the measures already described do not afford relief in the course of a few hours local blood-letting may be resorted to by means of an artificial or a natural leech, to be placed over the tragus or at the opening of the auditory canal. The use of sweet oil and of other greasy substances should never be allowed, as they do no good and may possibly do some harm. Laudanum, atropine, morphine, and cocaine have been highly recommended by some for instillation into the ear for the relief of pain. Recent experiments, however, have shown that a concentrated solution of cocaine, allowed to remain in the canal in such a manner as to cover the drumhead, had no anæsthetic effect whatever on the parts. It is a question whether it is not the heat of the solutions used, rather than the therapeutic value of the drugs which they contain, which affords the relief that is sometimes obtained. If depletion and the means enumerated do not afford prompt relief, and if the drumhead is seen to be bulging and infiltrated, an incision should be made at once through the tense tissues. A simple paracentesis or linear puncture, which may answer in the milder forms, does not always suffice in these cases, especially if the membrane is much swollen. The point of the knife should be made to enter at the upper posterior portion of the membrane, in the part which bulges most prominently, and, after penetrating as far as possible into the deep connective tissue, it should be carried far downward in a slightly curving direction. The utmost care should be exercised not to injure the ossicles. Before an incision is made the canal must be rendered as thoroughly aseptic as possible by first syringing with bichloride of mercury solution (1 to 2,000) and then swabbing the walls with alcohol. The surgeon's hands and instruments should be sterilized and every known antiseptic precaution should be used. After the incision has been made the ear should be cleansed of the discharge by the surgeon with sterilized cotton. The method employed by the author is to twist cotton on a holder, then to pass it through a flame before putting it into the canal. This is done at each visit, pains being taken to cleanse the ear very thoroughly. Between visits the nurse is instructed to renew the cotton in the ear as fast as it becomes wet through, each piece of cotton being handled with forceps and passed through a flame before it is placed in the meatus. In this way, so far as in the surgeon's power lies, every chance for infection from handling is removed. The ear is never syringed unless the discharge becomes decidedly purulent. Placing the patient in favorable surroundings, using whatever constitutional treatment may seem to be indicated, and caring for the ear in some such way as has just been described, establishes those conditions in which the disease is most likely to pursue an uncomplicated course. When the discharge becomes distinctly purulent and profuse it must be removed from the canal as often as it may seem best in any individual case—*i.e.*, from say three times a day to as often as every hour or two. The best manner of removing it is by gentle syringing, using warm water with sodium bicarbonate (a four-per-cent. solution), or a saturated solution of boric acid, or a bichloride solution (1 to 5,000). The sodium bicarbonate solution is the best, as it dissolves the mucus or renders it less adhesive, and at the same time is harmless. The bichloride solution should never be used in children on account of the danger of its passing through the Eustachian tube and being swallowed.

Solutions used in syringing the ear must always be warm and non-irritating, especially after the perforation has taken place. During the acute stage, previous to the establishment of a perforation, they should be used as hot as possible—the hotter the better. In some influenza cases, however, when there are numerous blood blisters on the drumhead and neighboring parts of the canal, the heat increases the pain. In such cases it is well to omit the douching and to apply ice over the mastoid, as cold affords greater relief.

After the discharge has ceased and convalescence is fully established, there is little to be done aside from the general care of the patient. But if the subacute stage is prolonged, some after-treatment of the middle ear, by inflations or by applications to the Eustachian tubes, may be necessary until the drumhead shall have resumed its normal position. These simple measures will generally be all that is necessary. There is danger of doing too much as well as too little. There is no condition that needs to be more carefully watched, both as regards the external parts and especially as regards the deeper portions of the canal and the drum membrane. At every visit careful inspection of these parts must be made, or an intelligent understanding of the case cannot be had.

Treatment of local conditions in the nose and throat is frequently necessary. When adenoid hyperplasia is present in the naso-pharynx the redundant gland tissue must be removed, as the ear disease cannot be permanently cured if it is permitted to remain. On the other hand, I have seen acute purulent middle-ear disease complicated with mastoid inflammation rapidly recover after operation for removal of adenoids.

After the period of active inflammation has passed the ear is apt to be extremely sensitive, and the patient should exercise the utmost care to avoid a recurrence of the disease, as relapses are frequent. And besides, in this disease a recurrence is especially apt to lead to serious consequences. A fresh cold, or a chilling of the body, during the active progress of the disease, is almost certain to develop disastrous consequences.

Sometimes the perforation closes before the discharge has ceased, thus necessitating reopening of the membrane. This procedure is frequently necessary when the disease has extended into the mastoid cells. The mastoid region should be constantly watched and tested by pressure over the antrum and tip, at each visit; and if there is the least sign of tenderness, after free opening of the tympanum, ice or heat should be applied. Cold applications are usually the most comfortable to the patient, but occasionally dry heat is better borne. If ice is used it can be applied by means of either the Leiter cooling apparatus (Fig. 1693) or the rubber bag devised by the author (Fig. 1692). This bag is to be filled with cracked ice every hour. It is securely closed by a metal clamp on the rim near the top. It is applied with the wide part over the mastoid, the clamped end uppermost, and the auricle protruding through the opening. It is held securely in place by tapes attached in the eyelets, and can be worn by the patient in either the upright or the recumbent posture. A piece of gauze or muslin over the surface next the skin will absorb the moisture which gathers on the surface and thus prevent wetting the skin.

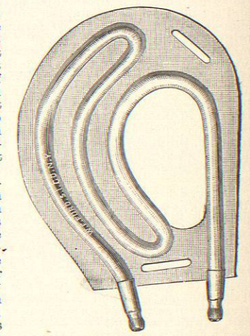

FIG. 1693.—The Leiter Cooling Apparatus, which affords a continuous flow of ice water through the coil.

Local blood-letting, in combination with the application of heat or cold, is very valuable. The leeches should be applied, one over the antrum and another over the tip. Usually the patient is then advised to go to bed, and for some reasons this is a good step for him to take; but the most important thing for him is to choose such a position of the head and body as will best conduce to good drainage of the ear and to relief of the congestion. The upright position, or one approximating to this, will be found to fulfil these conditions very closely.

The use of ice applications should not be kept up longer than for from three to five days, and they should be set aside just as soon as it becomes reasonably clear that the inflammation has abated; for while the ice undoubtedly reduces the congestion and consequently the pain and tenderness, yet it is possible for serious disease to be going on within the bone even when these symptoms are absent. At the end of two or three days the ice should be omitted for a few hours, and if the pain then returns it may be assumed that the disease in the bone is probably fully established, and operative interference should no longer be delayed. *Frank B. Sprague.*

EAR DISEASES: AFFECTIONS OF THE AUDITORY NERVE.—The study of the pathological processes involving the perceptive auditory mechanism is one attended by exceedingly great difficulties. Thanks, however, to the work of a constantly growing number of indefatigable workers, the mists which formerly obscured our vision of this region are gradually being dissolved, and we are seemingly warranted in hoping that in the near future we shall be in position to remove many of the affections of the auditory perceiving apparatus from the gloom of ignorance to the light of scientific knowledge, and the treatment of such conditions from an almost helpless empiricism to a position among the triumphal achievements in aural science. There will still remain many processes before which we shall continue to be helpless unless, happily, work along the line of prophylaxis may be productive of beneficent results. It is to be hoped that such shall prove to be the case. When one thinks that, until of late, fourteen per cent. of all aural cases were practically condemned to neglect and hopelessness, the incentive to renewed and tireless study of the diseases affecting this region is brought home to every ambitious and conscientious practitioner of aural surgery. For it is demonstrably true that in nearly fourteen per cent. of all aural cases the sound-perceiving apparatus is more or less deranged, either alone or as a complication. About ten per cent. of this number occur among children, and ninety per cent. among adults: the larger percentage of adults being due to the frequency of disturbances in the middle and internal ears combined. Uncomplicated disease of the internal ear is more common at the two extremes of life.

Congenital development of the parts specialized for the perception of sound is subject to variations from the normal. Thus, the labyrinth or the auditory nerve may be completely absent; such cases have been reported. Or, without going so far, there may occur an arrest in development, which most frequently affects that portion of the labyrinth called the cochlea. This arrest in development may involve both the osseous and the membranous labyrinth, or the latter alone. Fortunately, however, such congenital malformations are of rare occurrence. They are usually bilateral and of much the same degree on both sides. They may or may not be associated with

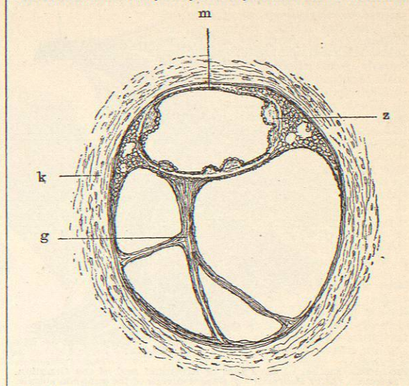

FIG. 1695.—Section of the Bony and Membranous Portions of the Semicircular Canal. (After Politzer.) *k*, Bony wall of semicircular canal; *m*, spot where the membranous canal is attached to the bone; *z*, mound-like irregularities of the inner surface of the membranous semicircular canal; *g*, vascular bands of connective tissue.

similar changes in the sound-conducting apparatus. The hearing ability may be very little, if at all, impaired in those cases in which the defects are unimportant, but the more marked the defects the greater becomes the deficiency in hearing, even up to the total abolishment of the function.

Acquired nervous deafness, if occurring in childhood, is usually unilateral, and probably is caused, in most cases, by overlooked infectious diseases, especially mumps, injuries to the skull, and hereditary syphilis; the last form, however, as a rule, is bilateral.

In taking up the pathology of this region, it is well to bring to the mind of the reader the difficulties which surround the investigator: the delicacy of the parts, the scarcity of material, and the amount of time and patience involved in the investigation. That so much is known is a matter for congratulation, and our thanks are principally due to such men as Politzer, Moos, Steinbruegge, Habermann, H. Knapp, Schwabach, Scheibe, J. Orne Green, Gradenigo, and Bezold.

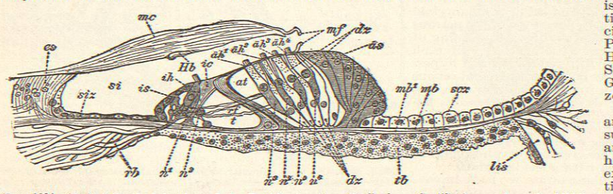

FIG. 1694.—Radial Vertical Section of the Papilla Acustica Basilaris or Corti's Organ, from the Middle Whorl of the Cochlea of a Man Twenty-nine Years of Age. (After Retzius.) *cs*, Limbus laminæ spiralis; *mc*, membrana tectoria or membrane of Corti; *Hb*, Hensen's band; *mf*, fibres which attach the membrane of Corti to the basilar membrane; *si*, sulcus spiralis internus; *siz*, epithelium of the sulcus spiralis internus; *is*, inner epithelial or supporting cells; *ic*, inner pillars, the heads of which articulate with those of the outer pillars; *t*, the tunnel-shaped space under the arch formed by the junction of the inner and outer pillars; *ih*, inner hair or ciliated cells; ih^1, ih^2, ih^3, ih^4, four rows of outer hair or ciliated cells; *dz*, Deiters cells, intercalated between the outer hair cells; *ds*, Hensen's supporting cells; *rb*, nerve fibres of the Ramulus basilaris; n^1, $n^2 \ldots n^6$, outer twigs or the spiral nerve fibres; *rf*, radial nerve twigs which cross the tunnel-like space; *at*, inner portion of Nuel's space; *mb*, upper layer of the membrana basilaris; mb^1, lower layer of the membrana basilaris; *tb*, tympanal coating of the membrana basilaris; *lis*, ligamentum spirale.

First, there are disturbances in the blood-vascular supply of the parts. Thus, an oligæmic or anæmic or hyperæmic condition may exist with little or no alteration in the anatomical structures. Degenerative changes have, however, been attributed to prolonged anæmia or oligæmia, and it is certainly true that hyperæmia, if long continued, may cause increased pigmentary deposits (a moderate quantity not being considered abnormal),

calcareous deposits, hypertrophy of the membranous labyrinth, dilatation of the vascular structures, or serous saturation. Hyperæmia of great intensity may cause rupture of the vascular walls with consecutive hemorrhage. Such hemorrhages may occur in any portion of the labyrinth, with or without any pre-existing hyperæmia. Hemorrhagic extravasations, so formed, may either be completely absorbed, or become organized, or undergo fibrous or calcareous degeneration; may cause atrophy and degeneration of the epithelium, connective tissue, and nerve elements, with an abundant formation of granular cells, hyaline corpuscles, and pigmentary deposits; or may induce inflammatory changes terminating in suppuration. Under certain conditions, emboli may lodge in the labyrinth or infectious thrombi may form.

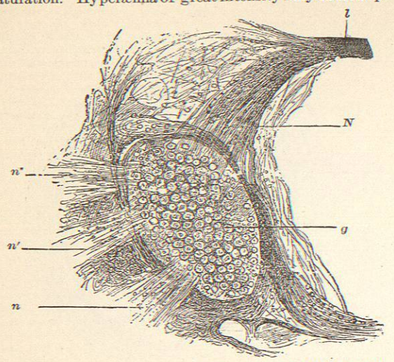

FIG. 1696.—Section of the Canal of Rosenthal and of the Ganglion Spirale. (After Politzer.) *g*, Ganglion cells of the ganglion spirale packed in the canal of Rosenthal; *n*, *n'*, *n''*, three separate nerve bundles of the cochlear branch of the auditory nerve entering the ganglion spirale; *N*, bundle of nerve filaments emerging from the upper pole of the ganglion spirale; *l*, entrance of this bundle into the lamina spiralis ossea.

The inflammatory processes that invade the labyrinth the writer has classified as hyperplastic (labyrinthitis hyperplastica) and exudative (labyrinthitis exudativa). In the former we may have hypertrophy of the auditory nerve stem, due to infiltration and proliferation of the neurilemma; deposits of calcareous salts or of amyloid bodies in and about the nerve; hyperostosis of the petrous bone narrowing the labyrinthine cavities; thickening of the periosteum; increased quantity of the perilymph and endolymph; infiltration with small cells and hyperplasia of the connective tissue between the membranous and the osseous labyrinth; a similar condition affecting the membranous labyrinth; development of osseous tissue from chronic inflammation of the labyrinthine periosteum; excessive epithelial growth on the inner side of the membranous labyrinth in chronic inflammation; chronic endarteritis; depositions of concretions of phosphate of lime and of corpora amylacea within the labyrinth.

In the exudative form of inflammation we have intense hyperæmia which may produce a serous saturation of the structures of the labyrinth; an infiltration with small lymphoid cells or round cells; a hemorrhagic exudation, as from a pachymeningitis hæmorrhagica; a purulent inflammation, due either to the direct propagation of pus from neighboring structures, or by way of the blood-vessels, or by the lymph spaces, or by dehiscences in the bony wall between the superior semicircular canal and the cerebral cavity, or to infection by the immigration of micro-organisms.

These inflammatory processes produce various alterations of the anatomical elements of the labyrinth: fatty degeneration of the endothelium of the blood-vessels, dependent upon an invasion of micro-organisms and causing coagulation and thrombosis and colloid degeneration of the labyrinthine tissues; injury of the acoustic nerve-apparatus by hemorrhages or mycotic degeneration—the axis cylinders resisting longest; stasis and thrombosis of the periosteal blood-vessels; rapid destruction of the connective-tissue elements; and destruction of the osseous tissue through entrance of the micro-organisms into the periosteum, the bone corpuscles, and the blood-vessels of the Haversian canals. In addition, the poisonous products of metabolism, the toxalbumins, probably play an important part. The micro-organisms (streptococcus, staphylococcus, and Fraenkel's diplococcus of pneumonia) gain entrance to the labyrinth through the aqueducts, the periosteal blood-vessels, and, probably, also along the sheath of the auditory nerve, as does the pus. In the beginning, the perilymphatic cavity is almost exclusively the seat of the disease, which later extends to the endolymphatic cavity. The micro-organisms seem to collect and to develop their greatest working power in the most dependent parts of the labyrinth. The inferior portions of the cochlea are, therefore, most affected. Steinbruegge, however, thinks the proneness of the disease to localize itself in this region is rather due to the propagation of the affection from the cranial cavity.

As a result of the inflammation of the labyrinth, the nerve fibres, cells, and ganglia are destroyed or atrophied through pressure, their place being taken by newly formed connective tissue, or left vacant, thus forming a system of lacunæ corresponding in arrangement to the normal nerve distribution of the part; the membranous labyrinth may be totally destroyed, likewise the structures of the labyrinthine windows, with displacement of the stapes; coagulation necrosis of the labyrinthine ligaments may be produced, with consequent collapse of the membranous semicircular canals; the osseous capsule may be more or less destroyed. If the quantity or virulence of the infection be great, there may be absence of all tendency to reactive inflammation and to the production of new tissue.

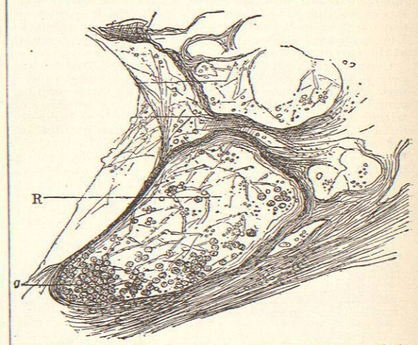

FIG. 1697.—Section Showing Atrophy and Disorganization of the Nervous Elements in the Canal of Rosenthal. (After Politzer.) *g*, Nuclei of ganglion cells in process of disorganization; *R*, canal of Rosenthal.

Should reactive inflammation be established, it results in the production of newly formed granulation, connective, fibrous, or osseous tissue; these new formations at times going so far as to produce complete obliteration of

the labyrinthine cavities, of the foramina cribrosa, of the aqueducts, and of the oval and round windows. Ossification proceeds from the remnants of periosteum and from the newly formed connective and fibrous tissues.

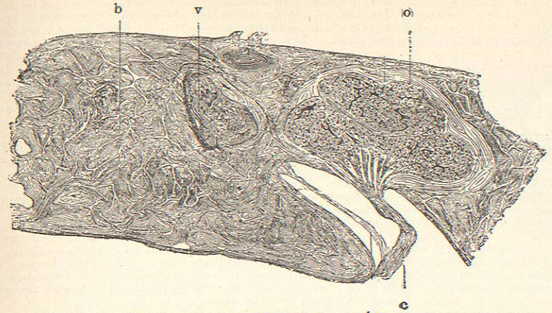

FIG. 1698.—Horizontal Section of a Cochleal Whorl, Showing the Results of Inflammatory Action. (After Politzer.) *o*, Cavity of cochlea completely filled with newly formed bone tissue; *c*, bundle of nerve filaments belonging to cochleal branch of auditory nerve; *v*, vestibule; *b*, entire absence of semicircular canals.

Among the pathological alterations of the acoustic nerve apparatus we will first take up changes in the stem of the auditory nerve. These may consist of the following: hyperæmia and ecchymosis; deposition of corpora amylacea or of concretions of phosphate of lime; fatty degeneration; gray degeneration; atrophy; leukæmic small-celled infiltration; purulent infiltration; embedding of the nerve in meningeal exudation. Tumors, principally sarcoma, fibroma, and so-called neuroma, may invade the internal auditory canal, exerting pressure, with consecutive atrophy, or even solution of continuity. The auditory nerve is more frequently the seat of morbid growths than is any other cerebral nerve. The changes most likely to occur in the region of the acoustic nerve origin in the medulla are due to thickening and purulent inflammation of the ependyma of the fourth ventricle and softening of the floor: effusion into the fourth ventricle, serous, aqueous, sero-purulent, or purulent, tumors in or about the fourth ventricle. Disease of the first and second convolutions of the left temporal lobe also interferes with audition, the cortical centre for hearing probably being located in this region. Of course, any pathological condition along the course of the cerebral acoustic nerve fibres also induces disturbances of function. Increased intracranial pressure may cause secondarily increased labyrinthine pressure with depression of Reissner's membrane and bulging outward of the membrane of the round window. Many cases, however, of increased intracranial pressure, as in chronic hydrocephalus, show no such change in labyrinthine pressure nor any impairment of the function of hearing.

The sound-perceiving apparatus is especially liable to be influenced by disturbances in the equilibrium of the system in general. Thus anæmia or oligæmia of the labyrinth occurs in connection with general anæmia, with continued fevers, with gestation and parturition, with aneurism of the basilar and atheroma of the internal auditory artery, with changes in the middle ear exerting pressure upon the labyrinthine structures through the round and oval windows.

Hyperæmia of the labyrinth occurs in all conditions producing congestion of the head: in conditions exerting pressure upon the venous channels of the brain (causing therefore obstruction to the return flow of blood from the ear), upon the vessels of the internal auditory canal, or upon the large veins of the neck; in disturbances of the circulation originating in the heart, lungs, or kidneys; in prolonged exposure to sharp sounds; and, finally, in the gouty or rheumatic diathesis. In the matter of the influence of prolonged exposure to occupation noises, as in the various trades, upon the labyrinthine structures, Coosemman, at the sixth International Otological Congress, presented the following conclusions as a result of his investigations: "All noisy trades are not necessarily injurious to the hearing. In order that they should be injurious the following conditions are necessary: 1. That the workmen should be predisposed to affections of the ear by the existence of lesions of the nose or pharynx, or else by inveterate addiction to alcohol or tobacco. 2. That the noise should be intermittent. 3. That it should be of a comparatively high-pitched tone." That such drugs as salicylic acid and quinine do have an effect upon labyrinthine conditions is well known, but just what this effect is was not determined with sufficient certainty until lately, when the experiments of Grunert, following upon and confirming those of Kirchner, would seem to settle the question in favor of the production of hyperæmia and extravasations of blood. Alt and others have found, on histological examination, that hemorrhages in the labyrinth sometimes result from exposure to compressed air, as in caissons. And, since Eichler's recent confirmation of Schwartze's clinical observations,—showing, as it does, that the congestion is the result of a reflex action, through the sympathetic, upon the vaso-motor nervous system of the labyrinth, rather than of a direct influence

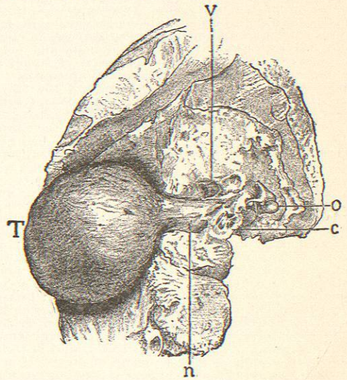

FIG. 1699.—Spinde-Cell Sarcoma of the Auditory Nerve, Growing into the Porus Acusticus Internus. (After Politzer.) *T*, Sarcomatous growth, the size of a walnut; *n*, extension of the same into the internal auditory canal; *c*, vestibule; *o*, tympanic cavity, with malleus and incus in place; *c*, cochlea.

through anastomoses—that form of hyperæmia of the labyrinth which occurs in connection with inflammation of the external or middle ear must certainly be considered here. Eichler found, as he claims, that the vascular supply of the labyrinth is entirely distinct from that of the surrounding tissues, and that the connection between the vessels of the tympanum and those of the labyrinth, which Politzer maintains, does not exist. Schwartze had long ago held that even in the very highest degrees of inflammation of the tympanum it is only exceptionally the fact that a simultaneous hyperæmia is met with in the labyrinth. It is a matter of observation that in chronic middle-ear suppuration with granulomata and polypi, the functional tests show no impairment of function of any importance in the sound-perceiving apparatus.

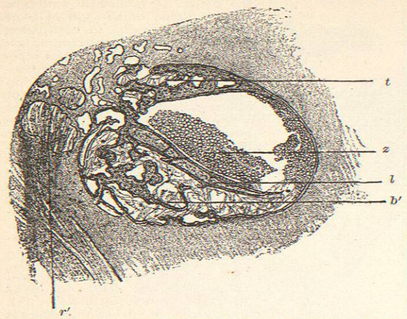

FIG. 1700.—Section of a Cochleal Whorl from a Deaf Person, Thirty-Two Years of Age, who had Died of Leukæmia. (After Politzer.) *l*, Lamina spiralis; *b'*, growth of bone and connective tissue in the scala tympani; *z*, leukæmia plaques in the scala vestibuli; *r'*, atrophied tissue of the ganglion spirale in the canal of Rosenthal; *t*, growth of bone on the medial wall of the scala vestibuli.

All conditions producing hyperæmia of the labyrinthine structures may enter into the causation of hemorrhages and ecchymoses. These may also be induced in the infectious diseases through changes in the vascular walls; in pachymeningitis hæmorrhagica; in leukæmia; in typhoid fever; in nephritis, gout, and rheumatism; in fracture or concussion of the skull; in diabetes, and sometimes in embolism of the arteria auditiva interna.

Atrophy and degeneration of the acoustic nerve apparatus may be caused by syphilis; by alcoholic excess; by any labyrinthine inflammation of sufficient gravity to interfere with nutrition; by changes in chronic otitis media exerting long-continued pressure on the labyrinth, and thus producing anæmia, which, if continued for a sufficient time, will result in nutritive changes of the nature of atrophy, and these secondary nerve affections may remain although the tympanic disease disappears; by acute hydrocephalus internus, leading to softening and shrivelling of the nuclei of the auditory nerve; and by fœtal ependymitis doing the same. Atrophy and degeneration may also occur in chronic hydrocephalus and in tumors of the brain and the nerve as a result of pressure; in the gray degeneration and atrophy accompanying tabes dorsalis; and in old age, through the presence of calcareous deposits and corpora amylacea. Finally, they may be caused by hemorrhage; by nephritis and influenza; by contraction of the basilar artery; by apoplectic and inflammatory processes involving the floor of the fourth ventricle; by professional concussion of sound; by purulent inflammation of the ependyma; by purulent inflammation of the stem of the auditory nerve from a similar condition of the meninges; and by emboli and embolic softening along the acoustic nerve tracts. Among the nerves of sense the auditory is the most "impressionable," that is, its function is more frequently impaired by general diseases and by chemical changes in the blood in infectious diseases. Affections of the auditory nerve attack, in the majority of cases, both organs of hearing. It is probable that degenerative processes involving one auditory nerve will in time pass over to the other. The view that atrophy of the auditory nerve can take place from inaction, as in ankylosis of the stapes, has not yet been corroborated by experience; in fact, the results of post-mortem examinations point the other way. The changes which occur in presbykousis and otitis media sclerosa seem to be due to a coincident trophic disturbance similar to that in the middle ear rather than to any atrophy from disuse. Central atrophy depends almost without exception upon cerebral disease, while the peripheral variety is most often a consequence of disorders of the auditory organ itself. The occurrence of the disturbances of hearing in these processes depends less upon the extent than upon the seat of the pathological accumulation.

Hyperplastic inflammation (labyrinthitis hyperplastica) may occur in syphilis, which is causative in most of the forms of this affection; in the first stages of exudative inflammation of the labyrinth due to infectious diseases, and the inflammatory process may advance no further; in gout and rheumatism; in rachitis; in typhoid fever and leukæmia; and in old age.

Exudative inflammation (labyrinthitis exudativa) may be caused by obstruction, in the internal auditory meatus, to the outflow of blood from the labyrinth; by typhoid fever; by leukæmia; by epidemic cerebrospinal, hemorrhagic, pachy- and simple meningitis; by syphilis, tuberculosis, measles, diphtheria, scarlatina, scarlatinal diphtheria, mumps, variola, and influenza; and by an extension from an otitis media purulenta of long standing. This form of inflammation occurs more frequently in children than in adults, because of the more frequent occurrence in children of the acute exanthemata, etc. Further, the anastomotic connections between the middle ear and the labyrinth on the one hand, and between the labyrinth and the cranial cavity on the other, are more numerous in children than in adults; and further, because in the child's ear, through the aqueducts, there is a freer communication between the labyrinthine fluid and the cerebro-spinal cavity than in the adult.

SYMPTOMATOLOGY.—*Functional Reactions in General.*—The normal limits of audibility lie between a tone of 16 v. d. (double vibrations per second) and one of from 20,480 to 27,361 v. d. Instruments that give 40,000 v. d. have thus far not been constructed, nor can tones of that pitch be heard. The low tone is obtained by the tuning-fork, and the high tone by the use of the Galton whistle or a modification thereof. A constant air current should be used to blow the whistle, and not a rubber bag or bulb, as is commonly the practice. The highest tones are produced with the Galton whistle at the mark 1.5, which represents about 20,000 v. d.

Before taking up the departures from the normal reactions to functional tests in diseases of the sound-perceiving apparatus, it is necessary to devote some attention to the normal decline in hearing evidenced in advancing age. Zwaardemaker has tabulated the average responses for the upper-tone limit at the different periods of life, about as follows:

Galton's whistle is heard under	10	years at the mark	..	1.22
"	"	"	from	20–30	"	"	"	..	1.39
"	"	"	"	40–50	"	"	"	..	2.23
"	"	"	"	over 60	"	"	"	..	3.03

A presbykousis (hearing of old age) may, however, be considered normal which is not lower than Galton 4.8. The lower-tone limit is elevated to about the same extent in old age. In old age the B. C. (bone conduction) does not alone experience a reduction, but sinks proportionately with the lessening of the hearing distance, the A. C. (air conduction), etc.

Commonly in diseases of the sound-perceiving apparatus, *the upper-tone limit*, obtained by means of the Galton whistle, *is lowered, i.e.*, the highest notes elicited by the whistle being denoted by one or fractions of one, and the lower notes by multiples of one and their fractions; as the obturator is withdrawn the note deepens or lowers at the same time that the indicator or graduated scale shows higher and higher numbers, and, therefore, a higher number on the scale—as, *e.g.*, 4.8—indicates a much lower note than a lower number, as 1.22. The *lower-tone limit by* A. C. (air conduction), as obtained by a clamped tuning-fork vibrating from 26 to 64 double vibrations in the second, *is impaired very little or not at all. The absolute duration of* B. C. (bone conduction), Schwabach's test, *is shortened or abolished* for all or for certain tones. A. C. > B. C. (air conduction is better than bone conduction), *both in intensity and in duration* throughout the musical scale (Rinné's test). If the disease is unilateral, *the vibrating tuning-fork* C^2, placed *in contact with the vertex*, midway between the ears, *should* be heard in the unaffected ear (Weber's test); or in the better hearing ear, if the disease is bilateral. This test is not so reliable as those previously described. In labyrinthine disease the *patients hear the deeper tones of speech very well, while the higher tones are no longer perceived.* It is well, in testing with the whisper or speech, to remember O. Wolf's division of the voice sounds into:

1. The deep, like R and V.
2. The middle, like the explosives B, K, and T.
3. The high and strong, like S, Sh, and G; and the high and weak, like F, L, N, and H (which are excluded as dependent on other tones—tone-borrowing).

Wolf devotes particular attention to the consonants. Bezold employs the names of numbers as test words, as these are familiar to both children and adults. Equal intensity of sound can be obtained by using the reserve air left after a forced inspiration followed by a normal expiration. To test the hearing for speech thoroughly, it is quite sufficient in most cases, after testing a few words, to note the distance for those words perceived with the greatest difficulty.

It is well to remember that Bezold has observed a number of otherwise characteristic affections of the inner ear which showed a more or less extensive defect in the lower boundary of hearing; in addition, that not only the upper and lower ends, but also the middle portions of the tone scale, can be lost to hearing. But when defects exist in these portions the power of hearing speech is at the same time more or less completely lost.

Bezold has definitely settled the question, by very painstaking investigations, that after loss of portions of the labyrinth no remnants of hearing remain. Ears with defective labyrinths only reflect, more or less completely, the hearing conditions of the sound ears; thus proving that an ear without a labyrinth has no independent hearing power.

Disturbances of equilibrium are apt to be observed in any process that causes irritation of the nerve endings in the vestibule or the semicircular canals, or of the corresponding filaments in the stem or at the point of origin of the auditory nerve.

In testing for disturbances of equilibrium, it is well first to determine the static (the body at rest) equilibrium and then the dynamic (the body in motion) equilibrium. The author tests the former by means of an apparatus consisting essentially of a movable inclined plane, after the method of von Stein. A person with normal powers of equilibrium should be able to maintain his erect position—when facing toward the apex of the angle (anterior inclination)—until the board reaches an inclination of 35° to 40° to the horizontal. In posterior inclination, with the back turned toward the apex, the normal angle varies from 20° to 30°; in lateral inclination, with the side toward the apex, it varies from 37° to 38°. In patients with labyrinthine disease, giving rise to vertigo, etc., the angle measures 20° or less by anterior inclination, etc., and this is much decreased when the eyes are closed. The static equilibrium should also be tested with the eyes open and shut, with the legs close together, while standing on the toes, and while standing on one leg. A healthy person can stand in these positions for some time, with slight balancing, while the eyes are closed; but a person with imperfect powers of equilibrium immediately begins to show some disturbance of these powers. The dynamic equilibrium is tested by walking forward and backward on a level, by turning on the vertical axis of the body to the right or to the left with legs together, and, finally, by turning about on one leg alone. The last movement is the most difficult, but a healthy person can go through these various motions with little if any trouble; whereas aural patients with disturbance of the powers of equilibrium find it more or less difficult or impossible, and their movements are attended by great weariness. (See also article on *Equilibrium* and *Equilibration.*)

Given these reactions, the inference is well founded that we have to do with an affection of the sound-perceiving apparatus. Still other tests have been devised by Bing, Brenner, Gradenigo, Gellé, and others; but the above have been more universally tried, are sufficient for the purposes of diagnosis, and are more reliable.

The symptoms of affections of the sound-perceiving apparatus, as they are observed in various pathological conditions, are more particularly described as follows:

Anæmia.—There is usually some dulness of hearing, which is manifested either as a slowness of perception only, or as a real impairment of the hearing power. The impairment in the hearing ability follows along the line of the test responses as given above, being especially noticeable, however, in the curtailment of the duration of B. C. Annoying tinnitus of a low pitch is commonly present. The patient may be subject to occasional attacks of vertigo, and usually is the victim of general anæmia.

Hyperæmia.—There is very little if any impairment of the hearing power, and there may be present hyperæsthesia of the nerve to certain sounds. Often there is a feeling of fulness and distention in the ears or in the head, with dulness of intellect or even giddiness or vertigo at times. With this is usually associated a high-pitched tinnitus. The functional tests show a limited involvement of the sound-perceiving apparatus. Paræsthesiæ are likely to be complained of.

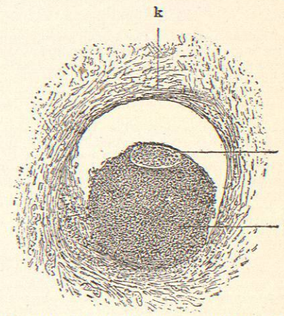

FIG. 1701.—Section of a Semicircular Canal, Showing Results of a Hemorrhage. (After Politzer.) *k*, Bony wall of semicircular canal; *h*, membranous portion; *e*, extravasated blood.

Hemorrhage is usually immediately followed by marked vertigo, aggravated on closure of the eyes, with possible falling or unconsciousness (the latter is rather rare) unless