the fewer their number, the lower or graver will it be. Now, the rate of the successive vibrations of different notes has been measured, and it has thus been found that if they are less than sixteen in a second, no sound is audible; while if they exceed 60,000 per second the sound is very faint, and is painful to the ear. The extreme limit of the capacity of the human

ear may be considered as included between these points; but the sounds which we ordinarily hear are embraced between 100 and 3,000 vibrations per second.

76. The *ear*, which is the proper organ of hearing, is the most complicated of all the structures that are employed in the reception of external impressions. The parts of which it is composed are numerous, and some of them are extremely small and delicate. Nearly all these parts are located in an irregularly shaped cavity hollowed out in the temporal, or "temple," bone

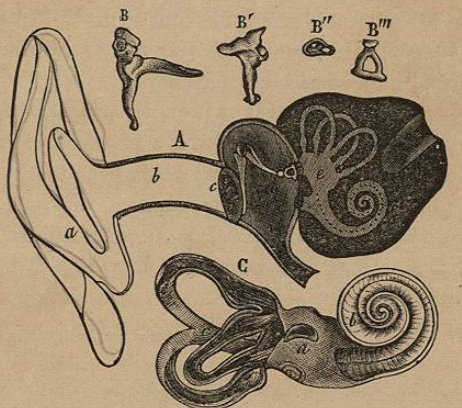

FIG. 41.—THE EAR AND ITS DIFFERENT PARTS.
A, Diagram of the Ear.
a, *b*, External Ear. *d*, Middle Ear.
c, Membrane tympani. *e*, Internal Ear.
B to B‴, Bones of the Middle Ear (magnified).
C, The Labyrinths, or Internal Ear (highly magnified).

of each side of the head. That part of the bone in which the auditory cavity is placed has the densest structure of all bones of the body, and has therefore been called the "petrous," or rocky part of the temporal bone. In studying the ear, it is necessary to consider it as divided into three portions, which are called, from their relative positions, the *external* ear, the *middle* ear, and the *internal* ear. (In the diagram, Fig. 41, A, the first is not shaded, the second is lightly shaded, and the last has a dark background.)

77. The External Ear.—The external portion of the organ of hearing, designated in Fig. 41, A, includes, first, that outer part (*a*), which is commonly spoken of as "the ear," but which in fact is only the portal of that organ; and, secondly, the *auditory canal* (*b*). The former consists of a flat flexible piece of cartilage, projecting slightly from the side of the head, attached to it by ligaments, and supplied with a few weak muscles. Its surface is uneven, and curiously curved, and from its resemblance to a shell, it has been called the *concha*. It probably serves to collect sounds, and to give them an inward direction; although its removal is said not to impair the acuteness of hearing more than a few days.

78. The *auditory canal* Fig. 41, A, *b*), which is continuous with the outer opening of the ear, is a passage, an inch and a quarter in length, its inner extremity being bounded by a closely-fitting, circular membrane. This canal is of oval form, is directed forward and inward, and is slightly curved; so that the inner end is ordinarily concealed from view. The pouch of the skin which lines this passage is smooth and thin, especially at the lower end, where it covers the membrane just mentioned.

79. As in the case of the nostrils, a number of small, stiff hairs garnish the margin of the auditory canal, and guard it, to some extent, against the entrance of insects and other foreign objects. The skin, too, covering its outer half, is furnished with a belt of little glands which secrete a yellow, bitter substance, called "ear-wax," which is especially obnoxious to small insects. As the outer layer of this wax-like material loses its useful properties, it becomes dry, and falls out of the ear in the form of minute, thin scales, a fresh supply being furnished from the little glands beneath. In its form, the auditory canal resembles the tube of an ear-trumpet, and serves to convey the waves of sound to the middle portion of the ear.

80. The Middle Ear, or Tympanum.—The middle ear is a small cavity, or chamber, of irregular shape, about one-fourth of an inch across from side to side, and half an inch long (see Fig, 41, A, *d*). From the peculiar arrangement of its various parts it has very properly been called the *tympanum*, or the "drum of the ear." The middle ear, like the external canal, contains air.

81. The circular membrane, already mentioned as closing the auditory canal, is the partition which separates the middle from the external ear, and is called the *membrana tympani* (*c*), and may be considered as the outer head of the drum of the ear. It is sometimes itself spoken of as the "drum," but this is incorrect; since a drum is not a membrane, but is the hollow space across which the membrane is stretched. This membranous drum-head is very tense and elastic, and so thin as to be almost transparent; its margin is fastened into a circular groove in the adjacent bone. Each wave of sound that touches this delicate membrane causes it to vibrate, and it, in turn, excites movements in the parts beyond.

82. Within the tympanum is arranged a chain of remarkable "little bones," or *ossicles*. They are chiefly three in number, and from their peculiar shapes bear the following names: *malleus*, or the mallet; *incus*, or the anvil; and *stapes*, or the stirrup. A fourth, the smallest bone in the body, in early life intervenes between the incus and stapes, but at a later period it becomes a part of the incus. It is called the *orbicular* bone. Small as are these ossicles—and they, together, weigh only a few grains—they have their little muscles, cartilages, and blood-vessels, as perfectly arranged as the larger bones of the body. One end of the chain of ossicles, the mallet, is attached to the membrane of the tympanum, or outer drum-head, while the other end, the stirrup, is firmly joined by its foot-piece to a membrane in the opposite side of the cavity. The chain, accordingly, hangs suspended across the drum between the two membranes; and when the outer one vibrates under the influence of the sound-wave, the chain swings inward and transmits the vibration to the entrance of the inner ear.

83. The musical instrument, the drum, is not complete if the air within be perfectly confined; we therefore find in all instruments of this kind a small opening in the side, through which air may pass freely. The tympanum, or drum of the ear, in like manner has an opening by means of which it communicates freely with the external air. This opening is a narrow canal, about an inch and a half long, called the *Eustachian tube*, after the name of its discoverer, Eustachius.

84. The course of this passage is indicated in Fig. 42, I,

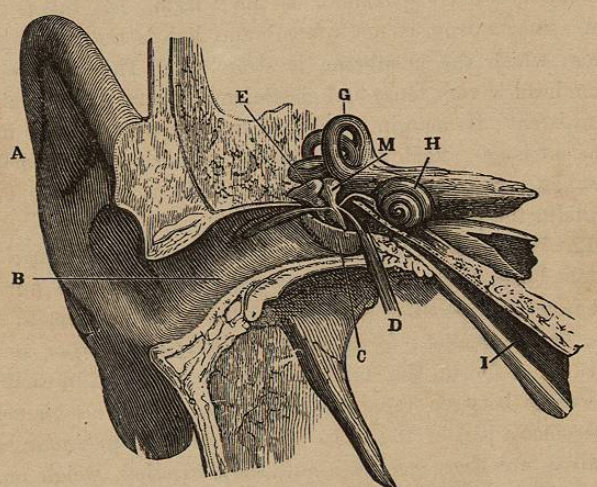

FIG. 42.—SECTION OF THE RIGHT EAR.

A, The Concha.
B, Auditory Canal.
C, Membrane of the Drum, (the lower half.)
D, A small muscle.
E, Incus, or Anvil.
M, Malleus, or Mallet.
I, Eustachian Tube.
G, Semicircular Canals
H, Cochlea, or snail's shell.

directed downward and inward: its other extremity opens into the upper part of the throat. The passage itself is ordinarily closed, but whenever the act of swallowing or gaping takes place, the orifice in the throat is stretched open, and the air of the cavity of the tympanum may then be renewed.

85. The Eustachian tube serves, also, as an escape-pipe for the fluids which form within the middle ear; and hence, when its lining membrane becomes thickened, in consequence of a cold, or sore throat, and the passage is thus more or less choked up, the fluids are unable to escape as usual, and therefore accumulate within the ear. When this takes place, the vibrations of the membrane are interfered with; the sounds heard appear muffled and indistinct; and a temporary difficulty of hearing, which is known as "throat-deafness," is the result. This result resembles the effect produced by interrupting the vibrations of a sonorous body, such as all are familiar with; if the finger be placed upon a piano-string or bell when it is struck, the proper sound is no longer fully and clearly emitted. But the primary use of this tube is to afford a free communication between the middle ear and the external atmosphere, and thus secure an equal pressure upon both sides of the membrane of the drum of the ear, however the density of the atmosphere may vary. If from undue tension of the membrane, pain is experienced in the ears, when ascending into a rare atmosphere, as in a balloon, or descending into a dense one, as in a diving-bell, it may be relieved by repeating the act of swallowing, from time to time, in order that the inner and outer pressure may thus be promptly equalized.

86. The Internal Ear, or Labyrinth.—The most essential part of the organ of hearing is the distribution of the *auditory nerve*. This is found within the cavity of the internal ear, which, from its exceedingly winding shape, has been termed the *labyrinth* (see Fig. 42, C). This cavity is hollowed out in dense bone, and consists of three parts; the *vestibule* (*a*), or ante-chamber, which is connected with the other two; the *cochlea* (*b*), or snail's shell; and the three *semicircular canals* (*c*). The manner in which the nerve of hearing is distributed is remarkable, and is peculiar to this nerve. In the vestibule and the canals its fibres are spread out over the inner surface, not of the bony cavity but of a membranous bag, which conforms to

and partially fills that cavity; and which floats in it, being both filled and surrounded with a clear, limpid fluid.

87. A singular addition to the mechanism of hearing is observed within this membranous bag of the labyrinth. This consists of two small oval ear-stones, and a quantity of fine powder of a calcareous nature, which is called "ear-sand." When examined under the microscope, these sandy particles are seen to lie scattered upon and among the delicate filaments of the auditory nerve; and it is probable, that, as the tremulous sound-wave traverses the fluid of the vestibule, the sand rises and falls upon the nerve filaments, and thus intensifies the sonorous impression.

88. In the cochlea, or snail's shell, which contains the fluid, but no membrane, the nerve branches upon a spiral shelf. As many as three thousand nerve fibres of different lengths have been counted therein; these, it has been thought, form the grand, yet minutely small key-board, upon which strike all the musical tones that are destined to be conveyed to the brain. The vestibule, it is also supposed, takes notice of noise as distinguished from musical sounds; while the office of the semicircular canals is, in part at least, to prevent internal echoes, or reverberations.

89. The vestibule communicates with the chain of bones of the middle ear by means of a small opening, called the "oval window," or *fenestra ovalis*. Across this window is stretched the membrane, which has already been alluded to as being joined to the stirrup-bone of the middle ear. Through this window, then, the sound-wave, which traverses the external and middle ear, arrives at last at the labyrinth. The limpid fluid which the latter contains, and which bathes the terminal fibres of the nerve of hearing, is thus agitated, the nerve-fibres are excited, and a sonorous impression is conducted to the brain, or, as we say, a sound is heard.

90. Protection of the Sense of Hearing.—From what has been seen of the complicated parts which compose the organ of

hearing, it is evident that while many of them possess an exquisite delicacy of structure, Nature has well and amply provided for their protection. We have observed the concealed situation of the most important parts of the mechanism of the ear, the length of its cavity, its partitions, the hardness of its walls, and its communication with the atmosphere; all these provisions rendering unnecessary any supervision or care on our part in reference to the interior of the ear. But in respect to its external parts, which are under our control and within the reach of harm, it is otherwise. We may both observe the dangers which threaten them, and learn the means necessary to protect them.

91. One source of danger to the hearing consists in lowering the temperature of the ear, especially by the introduction of cold water into the auditory canal. Every one is familiar with the unpleasant sensation of distension and the confusion of sounds which accompany the filling of the ear with water when bathing: the weight of the water within it really distends the membrane, and the cold chills the adjacent sensitive parts. It is not surprising, therefore, that the frequent introduction of cold water and its continued presence in the ear enfeeble the sense of hearing. Care should be taken to remove water from the ear after bathing, by holding the head on one side, and, at the same time, slightly expanding the outer orifice, so that the fluid may run out. For a like reason, the hair about the ears should not be allowed to remain wet, but should be thoroughly dried as soon as possible.

92. Caution.—It may be stated as a general rule, to which there are but few exceptions, that no cold liquid should ever be allowed to enter the ear. When a wash or injection is rendered necessary, it should always be warmed before use. The introduction of cold air is likewise hurtful, especially when it pours through a crevice directly into the ear, as it may often do through the broken or partially closed window of a car. The avoidance of this evil gives rise to another almost as great; namely, the in-

troduction of cotton or other soft substances into the ear to prevent it from "catching cold." This kind of protection tends to make the part unnaturally susceptible to changes of temperature, and its security seems to demand the continued presence of the "warm" covering. As a consequence of its presence, sounds are not naturally conveyed, and the sensitiveness of the nerve of hearing is gradually impaired.

93. The chief source of injury, however, to the ear is from the introduction of solid substances into the auditory canal, with the design of removing insects or other foreign objects that have found their way into the ear; or with the design of scraping out the ear-wax. For displacing a foreign object, it is usually sufficient to syringe the ear gently with warm water, the head being so held that the fluid easily escapes. If a live insect has gained entrance to the ear, it may first be suffocated by pouring a little oil upon it, and afterward removed by syringeing the ear as just mentioned.

94. The removal of ear-wax is generally unnecessary; for, as we have before seen, Nature provides that the excess of it shall become dry, and then spontaneously fall out in the form of fine scales. The danger from the introduction of solid implements into the outer ear is chiefly found in the fact that the membrane which lies at the bottom of it is very fragile, and that any injury of it is liable to be permanent, and to impair permanently the hearing of the injured ear.

QUESTIONS FOR TOPICAL REVIEW.