slightly. It then turns sharply backward and is horizontal near the middle third, where it again changes its course, the inner portion curving forward and decidedly downward.

In the cartilaginous floor of the canal are found one small and two large fissures running in a circular manner, called the fissures of Santorini. These spaces are filled

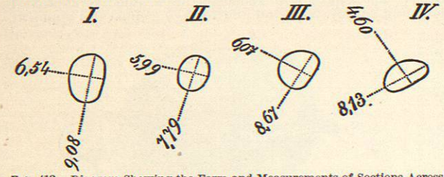

FIG. 413.—Diagram Showing the Form and Measurements of Sections Across the External Auditory Meatus. (From Schaefer, after Bezold.) *I.*, At commencement of cartilaginous portion; *II.*, near end of cartilaginous portion; *III.*, near beginning of osseous portion; *IV.*, near end of osseous portion. (The measurements are in millimetres.)

in with fibrous tissue and allow the passage of blood-vessels; at the same time they permit free motion of the canal, thus favoring the straightening of the meatus during examinations with the speculum. These fissures are sometimes the channel through which an abscess in the parotid gland may find its exit.

The canal is lined by a continuation of the cutaneous covering of the auricle. In the cartilaginous portion the skin is 1 to 2 mm. in thickness and loosely attached to the perichondrium. In the bony canal it is thinner and firmly united to the periosteum.

Kaufman describes a number of ridges or vascular

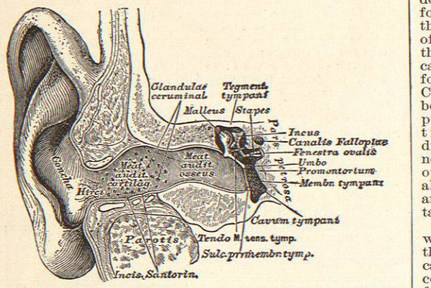

FIG. 414.—Vertical Section of the External Auditory Canal and Tympanic Cavity. (After Heitzmann.)

papillæ which occupy a circular position in the skin of the osseous portion of the canal, close to the membrana tympani, and which, in inflammatory conditions of the canal, may become quite large. Politzer states that these papillæ are often the starting point for polypi. At the inner end the skin continues over the membrana tympani and forms its outer layer.

Throughout the cartilaginous part, and extending in a triangular manner into the upper and back wall of the osseous canal, are found numerous hairs and sebaceous glands, and in addition, large oval, convoluted tubular glands resembling in form and structure the sweat gland —the *Glandulæ Ceruminosæ*. These glands secrete the cerumen or ear wax, and are found opening into and around the hair follicles. The hair development is sometimes abundant. The sebaceous glands secrete a small quantity of oily material for lubrication of the skin. The secretion from the ceruminous glands when first discharged is of a yellowish brown color and soft in consistency, but in a short time evaporation of the watery elements causes the mass to thicken and it becomes darker. Often it becomes inspissated, and by blocking the canal gives rise to much temporary discomfort. The function of the cerumen is probably to protect the ear from the entrance of insects and foreign particles that may get into the canal.

Röhrer found a number of organisms to exist in plugs of ear wax. It is of a pungent, bitter taste, and chemically, in addition to oil from the sebaceous glands, is made up of a dry material not soluble in water, alcohol, or ether, and of potash, stearin, a trace of soda and lime, and 0.1 per cent. water, mixed with numbers of broken-down epidermic exfoliations and loose hairs.

Of the very greatest importance to the aural surgeon is the surgical anatomy and relationship of the canal. These differ somewhat in the ear at birth and in the adult. At birth the only portion of the canal found to be bony is the *annulus tympanicus*. This is attached to the squama in front, below and behind to the petro-mastoid portion. Along the external margin of this ring are seen two small tubercles that are the starting points for the future bone development forming the anterior and lower wall of the canal. They do not immediately unite as one process, often leaving a gap until after the fifth or sixth year.

The roof of the canal is formed from the squama. As development takes place the portion below the temporal line assumes a horizontal position and presents two plates of bone containing between them honeycombed spaces. The superior plate forms a part of the floor of the middle cranial fossa and has resting upon it the dura mater. The lower plate, near its inner extremity, suddenly drops down in such a manner as to become wedge-shaped; it forms the outer wall of the attic of the tympanum, called the scutum, and gives attachment to the upper margin of the drum head. The cell spaces contained between the plates of the roof of the canal frequently communicate with the antrum and with the pneumatic spaces found as far forward as the root of the zygomatic process. Clinically these spaces are of importance since they may be the seat of suppuration in conjunction with mastoid diseases, and must not be overlooked in operations in which all the cellular spaces are suspected of containing pus.

The anterior bony wall of the meatus is the thinnest of the canal. It is slightly convex on the meatal face. Its front surface assists in the formation of the glenoid cavity in which rest the condyle of the lower jaw and part of the parotid gland. Blows on the lower jaw are therefore likely to fracture the wall of the canal. The floor is formed by the bony growth of the tympanic ring. It is thick and compact; toward the meatus the surface is convex except close to the membrana tympani, where a small concavity is found—"the Sinus of Meyer"—in which foreign bodies may lodge. The position of this concavity is such that it is often difficult to detect the presence of these foreign bodies and to remove them.

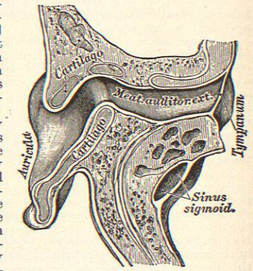

FIG. 415.—Horizontal Section of the Left External Auditory Canal. (After Heitzmann.)

The posterior wall of the osseous meatus is of much

surgical importance. It is formed by the union of the tympanic ring with the squama, and later with the anterior plate of the developed mastoid, this plate being quite thin and separating the canal from the cell spaces contained in the mastoid. Often the groove for the lateral sinus is in close proximity to this wall.

At the juncture of the upper and the posterior wall the scutum forms a portion of the outer wall of the mastoid antrum. In suppurative diseases of the tympanic cavity often carious tracts (fistulæ) are found in this region; they lead into either the tympanic attic or the antrum of the mastoid, and call for surgical interference. Just external to the upper posterior margin is often found a small bony spine—the supra-meatal spine—which is of value as a surgical landmark in the operation for opening the mastoid antrum.

In the fully developed ear the drum head is placed in an oblique position, the upper and back part forming an obtuse angle of about 135°, while the lower and anterior portion forms an acute angle of about 40°, with the canal wall.

The arterial supply to the auditory canal is quite abundant. The posterior auricular, a branch of the external carotid, sends a branch called the auricular. It passes in at the junction of the cartilaginous with the bony canal, and supplies the back wall of the canal, anastomosing with the anterior auricular, a branch of the temporal, which enters the anterior wall of the canal behind the condyle of the lower jaw. The tympanic branch of the internal maxillary enters the tympanic cavity through the Glaserian fissure, and sends a branch that supplies the skin of the canal adjacent to the membrana tympani. The veins take an irregular course. They empty their blood either directly (and this is the rule) into the external jugular or indirectly by way of the temporal or the internal maxillary vein.

The nerve supply is, first, from the auriculo-temporal branch of the inferior maxillary division of the fifth nerve. Three small branches of this nerve supply the skin on the anterior wall and in the cartilaginous portion. Second, the auricular branch of the pneumogastric—"Arnold's nerve"—enters the back wall of the canal at its junction with the mastoid, and supplies the larger portion of the bony canal and a part of the back wall of the cartilaginous section. Irritation of this nerve by the accumulations of wax, by foreign bodies, or by the speculum when the ear is being examined or cleansed, produces the familiar reflex ear cough.

But little seems to be known regarding the lymphatic vessels contained in the walls of the external canal. Politzer states that they are probably connected with the lymphatic glands overlying the parotid, by way of the fissures of Santorini, since it is a matter of clinical observation that swelling of the lateral cervical glands often occurs in inflammatory conditions affecting the meatus.

The skin lining the auditory canal maintains all the histological characteristics of the skin in other parts of the body, although that part which lines the bony canal becomes very firmly united to the periosteum and altered in color. In its development there is a gradual growth outward of the skin, thus producing a constant tendency for the ear wax to move outward, this being further facilitated by the pressure of the condyle of the jaw, which in mastication constantly pushes the parotid gland against the anterior wall of the canal and somewhat influences its lumen.

The sinuous course of the canal is such that sound waves do not strike the membrana tympani directly, but are reflected from the walls of the canal and are thus modified in their intensity. Politzer states that the two most important points where this reflection takes place are on the back wall of the cartilaginous canal and on the anterior inferior portion of the bony canal.

The size of the canal plays no influence in the acuteness of hearing, although Burnett observes that large straight canals are more likely to be found in those possessing a so-called ear for music. *J. Morrison Ray.*

AUDITORY NERVE AND ITS END ORGANS.—COMPARATIVE ANATOMY AND PHYLOGENY.—The functions of audition and equilibration seem to be closely associated throughout the animal kingdom. The so-called auditory organs, or otocysts, of the invertebrates, if we may trust the results of most recent experimental studies, are in the majority of cases concerned largely, if not wholly, with equilibrium, though in some cases (notably among insects) true auditory organs undoubtedly exist. The structure of these organs is usually similar to that of the organs in the labyrinth of vertebrates.

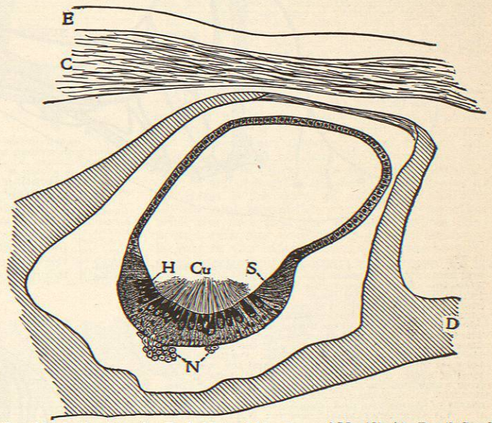

FIG. 416.—Section through a Typical Lateral-Line Organ of *Menidia* (the Fourth Canal Organ of the Mandibular Line of Fig. 417). *C*, Corium; *Cu*, cupula, composed of hairs from the hair cells matted together and more or less gelatinized; *D*, dentary bone; *E*, epidermis; *H*, hair cells, or specific sensory cells; *N*, nerve fibres supplying the latter; *S*, supporting cells.

For the proper morphological comprehension of the eighth nerve and its terminal organs we must look far back to the early phylogenetic stages of its development in the vertebrates. The fishes possess a system of cutaneous and subcutaneous sense organs, the so-called lateral-line organs (Fig. 416), widely distributed over the head and trunk. Part of these are in canals (the lateral-line or "mucous" canals), and part are variously distributed over the skin, either naked or sunken in separate pits (the pit organs of ganoids and ampullæ of elasmobranchs); but all closely resemble structurally the maculæ and cristæ of the internal ear, and all are innervated by nerves which arise with the auditory nerve from the tuberculum acusticum. These lateral-line nerves go out with the vagus and facial roots and are conventionally associated with these nerves. They have, however, really nothing to do with them, but are more logically associated with the auditory nerve to comprise the "acustico-lateralis" system of nerves (*cf. Cranial Nerves*). The peripheral distribution of this component in a typical fish is expressed in the accompanying diagram (Fig. 417).

The chief function of the acustico-lateral system of nerves in the fishes is undoubtedly equilibration. This has been demonstrated not only for the nerves of the lateral lines, but for the eighth nerve as well. Compare especially the experimental work of Lee. This author goes so far as to deny the sense of hearing to the fishes altogether, a position which is doubtless too extreme; yet it is clear that hearing, as we understand the term, plays a very subordinate rôle with these animals.

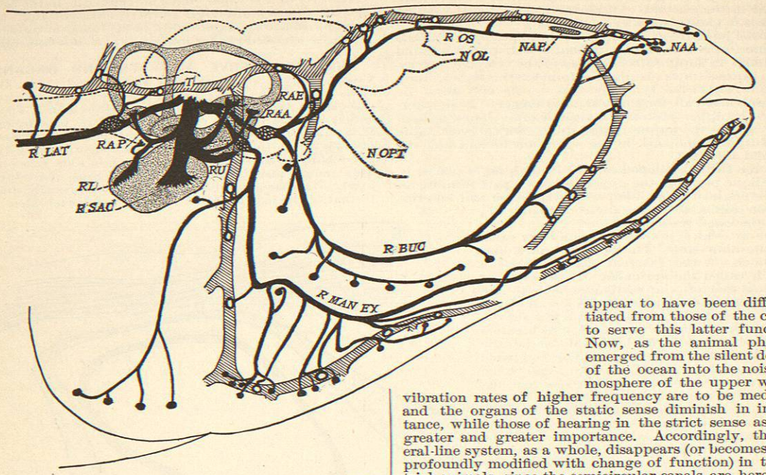

FIG. 417.—The Acustico-Lateral System of Nerves with Their Peripheral End Organs, as Seen from the Right Side, in the Silver Side, *Menidia*. Reconstructed from serial sections by projection upon the sagittal plane. ×12. The dotted outline represents the position of the brain, the lateral-line canals are shaded with cross-hatching, the auditory labyrinth is stippled, and the nerves are drawn in black. The organs of the lateral-line system are drawn as black discs when naked on the surface of the skin, and as black circles when lying in the canals. For the relation between the acustico-lateral nerves and the other systems of nerves in this fish, see the more detailed plot from which this was drawn off, in the *Journal of Comparative Neurology*, vol. ix., plate xv., or the *Archives of Neurology and Psychopath.*, vol. ii., plate ii. *NAA*, anterior nasal aperture; *NAP*, posterior nasal aperture; *N OL*, olfactory nerve; *N OPT*, optic nerve; *RAA*, ramulus acusticus ampullæ anterioris; *RAE*, ramulus acusticus ampullæ externæ; *RAP*, ramulus acusticus posterioris; *R BUC*, ramus buccalis facialis; *RL*, ramulus acusticus lagenæ; *R LAT*, ramus lateralis vagi; *R OS*, ramus ophthalmicus superficialis facialis; *R MAN EX*, ramus mandibularis externus facialis; *R SAC*, ramulus acusticus sacculi; *RU*, ramulus acusticus recessus utriculi; *T*, tuberculum acusticum.

Fishes, which have to maintain their equilibrium in a fluid medium, require a much more elaborate mechanism for the control of the spatial relations of the body than do the terrestrial animals. But the same organs which are adapted to receive stimuli from the pulsations of the fluid within the semicircular and lateral-line canals, due to changes in the position of the body, may also serve to register vibrations of low frequency arising outside of the body, such as the beating of the surf or the movements of the fins of an approaching enemy. The sensory spots of the utriculus, sacculus, and lagena would appear to have been differentiated from those of the canals to serve this latter function. Now, as the animal phylum emerged from the silent depths of the ocean into the noisy atmosphere of the upper world, vibration rates of higher frequency are to be mediated and the organs of the static sense diminish in importance, while those of hearing in the strict sense assume greater and greater importance. Accordingly, the lateral-line system, as a whole, disappears (or becomes very profoundly modified with change of function) in terrestrial animals, since the semicircular canals are here able to perform its functions, while the papilla lagenæ of the

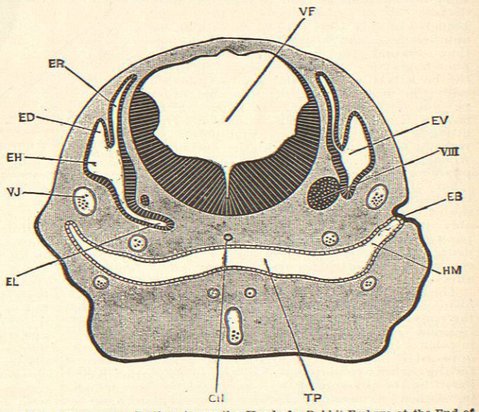

FIG. 418.—A Transverse Section Across the Head of a Rabbit Embryo at the End of the Eleventh Day. The plane of the right half of the figure is slightly anterior to that of the left half. ×30. From Marshall's "Embryology." *CH*, notochord; *EB*, membrane closing the hyomandibular cleft; *ED*, common stem of the two vertical semicircular canals; *EH*, rudiment of the external semicircular canal; *EL*, cochlear canal; *ER*, recessus vestibuli; *EV*, auditory vesicle; *HM*, hyomandibular pouch; *TP*, pharynx; *VF*, fourth ventricle; *VJ*, jugular vein; *VIII*, auditory nerve.

fishes undergoes a succession of metamorphoses until it appears as the cochlea of the mammals.

These alterations in the relative importance of the different members of the acustico-lateral complex are naturally reflected in the central nervous system. We therefore find that the size of the acustico-lateral centres (tuberculum acusticum and cerebellum) in the fishes is directly proportional to that of the peripheral organs of this system. With the development of a cochlea in the mammals, an entirely new set of connections is effected in the oblongata, which are by no means so closely related to the cerebellum as are the end stations of the vestibular root. These are the ventral and dorsal cochlear nuclei, the latter of which projects into the floor of the fourth ventricle, forming the "tuberculum acusticum" of human anatomy. It will be seen, therefore, that this structure is not homologous with the protuberance of the oblongata so named in the fishes, as the latter is the terminal nucleus of the vestibular and lateral-line roots. In connection with the fact that the secondary fibres connected with the cochlear root terminate very largely in the inferior member of the corpora quadrigemina (see below), it is interesting to note that this body appears upon the surface of the brain in the phylogeny contemporane-

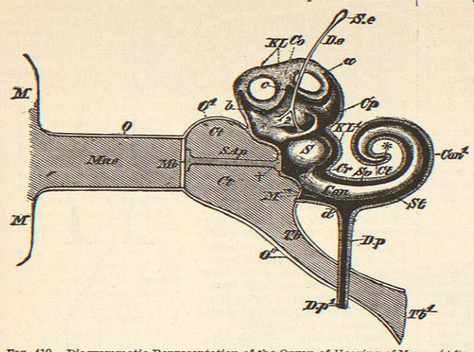

FIG. 419.—Diagrammatic Representation of the Organ of Hearing of Man. (After Wiedersheim.) *Outer ear*—*M*, *M*, auricle; *Mae*, meatus auditorius externus; *O*, its wall; *Mt*, membrana tympani. *Middle ear*—*Ct*, *Ct*, cavum tympani; *O*¹, its wall; *SAp*, sound-conducting apparatus, which is drawn as a simple rod-like body instead of the auditory ossicles; the place † corresponds to the stapedial plate, which closes the fenestra ovalis; *Tb*, Eustachian tube; *Tb*¹, its opening into the pharynx; *O'*, its wall. *Inner ear*—The bony labyrinth, *KL*, *KL*¹, for the most part cut away; *S*, sacculus; *a*, *b*, the two vertical semicircular canals, of which one (*b*) is cut through; *S.e*, *D.e*, saccus and ductus endolymphaticus, of which the latter is divided at 2 into two arms; *Op*, cavum perilymphaticum; *Cr*, canalis reuniens; *Con*, membranous cochlea, which produces at * the vestibular caecum; *Con*¹, bony cochlea; *Sc* and *St*, scala vestibuli and scala tympani, which at * communicate with each other at the cupula terminalis (*Ct*); *D.p*, ductus perilymphaticus, which arises from the scala tympani at *d* and opens out at *D.p*¹. The horizontal semicircular canal is not especially designated.

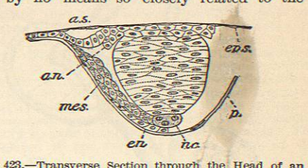

FIG. 423.—Transverse Section through the Head of an Embryo of the Sea Bass of Thirty-five Hours. (After H. V. Wilson.) *a.n.*, Auditory nerve; *a.s.*, auditory saucer; *en*, entoderm; *ep.s.*, epidermic stratum of ectoderm; *mes.*, mesoderm; *n.c.*, notochord; *p.*, periblast. The large oval mass of cells in the centre of the figure is the medulla oblongata.

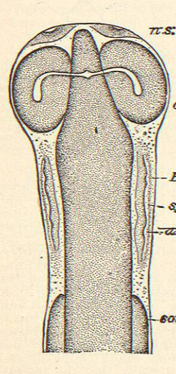

FIG. 420.

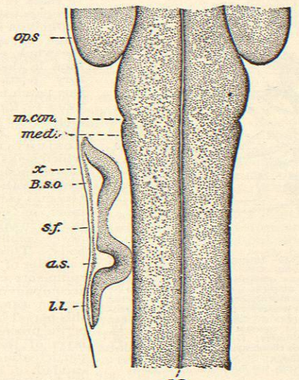

FIG. 421.

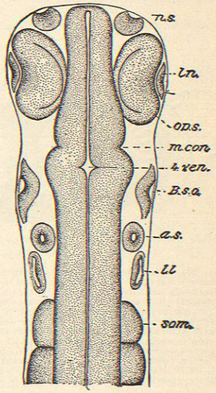

FIG. 422.

FIGS. 420–422.—Surface Views of Embryos of the Sea Bass of Thirty-three, Thirty-seven, and Forty-five Hours. (After H. V. Wilson.) *a.s.*, Auditory sac; *B.s.o.*, pre-auditory lateral-line rudiment; *c.c.*, canalis spinalis; *l.l.*, post-auditory lateral-line rudiment; *ln.*, lense; *m. con.*, constriction separating medulla from mid-brain; *med.*, medulla oblongata; *n.s.*, nasal sac; *op.s.*, optic sac; *s.f.*, sensory furrow, common acustico-lateral rudiment; *som.*, somites; *4 ven.*, fourth ventricle.