arrangement of the pillars, or rods of Corti. They are nearly homogeneous, except when treated with reagents, and are said to be of about the consistence of cartilage. They are closely set together, with very narrow spaces between them, and it is difficult to see how they can be stretched to any considerable degree of tension. The arch is longer at the summit than at the base of the cochlea, the longest rods, at the summit, measuring, according to Pritchard, about $\frac{1}{200}$ of an inch (125 μ), and the shortest, at the base, about $\frac{1}{500}$ of an inch (50 μ). At the base of the cochlea the two sets of rods are about equal in length. From the base to the apex, both sets, outer and inner, progressively increase in length, and the outer rods become the longer, so that near the apex they are nearly twice as long as the inner. The anatomical relations between the pillars and the terminal filaments of the auditory nerves are not definitely settled.

In addition to the pillars just described, various cellular elements enter into the structure of the organ of Corti. The most important of these are the inner and the outer hair-cells. These are 16,400 to 20,000 in number (Hensen, Waldeyer). The inner hair-cells are arranged in a single row, and the outer hair-cells, in three rows. Nothing definite is known of the uses of these cells. The relations of these parts are shown in Fig. 274. It is supposed by some anatomists that the filaments of the auditory nerves terminate in the cells above described; but this point is not definitely settled.

Uses of Different Parts of the Internal Ear.

The precise uses of the different parts found in the internal ear are obscure, notwithstanding the careful researches that have been made into the anatomy and the physiology of the labyrinth. There are several points, however, bearing upon the physiology of this portion of the auditory apparatus, concerning which there can be no doubt:

First, it is certain that impressions of sound are received by the terminal filaments of the auditory nerves and by these nerves are conveyed to the brain.

Second, the uses of the parts composing the external and the middle ear are chiefly accessory. The sonorous waves are collected by the pavilion and are conveyed by the external meatus, to the middle ear; the membrana tympani vibrates under their influence; and they are thus collected, repeated and transmitted to the internal ear.

Uses of the Semicircular Canals.—In the experiments of Flourens, upon pigeons and rabbits (1824), it was shown that destruction of the semicircular canals had apparently no effect upon the sense of hearing, while destruction of the cochlea upon both sides produced complete deafness. In addition it was observed that destruction of the semicircular canals on both sides was followed by remarkable disturbances in equilibration. The animals could maintain the standing position, but so soon as they made any movements, "the head began to be agitated; and this agitation increasing with the movements of the body, walking and all regular movements finally became impossible, in nearly the same way as when equilibrium and stability of move-

ments are lost after turning several times or violently shaking the head." These observations of Flourens, at least as far as regards the influence of the semicircular canals upon equilibration, have been confirmed by Goltz and are sustained by observations upon the human subject in the condition known as Ménierè's disease. As far as can be judged from experimental *data*, it does not seem probable that the nerves directly concerned in audition are distributed to any considerable extent in the semicircular canals. Indeed the uses of these parts is exceedingly obscure; for it can hardly be admitted, upon purely anatomical grounds, that they are concerned in the discrimination of the direction of sonorous vibrations, an idea which has been advanced by some physiologists.

Uses of the Parts contained in the Cochlea.—There can be no doubt with regard to the capital point in the physiology of the cochlea; namely, that those branches of the auditory nerve which are essential to the sense of hearing and which receive the impressions of sound are distributed mainly in the cochlea. An analysis of sonorous impressions shows that they possess various attributes, such as intensity, quality and pitch. As far as the terminal filaments of the auditory nerve are concerned, it is evident that the intensity of sound is appreciated in proportion to the power of the impression made upon these nerves. With regard to quality of sound, it has been seen that this is due to the form of sonorous vibrations, and that musical sounds usually are compound, their quality depending largely upon the relative power of the harmonics, partial tones etc. It has also been seen that consonating bodies repeat by influence, not only the actual pitch of tones, but their quality. If there be in the cochlea an anatomical arrangement of rods or fibres by which the sonorous vibrations conveyed to the ear by the atmosphere are repeated, there is reason to believe that the quality as well as the pitch is reproduced.

The arrangement of the rods which enter into the structure of the organ of Corti has afforded a theoretical explanation of the final mechanism of the appreciation of pitch. With the exception of the internal ear, the action of different portions of the auditory apparatus is simply to conduct and repeat sonorous vibrations; and the sole use of these accessory parts, aside from the protection of the organs, is to convey the vibrations to the terminal, nervous filaments. Whatever be the uses of the membrana tympani in repeating sounds by influence, it is certain that this membrane possesses no true, auditory nerves, and that the auditory nerves only are capable of receiving impressions of sound. Thus hearing, and even the appreciation of pitch, is not necessarily lost after destruction of the membrana tympani; and if sonorous vibrations reach the auditory nerves, they will be appreciated and appreciated correctly.

In view of the arrangement of the organ of Corti, with its eleven thousand or more rods of different lengths arranged with a certain degree of regularity, a number more than sufficient to represent all the notes of the musical scale, it is not surprising that they should be regarded as capable of repeating all the notes heard in music. Helmholtz formulated this idea in the theory that

sounds conveyed to the cochlea throw into vibration only those elements of the organ of Corti which are tuned, so to speak, in unison with them. According to this hypothesis, the rods of Corti constitute a harp of several thousand strings, played upon, as it were, by the sonorous vibrations. Theories analogous to the one proposed by Helmholtz, but of course lacking the basis of exact anatomical and physical details developed by modern researches and experiments, were advanced by Du Verney (1683) and by Le Cat (1767).

Viewing the question anatomically, it is by no means certain that the rods of Corti are so attached and stretched that they are capable of separate and individual vibrations. It has not been demonstrated that certain of these rods vibrate under the influence of certain notes or that they are tuned in accord with certain notes. Hensen and others have rejected the theory of Helmholtz, basing their opinions mainly upon the anatomical arrangement of the rods of Corti. Hensen assumed it to be a physical impossibility for the different rods to vibrate individually, and he regarded it as improbable that the rods are tuned in accord with different musical notes. Similar objections apply to the theory that different transverse fibres in the membrana basilaris vibrate in accord with particular notes. There is, indeed, no theory which affords an entirely satisfactory explanation of the mechanism of the final appreciation of the pitch of musical sounds.

It is not absolutely necessary that sonorous vibrations should pass to the cochlea through the external ear and parts in the middle ear. Sounds may be conducted to the auditory nerves through the bones of the head or through the Eustachian tube, as is shown by the simple and familiar experiment of placing a tuning-fork in contact with the head or between the teeth, the ears being closed.

The action of the two ears does not seem to be absolutely necessary to the correct appreciation of auditory impressions; but variations in the force of such impressions, made upon either ear, aid in determining the direction of sounds, although errors are often made in this regard.

The estimate of the distance of sounds is made by judging of the intensity, in connection with information obtained through other senses, especially the sense of sight. The power of estimating distance is largely influenced by experience and education.

Centres for Audition.—The centres for audition in dogs and monkeys are in the superior temporo-sphenoidal convolution (Ferrier, Munk). In man these centres are in the first (superior) and second temporal convolutions of the temporo-sphenoidal lobe, which are supplied by the fourth branch of the middle cerebral artery. This has been ascertained by pathological observations as well as by experiments on the lower animals. In man the action of these centres is not completely crossed, and destruction of the centre upon one side does not cause complete deafness in either ear. Complete destruction of the centres on both sides, however, produces total deafness. Injury of the first temporal convolution is often followed by the condition known as word-deafness, in which the subject hears the sound of words, but these sounds convey to him no idea. This is the psychical, auditory centre,

and it is confined to the first temporal convolution on the left side (Wernicke). Word-deafness is analogous to the condition already described under the name of word-blindness, and the centre usually is confined to the left side of the cerebrum. It has been suggested by Westphal that this centre may be on the right side of the cerebrum, in left-handed persons.

CHAPTER XXIV.

ORGANS AND ELEMENTS OF GENERATION.

General considerations—Female organs of generation—General arrangement of the female organs—The ovaries—Graafian follicles—The parovarium—The uterus—The Fallopian tubes—Structure of the ovum—Discharge of the ovum—Passage of ova into the Fallopian tubes—Puberty and menstruation—Changes in the Graafian follicle after its rupture (corpus luteum)—Male organs of generation—The testicles—Vesiculæ seminales—Prostate—Glands of the urethra—Male elements of generation—Spermatozoids.

GENERATION is one of the most important of the animal functions, and as such usually is treated of quite fully in works upon physiology; but a more or less extended account of this function is also to be found in every complete treatise on anatomy and in most works on obstetrics. While the physiological history of the human organism would not be complete without touching upon generation and development, it does not seem desirable to give a very full description of these processes, in which there would necessarily be a repetition of what is always to be found in works upon other subjects.

The question of so-called spontaneous generation in some of the lower animals was formerly much discussed by physiologists. This, however, is now of purely historical interest. As actual knowledge of facts has accumulated, the limits of what was thought to be spontaneous generation have become more and more restricted; until now it is generally admitted that spontaneous generation does not exist in the history of animals. The entire question, therefore, may be dismissed with this simple statement. There are, however, certain distinct forms of generation; but the only one that has any considerable importance in connection with human physiology is generation of new beings by the union of male and female elements in the fecundation of the ovum, with the development of the fecundated ovum. This is known as sexual generation. The two elements of generation are developed in separate beings, male and female, and these elements are brought together normally in what is known as sexual connection, or copulation.

FEMALE ORGANS OF GENERATION.

A knowledge of certain points in the anatomy of the female organs of generation is essential to the comprehension of the most important of the processes of reproduction. Following a fruitful intercourse of the sexes,