DISEASES OF THE EAR

A. A. GRAY

THE EAR AND ITS DISEASES

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BY

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WITH STEREOSCOPE, AND 123 ILLUSTRATIONS, OF
WHICH 37 ARE STEREOSCOPIC

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PREFACE

In the preparation of this work I have endeavoured to keep in view the interests of the student, the practitioner, and the aurist. In order to achieve this end satisfactorily, it seemed essential to begin with the first principles, and I have therefore devoted a chapter to the acoustical aspect of the subject. In this portion it was important to bear in mind the requirements of the medical man. Hence my aim has been to discuss the laws of harmonic motion and the transmission of sonorous vibrations, rather than those of harmony which appeal more particularly to the musician.

The anatomy of the subject has been described in considerable detail. With the exception of the brain, there is probably no part of human anatomy more difficult for the student to grasp than that of the temporal bone and the structures which it contains. By means of stereoscopic illustrations and special methods of preparation, I have endeavoured to overcome these difficulties as far as possible.

I have kept in view throughout the book the importance of associating the clinical phenomena with the pathological conditions present.

The cases and anatomical and pathological preparations from which the illustrations were made, with very few exceptions, are my own. The illustrations also have, in the majority of cases, been made by myself. I am, however, indebted to Dr. Leslie Buchanan for the care which he exercised in obtaining the photomicrographs, and to Dr. D. Otto McGregor for the illustration in Fig. 56.

The drawings of the tympanic membrane were made from my own cases by Mr. A. Kirkpatrick Maxwell, and I take this opportunity of thanking him for the trouble which he took in their execution.

The illustrations of instruments are from blocks kindly lent by Messrs. Mayer and Meltzer. A few of the illustrations are from Quain's 'Anatomy,' Politzer's 'Diseases of the Ear,' and from Everett's 'Sound and Vibratory Motion.' I am indebted to the publishers for permission to reproduce these illustrations.

The stereograms have all been made by myself from my own preparations. On examining them with the stereoscope, the great majority of readers will at once obtain the stereoscopic image. Some, however, may require a few minutes' practice to enable them to do this, and there may be a few in whom some visual abnormality prevents the appearance of the solid image. In these the correction of the ocular defect will enable them to obtain the stereoscopic picture.

The stereoscopes (which will be found inserted into the cover) have been made by the firm of R. and J. Beck, and I am much indebted to them for the trouble they have taken in making them optically accurate and at the same time exactly suited for the purpose in view.

I must take this opportunity of thanking Robert F. Muirhead, D.Sc., and my nephew, Dr. Arnold H. Gray, for the great trouble which they took in correcting the manuscript and proofs.

Finally, I must express my indebtedness to the publishers for their valuable advice and the care they have taken in the work of publication.

ALBERT A. GRAY.

14, Newton Terrace,
Glasgow,
May, 1910.

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DISEASES OF THE EAR

CHAPTER I

ACOUSTICS

If a rod of wood or other elastic material of suitable length be fixed at one end, it takes up a certain position; this is termed the *position of equilibrium* (Fig. 1, *A*). If now the free end be displaced laterally to *B* and then released, the elasticity of the rod will cause it to spring back to the position of equilibrium, and, having acquired a certain amount of kinetic energy, it will pass through this position and ultimately reach a position *C*, almost as remote on one side from the position of equilibrium as the original displacement was on the other side. The motion will then be reversed, and so on; the extent of the movement, however, becomes gradually less, until finally the rod assumes permanently the position of equilibrium. This is an example of harmonic motion, and the movement from *B* to *C* and back to *B* is termed a *vibration*. If the vibrations are of sufficient magnitude and are performed with sufficient frequency, sound is produced.[1]

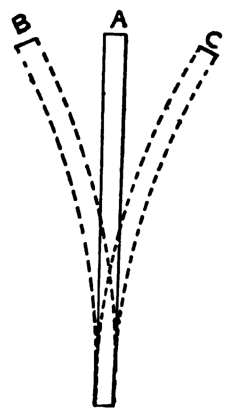

Fig. 1.

[1] Some writers use the term 'vibration' to indicate the movement from *B* to *C* alone. In order to distinguish the two conventions, the term 'single vibration' should be applied to the latter, while the terms 'complete vibration' or 'double vibration' may be used to indicate

The distance travelled by any particle of the rod from the position of equilibrium to that of extreme displacement is termed the *amplitude*. The time occupied by a complete vibration from *B* to *C* and back to *B* is termed the *period*, and the number of periods per second is termed the *frequency*. *Phase* in simple harmonic motion is that fraction of the whole period which has elapsed since the particle was last in its position of maximum displacement. Thus, the particle has a different phase at each point of its path, and returns to the same phase after one or any exact number of periods.

It is a general truth that, unless the displacement of any elastic body from its position of equilibrium is very considerable, its frequency remains constant. That is to say, no matter how great or how small the amplitude of the vibration may be, the time occupied by the vibration remains the same. This fact depends upon Hooke's law, *the force is proportional to the displacement.* Thus, if the rod be displaced 1 inch by a certain force, then it will require twice that force to displace it 2 inches.

Now, in the case of sound the pitch is dependent entirely on the frequency, and not on the amplitude, and it follows therefore that the pitch will remain constant whatever the amplitude may be. Thus, a tuning-fork, which is simply a rod bent double, will give a note of constant pitch, whether its vibrations be extensive or not. On the other hand, the loudness of a sound, provided the pitch remains constant, depends on the amplitude of the vibrations. If, however, the pitch be altered, this law is subject to limitations of a physiological nature, which will be referred to later.

The sensation of sound, then, is produced by vibrations, which are an example of harmonic motion ; and from what has been said above we may arrive at the following definition of harmonic motion : *When a particle is vibrating in a straight line under the influence of a force which urges it towards the middle point of its path, and which varies directly as the distance of the particle from this point, that particle is in simple*

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the complete movement described above in the text. The contractions v.s. and v.d. are employed to represent the two expressions respectively. In this work it will always be understood that a vibration means a complete or double vibration.

harmonic motion. This is one of the fundamental laws of acoustics.

Suppose a particle to be vibrating along the line AA_1 (Fig. 2), then its position of equilibrium will be at C. Now describe a circle with AA_1 as diameter, and let the particle be at a point X in the diameter. Then, according to the definition, the particle is urged towards C by a force represented by XC. From X draw XD at right angles to AA_1, and join DC. Now, if a particle be moving with uniform velocity in the circle DBA_1B_1, we know that it is acted on by a constant force directed towards C. This force is represented by the line DC. From D draw DY $\parallel AA_1$ to meet BB_1 at Y. The force DC may be resolved into the two forces DY and DX—that is, into CX and CY respectively. But we have already seen that CX represents the force acting on the particle X when it is undergoing harmonic motion along the line AA_1. Therefore we may say that, *if the path of a particle which is in harmonic motion be taken as the diameter of a circle, and a line be drawn from the particle perpendicular to the path, the point at which the perpendicular meets the circle will travel round the circle with uniform velocity. This circle is called the ' auxiliary circle.'*

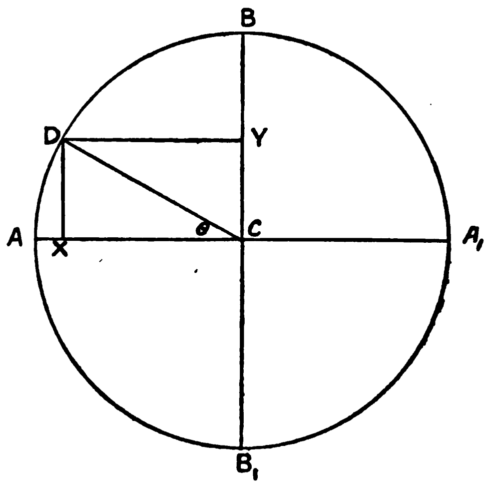


FIG. 2.

Since the circle $ADBA_1$ represents the path of a particle travelling with uniform velocity, it may be allowed to represent time, and the time of a complete revolution of the particle is represented by the whole circumference. In harmonic motion, however, the particle vibrates along the line AA_1, and its displacement from the position of equilibrium C at any given moment may be determined by means of the auxiliary circle. Thus, suppose the particle D to be revolving with uniform velocity in the direction AB, and that it has moved from the position A to D, then the arc AD represents the time it has taken. But if the particle, instead of travelling with uniform velocity round the circle, were oscillating, with the same periodic time, in harmonic motion along the line AA_1, it would have passed from A to X, and the displacement of the particle from the position of equilibrium will be represented by the line XC. AC is the amplitude of movement of the particle oscillating along AA_1. Let $AC = a$, and let $XC = x$. The angle DCA varies as the arc AD, and therefore represents the time. Let the angle $DCA = \theta$; then

$$x = a \cos \theta \quad - \quad - \quad - \quad - \quad (1).$$

This gives us the displacement at a given time of the particle oscillating in harmonic motion between the points AA_1.

By means of the auxiliary circle it is easy to find the velocity at any given moment of the particle oscillating between A and A_1. As the particle D moves with uniform velocity towards B, the particle X moves towards C with increasing velocity, and the angle θ increases with the time. The rate of increase of this velocity is obtained by differentiating equation (1) with respect to θ:

$$\frac{dx}{d\theta} = -a \sin \theta \quad - \quad - \quad - \quad - \quad (2).$$

Hence the velocity of the particle oscillating in harmonic motion along the line AA_1 varies with the sine of the angle representing the time elapsed since the particle was at A.

A further—and, from the point of view of the aurist, a more important—relationship can now be obtained in respect to the energy of the particle undergoing harmonic motion.

The kinetic energy of any particle in motion is found by multiplying the mass into half the square of the velocity: $E = \frac{mv^2}{2}$, where E = kinetic energy, m = the mass, and v = velocity. But $v = a \sin \theta$, and is greatest when $\sin \theta = \pm 1$ (that is, when the particle is passing through the position of equilibrium, C), and is least (that is, zero) when the particle is at the points of extreme displacement, A and A_1, for at these points $\sin \theta = 0$.

Hence at any given moment $E = \frac{m(a \sin \theta)^2}{2}$; or, modifying the equation, $E = \frac{m\{a \sin (\theta - \epsilon)\}^2}{2}$, where ϵ represents the angle measured from any given radius to the line AA_1.

If, therefore, any particle be undergoing harmonic motion, its capacity for overcoming frictional resistance is greatest when it is passing through the central point of its course—that is, the position of equilibrium; and, conversely, this capacity is least at the points of extreme displacement.

Again, supposing the mass, m, and the amplitude of movement, a, to remain constant, the velocity, v, will vary according to the 'frequency.' When, for example, the particle performs 200 vibrations per second, it is obvious that the mean velocity must be greater than when the particle performs only 100 vibrations per second. And as the velocity varies, so also does the energy in still greater degree.

On the other hand, the velocity, and therefore the energy, may remain the same when the particle is performing vibrations of different frequencies, provided the amplitude of movement is made to undergo corresponding variations.

Applying these laws to the case of sonorous vibrations, it will be seen that in the case of a note of high pitch—that is, one of great frequency—the same energy may be obtained with movements of small amplitude as may be obtained with movements of great amplitude from notes of low pitch. (It is assumed, of course, that the mass remains constant.) Consequently, if a restriction be placed upon the amplitude of movement, the energy will be restricted to a much greater extent in the case of the low than in the case of the high notes. Now, this has an important practical bearing from the point of view of the aurist, for it enables us to understand why, in the case of middle-ear disease, where the movements of the tympanic membrane or of the ossicles are interfered with, the hearing-power for the low notes is much more seriously affected than that for the high notes. Upon these principles depends one of the most valuable tests for hearing in the deaf (see p. 83).

A graphic representation of simple harmonic motion may be obtained by attaching to the free end of a prong of a deep-toned tuning-fork a piece of spun glass or other light style about ½ centimetre in length. A piece of smoked paper is then passed along with uniform velocity parallel with the prong, the style being in contact with the paper. The curve thus traced out represents the movement of the prong, which is an example of simple harmonic motion. The curve itself is called the *harmonic curve* or the 'curve of sines' (Fig. 3).

Hitherto we have spoken of the motion of the individual particles which are concerned in the generation or transmission of sound. But when sound travels through any medium it travels in the form of waves. The waves of sound, however, are not similar to those produced in a pond of still water by dropping a stone into it. In the latter case the waves are travelling in the plane of the surface of the pond,

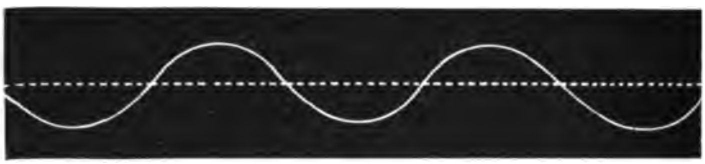


FIG. 3.

while the particles of water are moving in circles or ellipses in a plane perpendicular to this and to the wave-front. But when sound is travelling through any medium, the particles oscillate in the plane in which the waves are travelling. In fact, their motions are identical in character with the horizontal components of the motions of the particles of water referred to above. Hence in the case of sound-waves we get alternate condensations and rarefactions of the medium instead of elevations and depressions of the surface. When the transmitting medium is undergoing condensation, the sound-wave is said to be in its 'positive phase,' and, conversely, when the medium is undergoing rarefaction the wave is in its 'negative phase.' This may be expressed in other words by saying that when the particles are moving away from the source of sound they are in the positive phase, and when moving towards the source of sound they are in the negative phase.

It must be remembered therefore that, though for the sake of convenience we represent sound-waves graphically by a curved outline like those of water in a pond, such movement never actually occurs. The particles move in a straight line parallel with the force that produces the sound-waves.

When sound-waves spread out unhindered from the generating instrument, they are subject, like other forces, to the law of inverse squares. Thus, if a tuning-fork be sounded in an open space, the particles of air at a distance of 1 inch are possessed of a certain amount of energy, those at 2 inches distance are possessed of a quarter of that energy, and those at 3 inches distance of a ninth of the energy, and so on. This law has important practical bearings from the point of view of the aurist in respect to the testing of the hearing-power of the deaf. For example, if a patient hears a given sound at half the normal hearing distance, then his hearing-power for that sound has diminished to one-fourth of the normal, not to one-half, as is usually stated. Conversely, if a patient's hearing distance has, as the result of treatment or in the course of nature, been doubled, then his hearing-power has been quadrupled.

Waves vary in length inversely according to their frequency. Thus, a note of the frequency 512 is composed of waves of a length of one-half that of the waves composing a note of a frequency of 256. The normal human ear is capable of hearing all sounds of a certain intensity produced by vibrations of between 16 v.d. and 20,000 to 30,000 v.d. approximately. The lengths of these waves are about 70 feet and $\frac{2}{3}$ to $\frac{1}{2}$ inch respectively, but it must be pointed out that, particularly in regard to the upper limit, considerable individual differences occur without indicating any pathological condition. There is very good reason for supposing that some animals can hear sounds of a higher pitch than man is capable of perceiving.

Pitch is entirely dependent upon the frequency of the vibrations, and notes of small frequency are said to be of low pitch, while those of great frequency are said to be of high pitch.

Simple and Compound Tones.—Hitherto we have only considered the conditions occurring when one series of waves, all of identical length, are passing through the air; or, expressed in terms of the number of vibrations, when the sound has been produced by one set of vibrations occurring a certain number of times per second. A sound produced by such a series of vibrations is termed a *simple tone* or a *pure tone*. But we can easily imagine two or more sets of vibrations traversing the air at the same moment. Thus, one set may consist of 256, and another of 200 or 300 vibrations per second, and so on. The tones produced under such conditions are termed *compound tones*. Almost all notes used in music and all noises are of this description. Pure tones, such as those produced by a tuning-fork when not sounded too loudly, are certainly very sweet, but musicians would not find them rich enough in quality for the purposes of their art.

The production of a compound tone in music is most easily illustrated by the stringed instrument. Suppose a cord to be stretched between the points *A* and *B* (Fig. 4). If this be

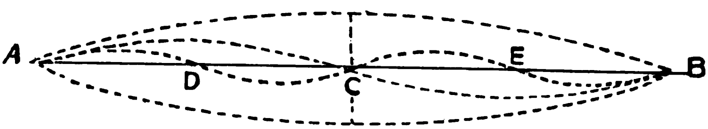


FIG. 4.

set into vibration, the cord from *A* to *B* will perform vibrations at a certain rate per second, and will give out a corresponding note. But besides this motion of the cord as a whole, certain portions of it will also vibrate on their own account. Thus, the two portions from *A* to *C* and from *C* to *B* will vibrate on their own account, and, according to the laws governing the vibrations of strings, they will vibrate twice as rapidly as the whole portion, and will therefore give out a note correspondingly higher in pitch. Similarly, the portions from *A* to *D* and *D* to *C*, and *C* to *E* and *E* to *B*, will vibrate independently. With these and other modes of vibration there will arise a series of notes, each of which has a frequency which is an exact multiple of the frequency of the cord vibrating as a whole. The note produced by the cord vibrating as a whole is called the *fundamental*, while those produced by the separate segments are called the *partial tones*, *overtones*, or *harmonics*. In practice the fundamental determines the name of the note. Thus, if the note G be referred to, that note is meant which has a fundamental tone of a certain frequency corresponding to the pure tone G.

Quality (German, *Klangfarbe;* French, *Timbre*).—Since all notes used in music have partial tones, it will not be out of place to consider the effect these have upon the notes as perceived by the ear. If the note G be sounded upon different instruments, a different sensation will be produced in each case. It is this difference which determines the *quality* of the note, and which is due to the pitch and intensity of the partial tones present. Thus, in the case of the violin the partial tones present are high and of considerable intensity relative to the fundamental, whereas in the organ this feature is much less pronounced.

Interference.—When two independent sources of sound produce vibrations simultaneously in the same region, interference occurs. If the two notes have the same period, then there are some points at which, at a given instant, both sources are producing condensations, and some at which one source is producing condensations and the other rarefactions. At the points first mentioned the sound is reinforced, and this reinforcement is permanent. At the other points the sounds neutralize each other, more or less, and this condition is also permanent. If the ear moves through this region, it passes alternately points of both sorts, and perceives a periodic variation in the loudness of the sound passing from reinforcement to neutralization and back.

Beats.—This periodic change of loudness is also produced when two notes, whose frequencies differ by only a small number, are produced in the same region. At any given instant the sounds reinforce or neutralize one another, but the position of the points is no longer fixed, and the ear, if stationary, perceives the same periodic variations of loudness as it did in the previously described case when in motion. Take, for example, the case of two notes whose frequencies are respectively 256 and 257. If at any instant condensations (or rarefactions) arrive at the ear simultaneously from both sources, then this state of affairs will only last for a short time. At the end of half a second the condensation produced by one of the sources of sound will coincide with the rarefaction produced by the other source, which by this time will lag half a period behind. Half a second later, again, reinforcement will be re-established, to give place again to neutralization, and so on.

It is clear from this that the frequency of the periodic changes of loudness, which is called *beating*, will be exactly equal to the differences between the frequencies of the two notes; *e.g.*, notes of frequencies of 500 and 506 will give beats of 6 per second.

Beats are also produced by compound notes, provided any harmonic of one differs only slightly in frequency from any of the others or their harmonics. Since each harmonic is, except in frequency, physically identical in character with a pure fundamental note, the explanation in this case is the same. As an example, we might hear beats of a frequency of 2 from notes whose frequencies are 258 and 386 respectively, if the former contains the harmonic 3×258 and the latter the harmonic 2×386, because these frequencies differ by 2.

Beats when occurring slowly are not unpleasant to the ear, but when rapid they give a jerky effect which is disagreeable. If the beats occur still more rapidly, above about 20 per second or more, then they are no longer perceived as beats by the ear, but a new and interesting phenomenon occurs. The beats blend to form a new tone, whose frequency is still equal to the difference between the frequencies of the two generating tones. This new tone is therefore called the *differential tone* or *beat tone*. According to Helmholtz, another tone is also heard under such circumstances, this tone having a frequency equal to the sum of the frequencies of the two generating tones—*i.e.*, in the particular case cited, a frequency equal to $258 + 386 = 644$ vibrations per second. Helmholtz termed this the *summational tone*. Many observers cannot hear any such tone, and some doubt its existence altogether.

There has been much discussion as to the point of origin of these differential and summational tones. According to some authorities, they arise in the air, while others hold that they are purely subjective and are generated in the mind of the listener. The reader will find the matter discussed in the 'Textbook of Physiology,' vol. ii., p. 1187, chapter by McKendrick and Gray, edited by Schäfer. Other references to the subject will also be found there.

Analysis.—When two or more pure notes of different frequencies are sounded together, the ear can, by a certain degree of effort, analyze the compound tone thus produced. The faculty of being able to analyze compound notes in this way varies greatly in individuals, and the possession of it in a high degree underlies what is termed a 'good ear for music.' Thus, if a chord be sounded on the piano, an individual possessing a good musical ear will be able to hear as such the various pure tones of which it is composed. It must be understood that these must be present with a certain degree of intensity. This power of analysis of sounds composed of various pure tones is only present to a limited degree even in the finest musical ears. Thus, a noise as distinguished from a musical note can never be entirely analyzed into its constituents, yet there is no doubt that physically it also is composed ultimately of simple pure tones.

There is, however, a mechanical means by which the ear may be assisted in analyzing compound notes, and to a certain extent even noises. This will be referred to under the heading Sympathetic Resonance.

Before leaving the subject of analysis of compound tones, it is necessary to say a few words on the mathematical aspect of the question. Suppose a compound note be represented graphically by a curve. This curve will in general be irregular in proportion to the number and frequencies of the pure tones which go to produce the compound tone which it represents. Further, however complicated such a curve may be, it will ultimately come to repeat itself, provided the quality of the sound remains unaltered.

Now, Fourier, the mathematician, showed that such a curve, however complex, could be finally analyzed into a series of simple harmonic curves, whose periods are submultiples of the fundamental, each representing one of the pure tones of which the compound tone is composed. This is known as *Fourier's theorem*. It of course applies to other quantities than those representing sonorous vibrations, but with these we have nothing to do at present. The important point to remember is, that within certain limits the ear performs for us an analysis of compound tones, comparable with that which the mathematician can do with the abstract quantities which represent such notes.

Communication of Vibrations; Sympathetic Resonance.

All vibrating bodies communicate their motion to surrounding media and to any other body that may be in proximity. Thus, a tuning-fork sets the air in vibration, and the air sets the tympanic membrane or any other object such as the walls of the room and various objects in it, in vibration. In this process some of the energy is transformed into heat, but if the structure be not too massive and be elastic in character, such as a stretched membrane or a thin board of wood, it will begin to vibrate with the same frequency as the instrument which generates the sound.

Such are termed *forced vibrations*, in contradistinction to what we now proceed to describe as *free vibrations*.

Suppose two tuning-forks of exactly the same pitch (that is, of the same frequency) be placed in proximity to each other, and one of these be set vibrating, it will be found that after a short interval the other fork begins to vibrate; and if the first fork be stopped, the second one is still heard to be sounding loudly. Let us consider what has occurred in this case. The moment the first fork is set vibrating, the vibrations are transmitted by the air to the second fork, and this is displaced for a certain length of time, according to the pitch of the forks. At the end of this period the particles of air surrounding the second fork begin to move in the opposite direction, and tend to drag it back with them. There thus occurs an accumulation of energy in the second fork, and after a few vibrations have taken place the resulting movement is of such an amplitude as to produce a sound quite audible. Further, the amplitude of movement being so great, the inherent elasticity of the second fork keeps up the movement for some considerable time after the first fork has been stopped. Vibrations which continue after the exciting cause has ceased acting are called 'free vibrations,' and the whole phenomenon is known as *sympathetic resonance.* There is, of course, no necessity for the two instruments to be of the same kind; all that is requisite is that the period of vibration of the generating instrument be the same as that of the sympathizing or resonating instrument. For scientific purposes the instrument generally used as a sympathizer, or *resonator* as it is called, is a hollow brass sphere which has two openings at opposite poles (Fig. 5). The larger opening, about 2 centimetres in diameter, is to allow the vibrations to gain entrance from the air; while the smaller opening, of about 5 millimetres diameter, is placed at the end of a little cone-shaped projection, which is inserted into the external meatus of the ear. These resonators were designed by Helmholtz, and since each instrument only responds properly to one tone, a set is usually obtained each an octave above the preceding one. Now, since a given resonator, whose frequency is, say, 256, will respond strongly to a note of that pitch, and to that note only, it is obvious that by this means we can ascertain whether the note is present in a noise or compound tone, even when the unaided ear is unable to detect it. Other means are sometimes used on the same principle to detect the presence or absence of certain pure tones in a given compound one. Thus, if the dampers be raised from the strings in a piano, and a compound tone be sung into the instrument, the various strings which have frequencies corresponding to the constituent pure tones of the compound note which has been sung will be set in vibration.

FIG. 5.

Again, instead of a compound note being sung and the constituent pure tones ascertained as above by sympathetic resonance, let a noise, of some little duration of time, be made. The constituent pure tones of the noise may be ascertained in the same way as, though less completely than, when a musical note is sounded. Still, even in this case, if it were possible to have a sufficient number of resonators of the requisite description, and if the noise were of sufficient duration, all the constituent pure tones might be ascertained.

The difference between noise and musical sound is not properly defined; indeed, it depends to a certain extent on the ear of the listener, and on the effort of will which he may choose to make. The most that can be said is that a musical note has a certain smoothness which is lacking in a noise.

From what has been said relating to forced and free vibrations, it will be clear to the reader that, so far as transmission of the sound by the conducting apparatus in the ear is concerned, we are dealing almost entirely with forced vibrations. Thus, while it is conceivable that the tympanic membrane and chain of ossicles may have frequencies of their own, and respond with particular freedom to notes of these frequencies, yet their chief function is to conduct notes of all frequencies to the nerve-terminations in the cochlea. Hence no analysis of sound takes place in the middle ear. In the cochlea, on the other hand, it is almost certain that analysis of the compound sound-waves does take place, and it is very possible that this analysis is achieved by means of sympathetic resonance, though the question as to which structures perform this analysis is not yet settled. (See p. 69.)

A consideration of the facts just described regarding forced and free vibrations, taken in conjunction with the laws respecting the energy of vibrations, will lead the reader to the following important conclusions: *If an instrument be subjected to the influence of harmonic vibrations in the air, it will respond the more quickly, other things being equal, the less the mass of the instrument; and, conversely, it will the sooner cease vibrating when the generating vibrations are stopped.* For the purpose, therefore, of transmitting all ordinary musical sounds and noises, a light instrument, such as a stretched membrane or thin wooden or metal plate, is employed. If, on the other hand, it is only desired to transmit one note which can be sounded for some little time, then the object is best accomplished by means of a comparatively massive resonator which is in exact sympathy with that note; for by this means the loudness of the note is greatly increased.

It is of interest to observe that these laws have had a profound effect in the evolution of species in the animal kingdom. For, so far as is definitely known, the means employed in transmitting sound to the nerve-terminations in all air-breathing animals is that of a stretched membrane, usually associated with a chain of cartilage or bone. In the process of natural selection it is clear that, for the purposes of offence and defence, this means of transmission was found to be the best:

In conclusion, it is necessary to say a few words about musical and acoustical instruments, in so far as they are requisite for the purposes of the aurist. These instruments are tuning-forks, organ-pipes, Galton's whistle and, less commonly, steel rods and plates.

Tuning-forks are steel or brass rods fixed at their middle points by a handle or stem, and with the projecting ends bent round so as to be parallel with the handle. They are set in vibration either by being struck at the end of one of the prongs, or by drawing a well-resined violoncello bow across the distal end of the prongs. Of all instruments tuning-forks give out by far the purest tones, but it is a mistake to assume, as is sometimes done, that the tones they produce are quite free from overtones. No instrument, if it is sounded sufficiently loudly, is quite free from overtones, but those of tuning-forks are far removed in pitch from the fundamental, and thus confusion is not likely to occur. Besides this, they die away much more quickly than the fundamental, so that by waiting for a moment the note becomes quite pure. For this reason these instruments are used for testing the hearing-power for the low notes, for it is obvious that no audible note should be present except the particular one which is desired.

For the purposes of the aurist, tuning-forks should be provided with sliding metal clamps by means of which the pitch may be altered within certain limits, according to the position of the clamps (Fig. 45.)

For the purpose of generating notes of a high pitch, Galton's whistle is the instrument most commonly used (Fig. 46). This instrument has been modified in an important way by Edelmann of Munich, and with this improved whistle he claims to be able to produce notes up to and beyond the limit of hearing for the normal human ear.

For the production of high notes use may also be made of flat metal discs, which are fixed to a stand by their middle points, and are set in vibration by drawing a violin bow across the edge. Some aurists use König's cylinders for the purpose of producing notes of high pitch. These are solid steel cylinders suspended by fine threads, and they are sounded by striking one end of the cylinder with a steel hammer. One objection to this instrument is that the high notes last for only a short moment.

In addition to the instruments already described, Bezold, who was one of the highest authorities in regard to the application of acoustical instruments to the purposes of the aurist, introduced two small covered organ-pipes. These help to bridge over the gap between the highest convenient tuning-fork and the lowest note of Galton's whistle.

CHAPTER II

ANATOMY AND PHYSIOLOGY OF THE OUTER AND MIDDLE EAR

ANATOMICAL.

In the preceding section we have discussed the physical characteristics of those vibrations which produce the sensation of sound. We now proceed to consider the means by which these vibrations are transmitted to the termination of the auditory nerve, and their method of stimulating that nerve.

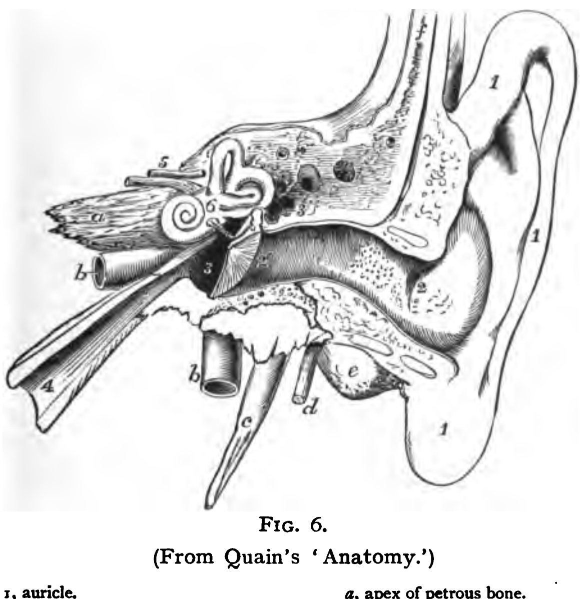


Fig. 6.

(From Quain's 'Anatomy.')

1, auricle.
2-2', external meatus.
2', tympanic membrane.
3, tympanic cavity.
4, Eustachian tube.
5, internal meatus.
6, vestibule.

a, apex of petrous bone.
b, internal carotid artery.
c, styloid process.
d, facial nerve.
e, mastoid process.
f, squamous portion of temporal bone.

The organ of hearing may be divided into three parts: the outer ear, the middle ear, and the inner ear or labyrinth.

THE OUTER EAR.

The outer ear consists of the *auricle and the external meatus* (Fig. 8). The auricle is roughly elliptical in its typical

FIG. 7.

a, helix.
b, fossa of antihelix.
c, Darwin's tubercle.
d, antihelix.
e, f, concha.
g, tragus.
h, antitragus.
i, lobule.

form, but great variations occur. It is marked by several ridges and hollows, which are sufficiently indicated in the figure (Fig. 7).

Structurally the auricle consists of a framework of cartilage covered by epidermis, and giving attachment to some small muscles.

The epithelium is richly supplied with large sebaceous glands, and is firmly attached to the perichondrium on the outer and anterior surface. The sweat-glands are few in number. The lobule is not supported by cartilage, and is therefore more pliable.

The *muscles* of the ear in the human subject are small and of little physiological importance. The attollens auriculæ is a fan-shaped muscle arising from the aponeurosis of the

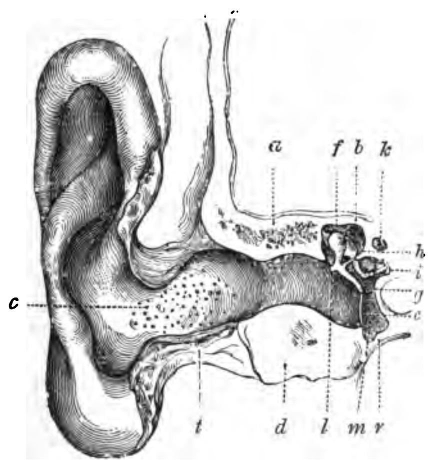


FIG. 8.

(Politzer.)

a, upper wall of bony meatus.
f, head of malleus.
b, tegmen tympani.
k, facial canal.
h, incus.
i, stapes.
g, handle of malleus.
e, tympanic membrane.
r, floor of tympanum.
m, cavity of tympanum.
l, short process of malleus.
d, lower wall of bony meatus.
t, lower wall of cartilaginous meatus.
c, openings of ceruminous glands.

cranium, and is attached to the upper rounded surface of the auricle. The attrahens auriculæ arises from the aponeurosis above the zygoma, and is attached to the anterior portion of the helix. The retrahens auriculæ arises from the outer surface of the mastoid process, and is attached to the posterior surface of the concha. These muscles move the auricle upwards, forwards, and backwards, respectively.

Another group of still smaller muscles is concerned in producing very slight alterations in the shape of the ear.

Four or five of these lie on the concave, and two on the convex surface of the auricle. They do not require description.

The *blood-supply* of the auricle is from the posterior auricular branch of the external carotid artery, the anterior auricular from the temporal, and the auricular branch from the occipital. The *nerve-supply* of the outer ear is from the great auricular of the cervical plexus, the auricular branch of the pneumogastric, the posterior auricular from the facial, and the auriculo-temporal branch of the inferior maxillary nerve.

The *external meatus* may be considered as the continuation inwards of the auricle. It consists of a tube the walls of which are composed for the most part of cartilage in the outer and bone in the inner portions, both being covered by epidermis. The cartilage in the outer portion does not form a complete tube, but only a channel as it were, there being a gap in the upper wall, which is bridged over by fibrous tissue. The length of the cartilaginous meatus is about 10 millimetres at its longest—that is, its lowest—border. It is marked by two, or sometimes more, transverse fissures—the fissures of Santorini. These fissures are occupied by fibrous tissue, through which bloodvessels pass.

The osseous meatus is a direct continuation inwards of the cartilaginous meatus, while it terminates internally in an elliptical ridge, which has a groove running along its free surface. This groove is for the insertion of the tympanic membrane. Neither the ridge nor the groove form a complete ellipse, there being a hiatus in the upper wall. This is known as the notch of Rivini, and its edge gives attachment to the small portion of the tympanic membrane known as Shrapnell's membrane. In early infancy the osseous portion of the meatus can hardly be said to exist. It is represented, however, by a ring of bone, the annulus tympanicus, which bears the grooved ridge just described. As development proceeds, this osseous ring is displaced farther and farther inwards. The tympanic membrane is therefore nearer to the opening of the meatus in the child than in the adult.

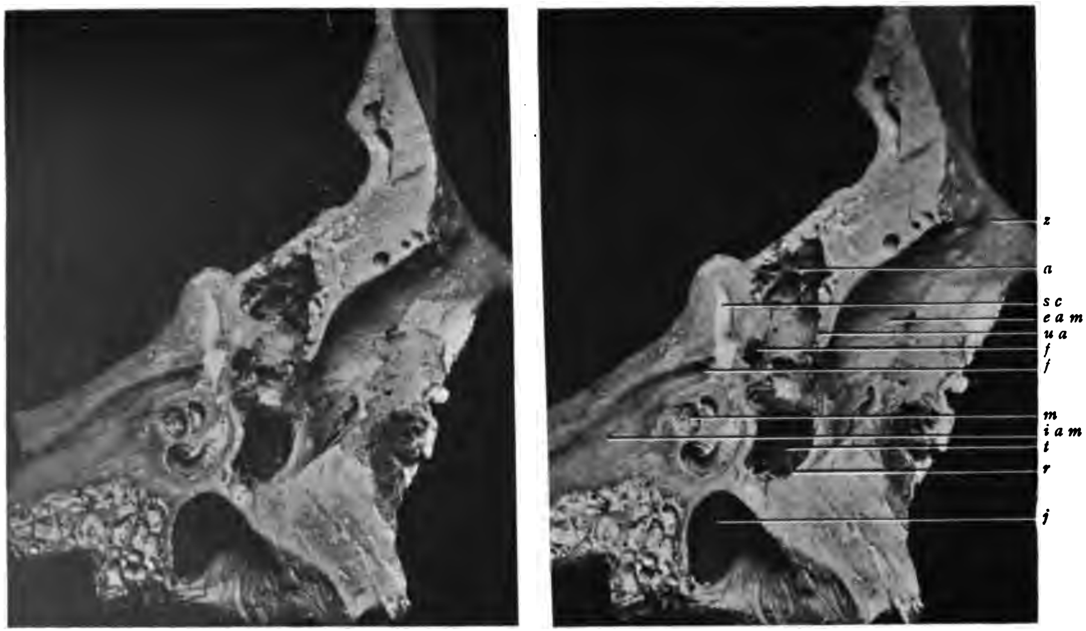
The general direction of the meatus is inwards, but also forwards to a slight extent, and while its outer half is inclined slightly upwards from without inwards, its inner half is inclined downwards in the same direction (Fig. 8).

In transverse section the meatus has roughly the form of

FIG. 9.—TRANSVERSE SECTION THROUGH THE TEMPORAL BONE: VIEWED FROM BEHIND. $\times \frac{7}{4}$.

(Prepared and photographed by the Author.)

z, zygoma.
a, attic.
s c, superior semicircular canal.
e a m, external auditory meatus.
u a, outer wall of attic.
f f, facial canal.
m, base of modiolus.
i a m, internal auditory meatus.
t, tympanum.
r, grooved ridge for insertion of tympanic membrane.
j, carotid canal.



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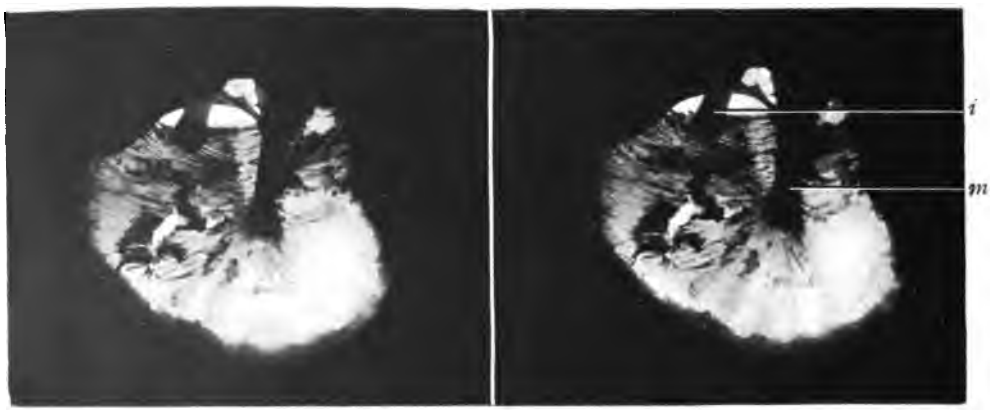


FIG. 10.—TYMPANIC MEMBRANE, SHOWING THE ARRANGEMENT OF THE RADIAL FIBRES: VIEWED FROM THE OUTER ASPECT. × 3½.

(Prepared and photographed by the Author.)

i, long process of incus. *m*, handle of malleus.

[*To face p.* 21.

a broad ellipse, of which the major axis is approximately vertical at the entrance, but becomes more horizontal in the deeper portions. At the entrance this axis measures from 6 to 9 millimetres, but the measurement varies greatly in different subjects.

The length of the meatus varies from 23 millimetres along its upper posterior wall, to 30 millimetres along the lower and anterior wall. The difference is due to the relatively oblique position in which the tympanic membrane lies, being from behind and above, downwards, forwards and inwards.

The cartilaginous meatus occupies about one-third of the whole, and the osseous meatus the remaining two-thirds. The epithelium of the meatus is of a moderate degree of thickness at the entrance, but becomes thinner on passing inwards. The outer portion is supplied with hairs, sebaceous glands, and ceruminous glands, the last being a modification of the sweat-glands of the skin—that is, they are tubular. These glands are found all over the cartilaginous portion of the meatus, but in the osseous portion they are confined to the outermost part of the upper wall. Their mouths can be seen in the living subject as small black specks. The hairs are usually small and insignificant in number, but occasionally they form quite a tuft and obstruct the view of the aurist.

The meatus is closed at its inner extremity by the *tympanic membrane.* As this structure is inserted into the groove in the elliptical ridge, which terminates the osseous meatus internally, the plane in which the membrane lies will be, generally speaking, the same as that of the ridge, forming an angle of 55 degrees with the horizontal plane. Its outermost point is above and behind, and its innermost below and in front. According to Pollak, this inclination is the same in children as in adults. In detail, however, the membrane departs from the simple plane just described. About its centre it is depressed inward at the umbo, thus forming the outline of a shallow cone with the apex directed inwards. Furthermore, the sides of the cone just mentioned are convex outwardly. As described by the author, it is like a spider's web in which the centre point is pushed away from the observer (Fig. 10). In its longest axis the membrane measures on an average 10 millimetres, and in its shortest about 9 millimetres.

The tympanic membrane is composed of three layers: An outer epithelial layer continuous with the epithelium of the meatus, a middle fibrous layer, and an internal epithelial layer continuous with the mucous lining of the middle ear.

Of the outer and inner layers nothing more need be said at present, but the structure of the middle layer is more important. It is composed of fibrous tissue, of which the constituent fibres are arranged in two groups—a circular and a radiating group. The circular fibres are scanty, especially towards the centre of the membrane, and become more numerous towards the outer region, where they form a tendinous ring, the annulus tendinosus. At the actual margin of the membrane they are absent. In one part of the tympanic membrane the fibrous layer is quite absent. This portion is triangular in shape, the angles of the triangle being at the short process of the malleus, and at the anterior and posterior edges of the notch of Rivini. This portion of the drumhead is known as Shrapnell's membrane or the membrana flaccida.

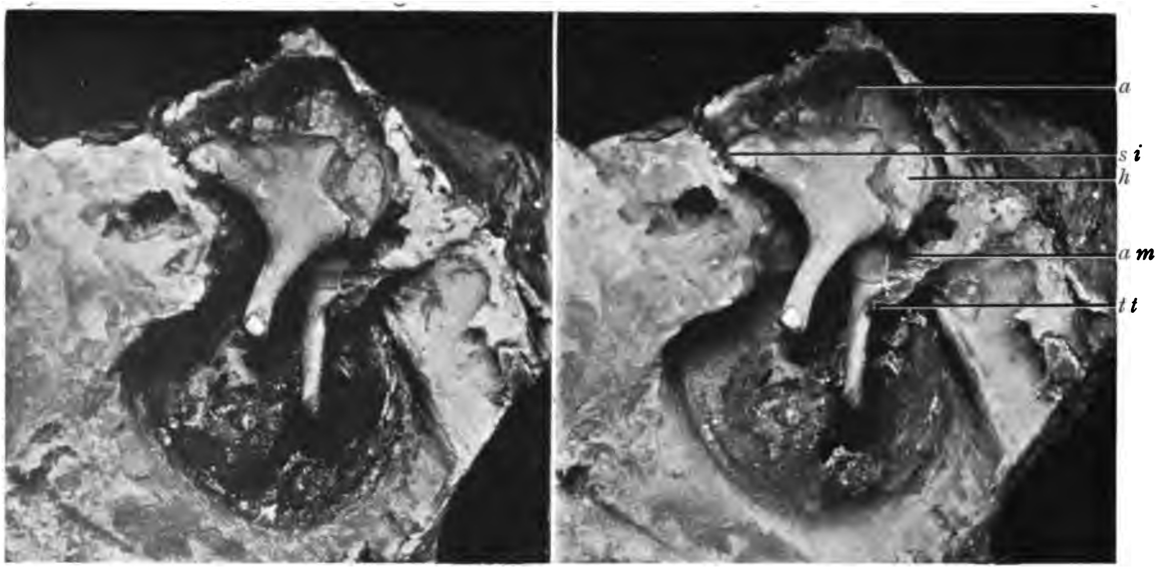
Extending from about the middle of the tympanum upwards and forwards is the long process, or manubrium, of the malleus. It does not, however, reach quite to the edge of the membrane, its termination at the short process being about 1 to 2 millimetres from the edge of the notch of Rivini above. The tip of the long process is firmly fixed to the membrane at the umbo. Passing upwards, the manubrium is not so completely incorporated in the membrane, and above the short process the bone is not attached at all (Fig. 21). From the short process of the malleus there pass two whitish striæ, the folds of the membrana tympani. One of these folds passes upwards and forwards, and is inserted into the anterior angle of the notch of Rivini; the other passes upwards and backwards to the posterior angle (spina tympanici postica) of that notch. These folds are much more pronounced in certain pathological conditions (Fig. 91). The membrane is not inserted directly into either the ridge at the inner end of the meatus, or into the manubrium of the malleus. At both these positions a layer of cartilage separates the fibres from the bone.

The vessels of the membrane consist of two sets of vascular anastomosing loops—an outer set in the outer layer, and an

FIG. 11.—THE OUTER WALL OF THE TYMPANUM: VIEWED FROM THE INNER ASPECT. × 3.

(Prepared and photographed by the Author.)

a, attic.
s i, tip of short process of incus.
h, head of malleus.
a m, anterior ligament of malleus.
t t, tendon of tensor tympani cut short.



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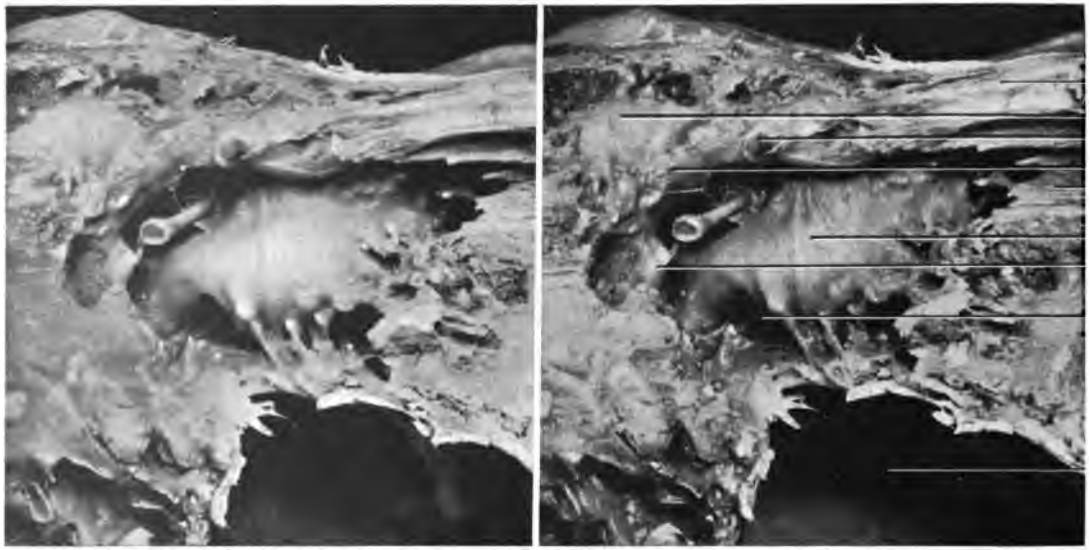


FIG. 12.—INNER WALL OF TYMPANUM, ETC.: VIEWED FROM THE OUTER ASPECT. × 2½.

The preparation has been rotated 30 degrees counter-clockwise. (Prepared and photographed by the Author.)

t, tensor tympani.
h, prominence of horizontal canal.
t t, tendon of tensor tympani.
f, prominence of facial canal.
e t, Eustachian tube.
p, promontory.
p s, pyramid, with tendon of stapedius emerging and dragged inwards by a dislocation of the stapes.
r, round window.
j, bulb of jugular vein.

[*To face p.* 23.

inner set in the inner or mucous layer. These two sets anastomose through the fibrous layer. The external network is derived from the deep auricular artery, which sends a branch down behind the manubrium to the umbo, where it breaks up, and the branches, radiating outwards, anastomose with vessels coming inwards from the periphery. A somewhat similar arterial supply is furnished in the inner lining of the membrane, but the vessels are branches from those of the tympanic cavity. The veins and lymphatics are arranged in a manner similar to that of the arteries.

The outer layer of the tympanic membrane is supplied with nerve fibres from the auriculo-temporal branch of the trigeminus, while the inner layer is innervated from the tympanic plexus.

The Tympanum or Middle Ear.

The tympanum is a cavity of irregular shape, bounded by walls marked in various ways, and containing air and a chain of small bones. It may be described as having six walls: outer, inner, anterior, posterior, upper and lower.

The *outer wall* consists for the most part of the tympanic membrane already described (Fig. 11). There is, however, a portion of the outer wall which extends above that structure, and consists of bone. It is part of the squamous portion of the temporal bone, and lies external to the membrane as well as above it. There is thus a space left between the external wall and the upper portion of the chain of bones to be described later (see Fig. 15). This space therefore lies above the inner portion of the external meatus; it is termed the outer attic. Just in front of the tympanic ring is a small perforation at the inner termination of the fissure of Glaser, through which passes the chorda tympani on its way to join the lingual branch of the fifth nerve.

The *inner wall* is very irregular. It contains in its posterior portion two openings: the fenestra ovalis and the fenestra rotunda (Fig. 13). Of these the former is kidney-shaped, the long diameter being nearly horizontal. It lies at the bottom of a shallow depression, the pelvis ovalis, and opens into the vestibule of the labyrinth, but in the recent state is closed by the stapes and the annular ligament (Fig. 12).

Below and slightly behind the fenestra ovalis is the fenestra rotunda, or round window. It looks backwards and slightly outwards, and opens into the scala tympani of the cochlea; but in the recent state it is closed by a membrane—the

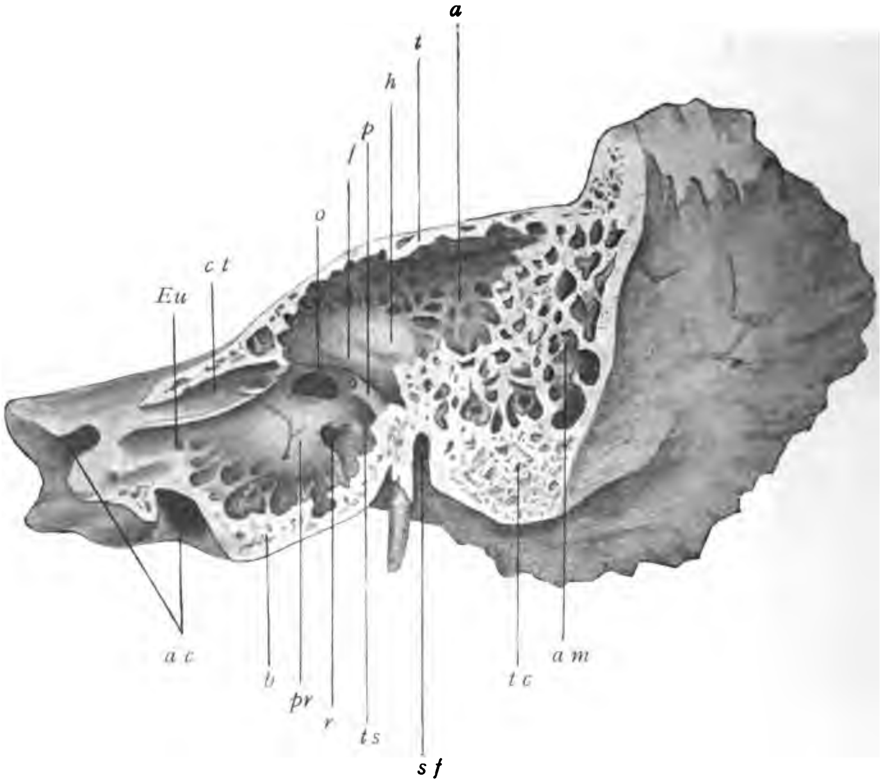


FIG. 13.—SECTION OF TEMPORAL BONE OF A CHILD FIVE YEARS OLD.
(From Quain's 'Anatomy.')

a, antrum.
t, tegmen tympani.
h, prominence of horizontal canal.
p, pyramid.
f, canal of facial nerve.
o, oval window.
c t, canal for tensor tympani.
Eu, Eustachian tube.
a c, carotid canal.
b, floor of tympanum.
pr, promontory.
r, round window.
t s, tympanic sinus.
s f, stylo-mastoid foramen.
t c, cancellous tissue.
a m, mastoid cells.

membrana tympani secundaria. This membrane is composed of a middle fibrous layer and an outer and inner layer, the last two being derived from the tympanic mucous lining and the endosteum of the cochlea respectively. This membrane of the round window is continued above and behind into the membranous spiral lamina of the cochlea.

The measurements of these two windows are as follows: The oval window 3 millimetres by 1·5 millimetres, the round window 1·5 to 2 millimetres, in diameter.

Immediately above the oval window is a canal, sometimes incomplete in its tympanic aspect, for the passage of the facial nerve; and immediately above and external to this canal is a slight prominence, the anterior external portion of the horizontal semicircular canal. On passing upwards from this prominence the inner wall of the tympanum passes backwards to form the inner wall of the aditus ad antrum. Behind the fenestra ovalis there is a cul-de-sac, the deeper portion of which lies close to the ampulla of the posterior semicircular canal.

In front of the round window is a smooth prominence. This is the promontory, and it is here that the outer and inner walls approach each other most closely. It is almost exactly opposite the centre of the tympanic membrane (Figs. 12 and 21). A short distance above the promontory is a hooklike projection of bone—the processus cochleariformis—round which plays the tendon of the tensor tympani muscle. The bony projection is continued forwards, inwards, and downwards, into the walls of the canal for that muscle. Below this canal the inner wall of the tympanum ends in the Eustachian tube, the orifice of which opens two or three millimetres above the floor of the cavity. The space between the orifice and the floor is occupied by a plate of bone, which in part separates the carotid artery from the tympanum, and allows the passage of small vessels and nerves from the canal in the petrosal portion of the temporal bone that lodges that artery. Dehiscences are occasionally found in this plate of bone.

An *anterior wall* can hardly be said to exist in the lower half of the tympanic cavity. The opening of the Eustachian tube occupies the place where it would lie in its lower part, and above this it passes into the anterior wall of that portion of the tympanum which is known as the recessus epitympanicus or attic. A small portion of an anterior wall does, however, exist between the lower lip of the Eustachian opening and the floor of the tympanic cavity (Fig. 21).

The *posterior wall* (Fig. 14) is naturally divided into two portions—a lower one bounding the tympanum proper, and an upper one belonging to the attic. In the upper part of the lower division is a well-marked conical eminence—the pyramid or eminentia papillaris, with a small foramen at its tip, which points forwards, and is directly outside of, and posterior to the oval window. The inside of this cone is hollow and curved, and lodges and gives attachment to the stapedius muscle, the tendon of which passes out through the small foramen at the tip, and is attached to the head of the stapes. The canal itself turns down behind the posterior wall, and sometimes opens by a small perforation immediately in front of the stylo-mastoid foramen.

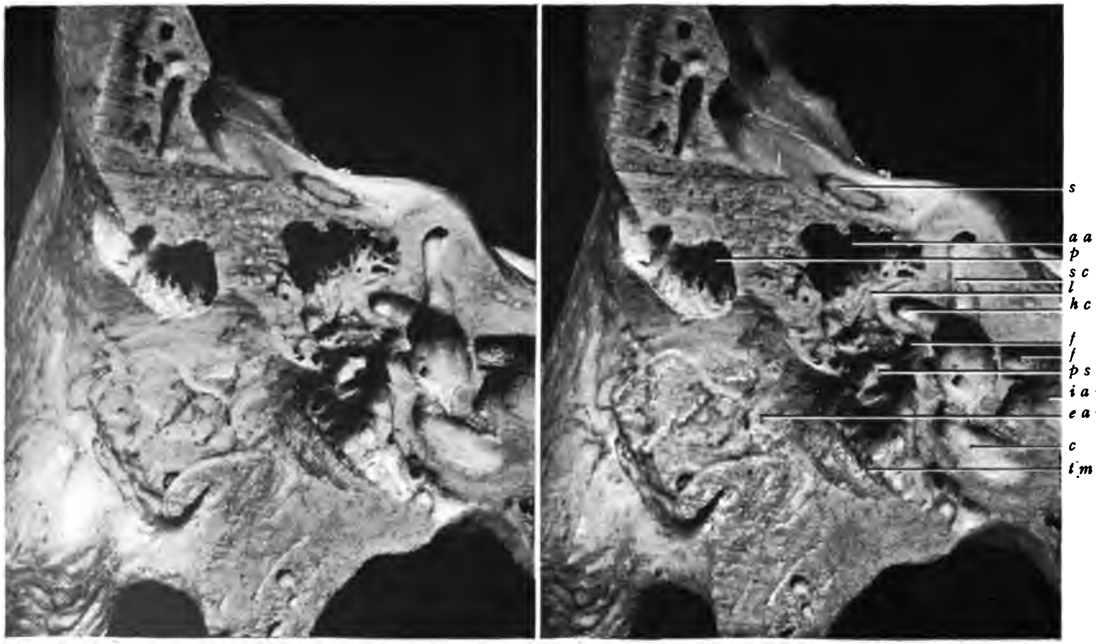
Above the pyramid the posterior wall passes upwards and outwards to the floor of the opening into the mastoid antrum; the rest of the posterior wall is occupied by this opening. At their junction the posterior wall and the floor of the entrance to the antrum form a sharp angle, which gives attachment to the ligament binding down the short process of the incus. A small aperture will be seen in the outer margin of the posterior wall at the level of the oval window. This gives passage to the chorda tympani nerve as it enters the tympanum.

The *superior wall* or *tegmen tympani* (Figs. 9 and 14) is a thin plate of bone, and is formed by the outer portion of the upper surface of the petrous portion of the temporal bone. The fissure which demarcates the petrous from the squamous portion of the temporal bone (petro-squamous fissure) is thus external to the roof. In its anterior portion the roof meets the upper margin of the anterior wall, and posteriorly it passes backwards to form the roof of the aditus and inner portion of the mastoid antrum. It has no anatomical features of special interest, but is of great surgical importance, since in cases of brain abscess the infection frequently passes from the middle ear through the roof. There is occasionally a small dehiscence in the tegmen.

The *floor of the tympanum* is narrow from without inwards, as the outer and inner walls approach each other as they descend, and it lies on a level a little lower than the floor of the meatus. In its posterior portion there is occasionally a dehiscence which allows the bulb of the jugular vein to be seen

FIG. 14.—SECTION THROUGH TEMPORAL BONE: VIEWED FROM IN FRONT. × 2½. (Prepared and photographed by the Author.)

s, intracranial surface of tegmen.
a a, aditus ad antrum.
p, artificial perforation into antrum through upper posterior wall of meatus.
s c, superior semicircular canal.
l, surface for articulation with short process of incus.
h c, horizontal canal.
f, facial canal.
p s, pyramid, with foramen at tip for tendon of stapedius.
i a m, internal auditory meatus.
e a m, external auditory meatus.
c, lowest whorl of cochlea.
t m, margo tympani.



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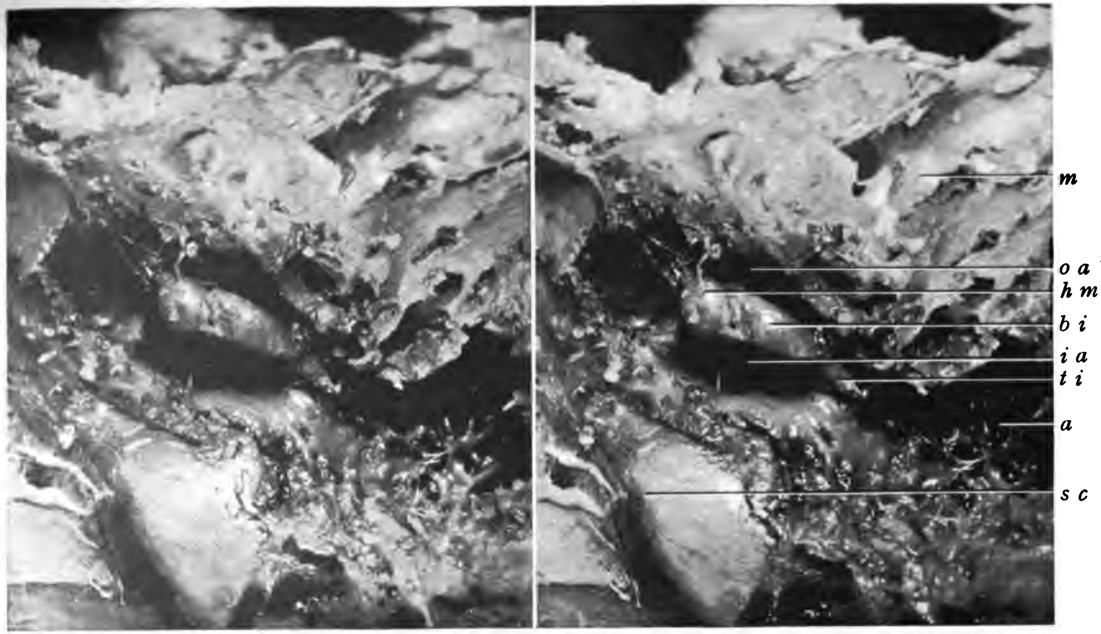


FIG. 15.—TYMPANUM AND ANTRUM: VIEWED FROM ABOVE, AFTER REMOVAL OF TEGMEN, ETC. × 2.

(Prepared and photographed by the Author.)

m, external meatus. *o a*, outer attic. *h m*, head of malleus. *b i*, body of incus. *i a*, inner attic. *t i*, tip of short process of incus. *a*, antrum. *s c*, prominence of superior semicircular canal.

[*To face p.* 27.

from the tympanum, and even to give a bluish tint to the lower part of the tympanic membrane as seen by the speculum in the living subject. This possibility must be remembered in performing myringotomy (incision of the membrane), and the author is of opinion that this dehiscence is not quite so rare as is sometimes supposed (Fig. 12).

In the preceding description the tympanum has been understood to include all the height of the cavity up to the tegmen. In the recent state, however, the upper portion is in large part shut off from the lower, and is termed the attic. This division of the cavity is that portion which lies above the level of the two tympanic spines. It lodges the head of the malleus and the body of the incus, and gives attachment to several ligaments, besides taking part in the formation of several recesses, all of which will be described later.

The *attic* (Fig. 15) communicates behind with the mastoid antrum by means of the aditus ad antrum. This short channel is in some rare cases closed from the tympanic cavity by a membrane. On its lower wall there is noticeable in many bones a small rough spot. This is the point at which the tip of the short process of the incus is fixed down by ligaments, and it therefore forms one end of the axis round which the incus rotates.

The aditus passes directly backwards, and opens into the *mastoid antrum* (Fig. 15). This cavity, so important from a surgical point of view, varies much in different individuals. In general it may be said to be oval, the long axis running from the aditus outwards, backwards and downwards. The walls of the mastoid antrum are irregular, consisting, in fact, of numerous small air-containing cavities, the mastoid cells, which form a large part of the bulk of the mastoid process.

The petro-squamosal suture, which frequently becomes obliterated in adult life, passes through the bone down to the mastoid antrum, as also does the squamo-mastoid suture, which may be seen on the outer surface of the temporal bone.

As the anatomical relationships of the mastoid portion and its contents are of great surgical importance, it would not be out of place to devote a few sentences to the subject. Viewed from the outer surface, the mastoid process is conical, with the apex pointing downwards and forwards (Fig. 17). In front of its middle portion is the external meatus, while above it passes into the squamous portion of the bone. The root of the zygoma or suprameatal crest arises in front of this latter part of the anterior margin of the mastoid portion, and passes downwards and forwards almost parallel with, and about 8 millimetres in front of it. Although, therefore, the root of the zygoma is in the squamous portion of the temporal bone, it forms an important landmark in performing the operation

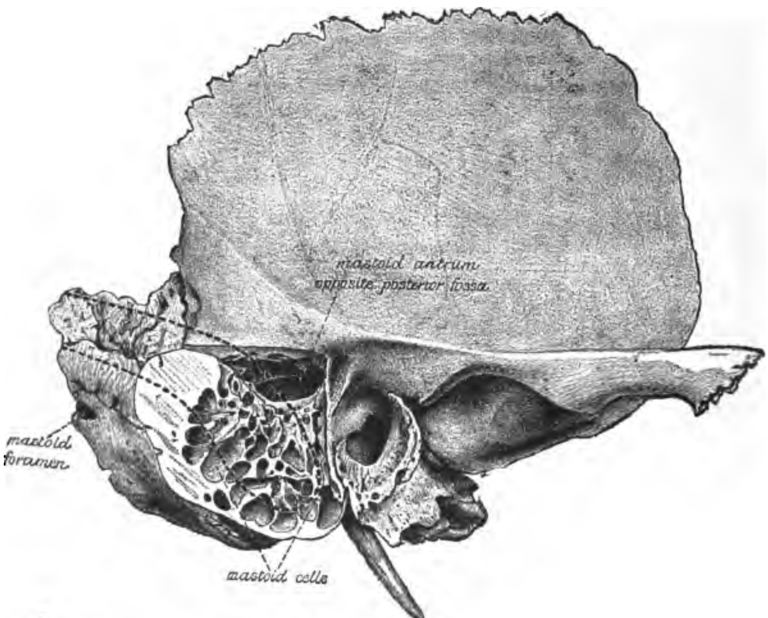


FIG. 16.—TEMPORAL BONE, FROM WHICH THE SUPERFICIAL PORTIONS OF THE MASTOID REGION HAVE BEEN REMOVED.

The dotted line indicates the position of the lateral sinus. (Quain.)

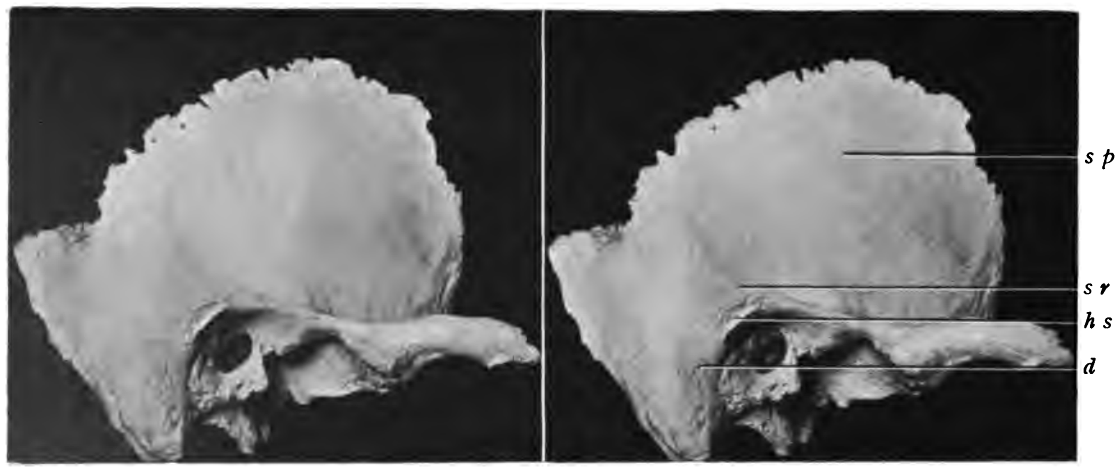
of opening the mastoid antrum. Immediately below and behind the ridge formed by the root of the zygoma is a shallow depression of about a finger's breadth. This depression contains the squamo-mastoid suture, and passes below and in front into the external meatus. The *spine of Henle* is at the upper posterior portion of the entrance to the bony meatus (Fig. 17).

Above and behind, the mastoid portion is in contact with the parietal bone for a distance of $1\frac{1}{2}$ centimetres. Its posterior

FIG. 17.—TEMPORAL BONE: VIEWED FROM THE OUTER ASPECT. $\times \frac{3}{4}$.

(Photographed by the Author.)

$s p$, squamous portion. **$s r$, suprameatal ridge.** **$h s$, spine of Henle.** **d, depression on surface of mastoid process.**



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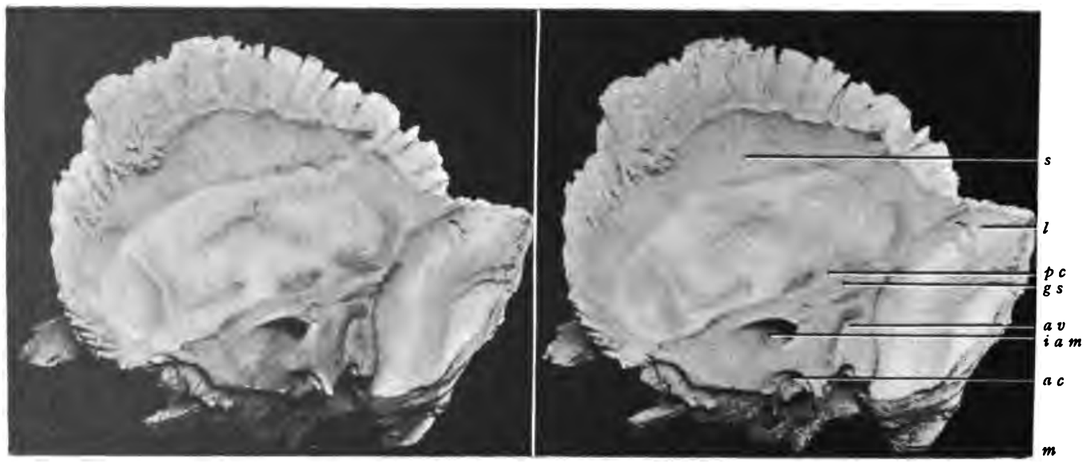

FIG. 18.—TEMPORAL BONE: VIEWED FROM THE INNER ASPECT. $\times \frac{4}{5}$.

(Photographed by the Author.)

s, squamous portion.
l, groove for lateral sinus.
p c, prominence of superior semicircular canal.
g s, groove for superior petrosal sinus.
a v, opening of aqueduct of vestibule.
i a m, internal auditory meatus.
a c, opening of aqueduct of cochlea.
m, tip of mastoid process.

[*To face p.* 29.

margin is directed downwards and forwards, and is in contact with the occipital bone three-fourths of its whole length, forming the occipito-mastoid suture. Near the middle of this suture, but placed in the occipital bone, is a perforation, the mastoid foramen (Fig. 16), giving passage to a vein running from the lateral sinus within the cranium to the veins of the scalp. There are occasionally several perforations instead of one. When thrombosis of the lateral sinus occurs, the clot may extend outwards by the vein occupying this foramen, and by its evidence assist in diagnosis. The extent to which the sigmoid fossa encroaches upon the mastoid portion of the temporal bone varies considerably in the individual, a state of affairs which has an important bearing upon the operation of opening the mastoid antrum, which will be referred to later (p. 281).

The inner surface of the mastoid portion may be divided into two parts—an upper one, the sigmoid fossa, which lodges the lateral or sigmoid sinus at its bend; and a lower one, which contains a cleft in which is inserted the digastric muscle. The occipital suture separates these portions. At their lower extremities the inner and outer surfaces meet to form the apex of a cone, from which the sterno-mastoid muscle takes origin. Near the anterior end of the fissure for the digastric muscle is the stylo-mastoid foramen (Fig. 20), giving exit to the facial nerve and entrance to the stylo-mastoid artery. Immediately in front of this foramen is the styloid process. Before the facial nerve leaves the bone by the stylo-mastoid foramen, it gives off the chorda tympani. This nerve, doubling back as it were upon the facial, passes upwards and forwards through a canal of its own, to emerge into the tympanum internal to the posterior margin of the membrana tympani.

Before leaving the mastoid portion of the bone, reference must be made to two important structures on the inner wall of the antrum, the horizontal semicircular canal and the facial nerve. The first of these forms a slight projection on the inner wall of the aditus, where the latter is just opening out into the antrum (Fig. 14). The facial nerve, after passing backwards above the fenestra ovalis for a short distance, turns outwards and downwards in its course to the stylo-mastoid foramen (Fig. 24). It passes, therefore, below and in front of the inner portion of the mastoid antrum, and behind the inner and lower portion of the external meatus.

In the child the relationships of the mastoid antrum are different from those of the adult, and these differences have an important bearing on surgical procedures (Fig. 19).

In the newly-born child there is no mastoid process properly so called, nor are there any air-spaces surrounding the mastoid antrum. The mastoid antrum lies somewhat higher in the child than in the adult, and its outer portion does not dip downwards to such a great extent. Still more important is the fact that it is much nearer the outer surface of the tem-

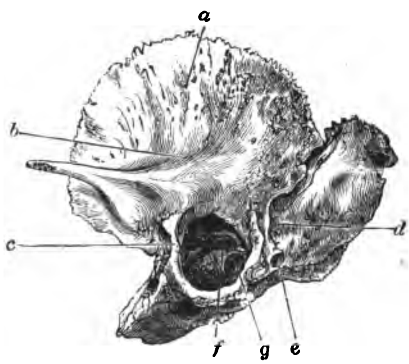

FIG. 19.—TEMPORAL BONE OF NEWLY-BORN INFANT. (Politzer.)

a, squamous portion.
b, upper portion of root of zygoma.
c, tympanic ring.
d, squamo-mastoid suture.
f, oval window.
g, round window.
e, stylo-mastoid foramen.

poral bones, and consequently the surgeon needs to remove only a small layer of bone in order to reach the cavity. To those cognizant with the comparative anatomy of the temporal bone these facts will suggest interesting evolutionary relationships, but space is too limited to discuss these.

It has been stated that the tympanic membrane in the child lies in a more horizontal plane than in the adult, but Symington has shown that this is not really the case.

The *Eustachian tube* (Fig. 6), by means of which the cavities of the naso-pharnyx and the tympanum are brought into direct communication, consists of an inner cartilaginous portion and

FIG. 20.—TEMPORAL BONE: VIEWED FROM BELOW. NATURAL SIZE.

(Photographed by the Author.)

c, carotid canal.
a c, opening of aqueduct of cochlea.
f, foramen for the passage of nerve of Jacobson.
j, jugular fossa.
g, fissure of Glaser.
s, styloid process broken short.
o, stylo-mastoid foramen.
m, surface for articulation with lower jaw.
d, digastric fossa.
e a m, external auditory meatus.
p m, mastoid process.
z, zygoma.

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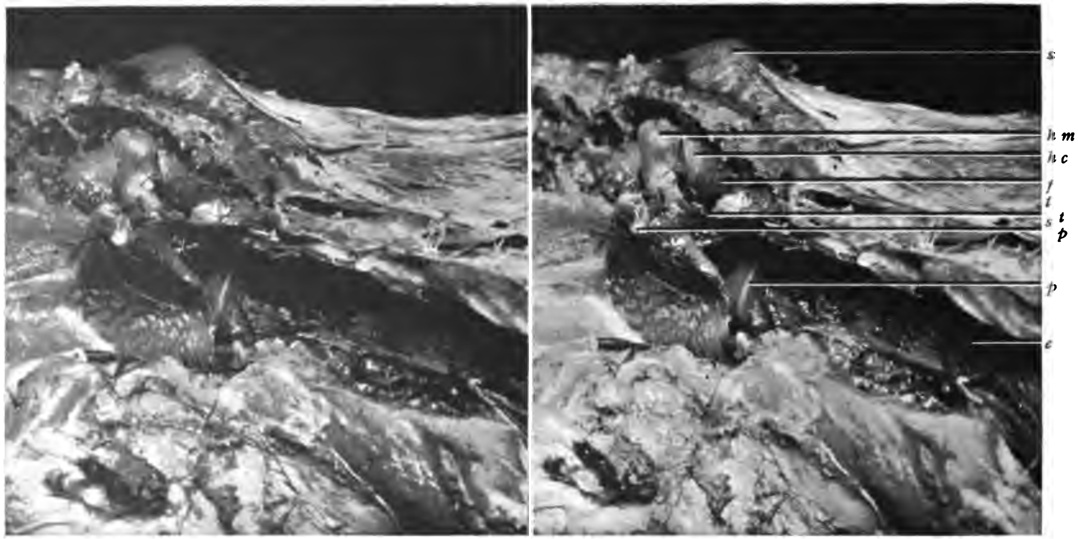

FIG. 21.—THE MIDDLE EAR: VIEWED FROM IN FRONT. $\times \frac{4}{3}$. (Prepared and photographed by the Author.)

The anterior portion of the tympanic membrane, the outer wall of the Eustachian tube, the upper wall of the canal for the tensor tympani, and the incus have all been removed. The posterior upper wall of the meatus and the tegmen tympani and tegmen antri have also been removed.

s, prominence of superior semicircular canal.
h m, head of malleus.
h c, prominence of horizontal semicircular canal.
f, prominence of the facial canal.
t t, tendon of tensor tympani. The pointer crosses the muscle itself.
s p, short process of hammer.
p, promontory.
e, Eustachian tube.

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an outer osseous portion. It varies in length from 35 millimetres to 40 millimetres, of which the outer third is osseous and the remaining two-thirds cartilaginous. Its naso-

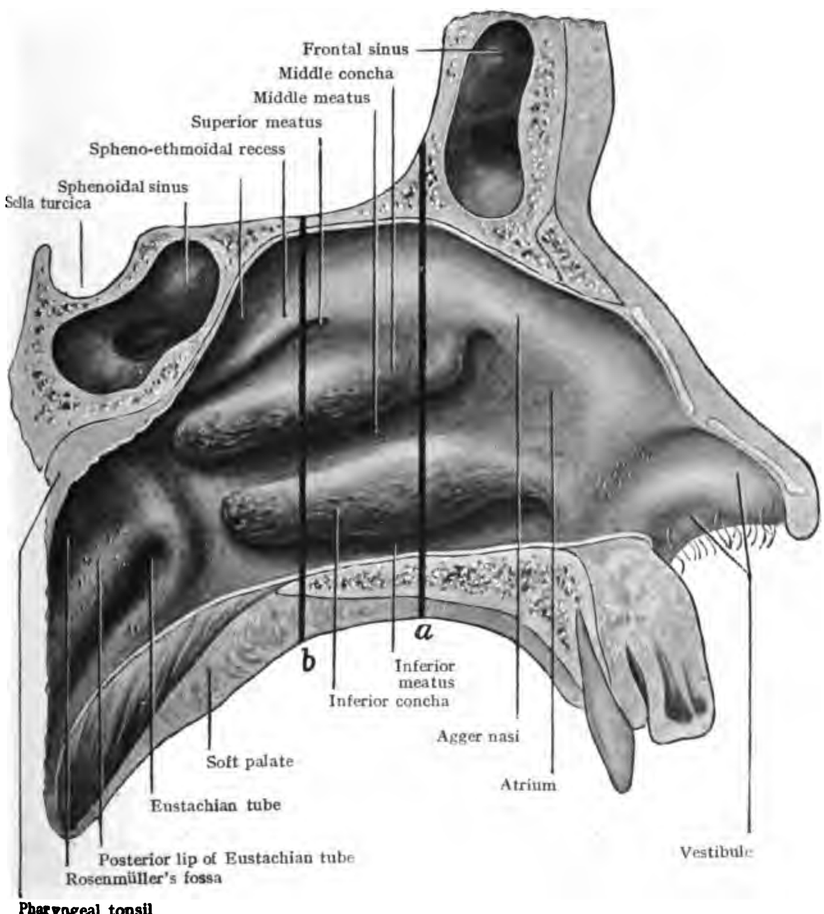


FIG. 22.

(Quain.)

pharyngeal orifice, the ostium pharyngeum, is to be found on the lateral wall of the naso-pharynx behind the posterior end of the inferior turbinated body. It passes below directly into the wall of the naso-pharynx, but in front, above and behind, there is a ridge, usually described as hook-shaped. This ridge is the inner termination of the cartilage, which is deficient below where the ridge is absent. The mouth of the tube is directed downwards, forwards, and inwards. Immediately behind the opening of the tube is the lateral recess of the naso-pharynx or fossa of Rosenmüller (Fig. 22). The cartilage is largest at the ostium pharyngeum, measuring 12 millimetres from above downwards, and 7 millimetres in thickness. Passing outwards, upwards, and backwards, the tube diminishes in size, and is frequently traversed by fissures, and small isolated pieces of cartilage are sometimes present. The tube is completed on its lower aspect by tough fibrous tissue, which is more or less resilient. The cartilaginous portion of the tube is trumpet-shaped, the wide end of the trumpet being the ostium pharyngeum (Fig. 22). The tube is from 4 to 5 millimetres in diameter at its broadest part, the ostium pharyngeum, and 2 millimetres in diameter at its narrowest, the isthmus. It forms an angle of 130 degrees with the nasal septum.

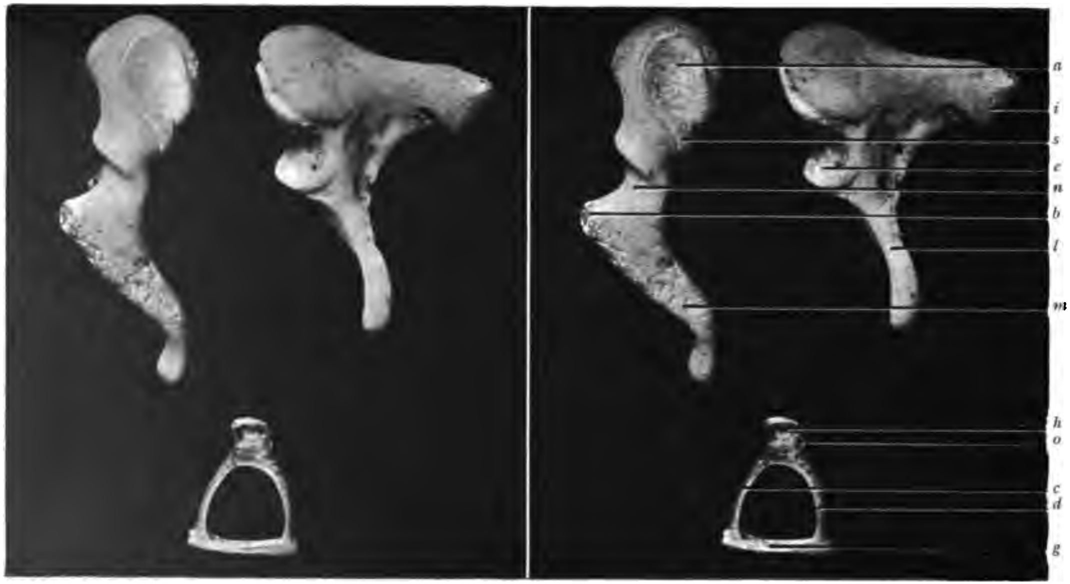
The osseous portion, about 12 millimetres in length, is united to the cartilaginous portion at the isthmus tubæ, the narrowest part of the tube. It is slightly more horizontal than the cartilaginous portion, but in general follows the same direction, and opens externally into the tympanum at the ostium tympanicum, a little above the level of the floor of that cavity (Fig. 21). Immediately above the osseous portion of the tube lies the canal for the tensor tympani muscle, and behind and internal to it is the carotid canal, a thin partition separating the two.

Attached to the lower wall of the cartilaginous portion is a bundle of muscle fibres, forming part of the tensor palati, and named by Rüdinger the dilator tubæ. The levator palati also takes its origin from the lower margin of the cartilaginous portion at its mesial extremity, and from the adjacent membrane that forms the floor of the tube at that part. The portion of the palato-pharyngeus muscle known as the salpingo-pharyngeus of Santorini also arises from the mesial extremity of the lower margin of the cartilaginous portion, and passes downwards to the palato-pharyngeus muscle itself.

FIG. 23.—THE AUDITORY OSSICLES. × 4 *circa*. (Prepared and photographed by the Author.)

The malleus (left) is viewed from behind, the incus (left) from the outer aspect, and the stapes (right) from above.

a, surface on head of malleus for articulation with incus.
i, short process of incus.
s, spur-like ridge on posterior margin of articular surface of malleus.
e, articular surface of incus.
n, neck of malleus.
l, long process of incus.
m, manubrium mallei.
h, head of stapes.
o, point of insertion of tendon of stapedius muscle.
c, anterior crus of stapes.
d, posterior crus of stapes.
g, footplate of stapes.
b, short process of malleus.



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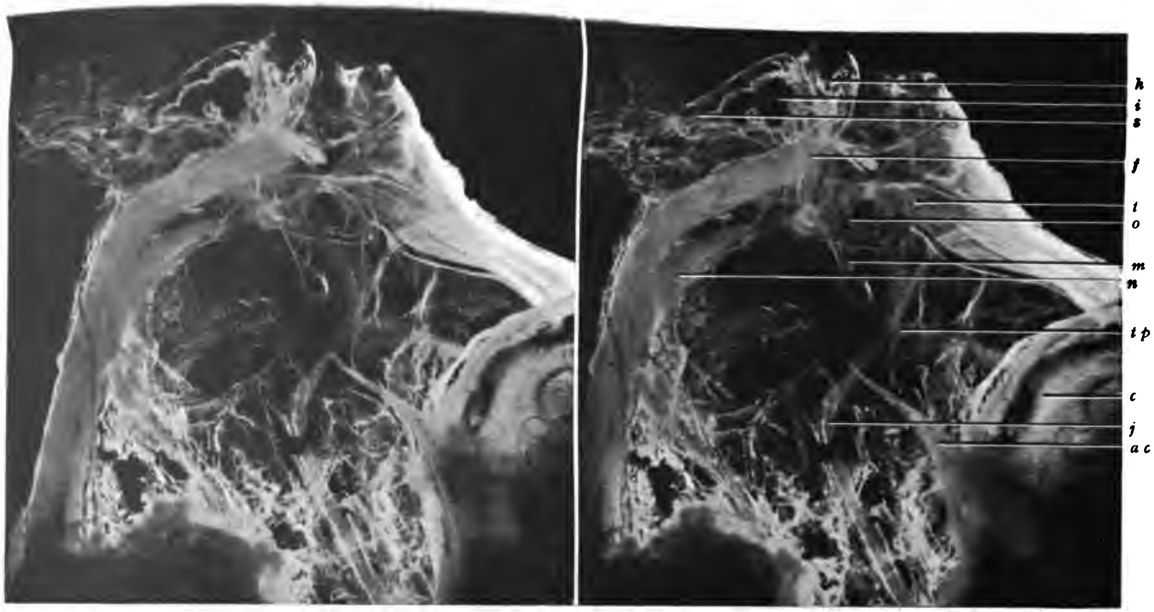


FIG. 24.—THE SOFT PARTS OF THE TYMPANUM AND ADJACENT REGIONS: VIEWED FROM THE INNER ASPECT AND BEHIND. × 3½. (Prepared and photographed by the Author.)

h, head of malleus. *i*, body of incus; the dark portion is a remnant of undecalcified bone. *s*, short process of incus. *f*, facial nerve broken at its bend above the oval window. *t*, tensor tympani muscle; the tendon may be seen running outwards to be inserted into the malleus. *o*, stapes in position in oval window. *m*, manubrium mallei. *n*, stapedius muscle; the tendon can be seen running towards its point of insertion in the stapes. *t p*, tympanic plexus. The nerve of Jacobson (*j*) is seen running upwards into it, and the branches to the carotid canal, to the Eustachian tube, and to the great superficial petrosal may also be seen. *c*, carotid artery. *j*, nerve of Jacobson, broken over a short distance at the place where it enters the floor of the tympanum. *a c*, aqueduct of the cochlea; the rest of the inner ear has been removed.

[*To face p.* 33

In the opinion of most anatomists, the function of these muscles is to open the tube during their contraction, such as occurs in swallowing. Some anatomists, however, dispute this.[1]

The mucous membrane of the tube is fixed firmly to the periosteum in the osseous portion, except at its inferior wall, where a plexus of veins separates the two. In this portion it is lined with ciliated epithelium, but there are no glands. The movements of the cilia are from the tympanum towards the ostium pharyngeum. Similarly, there is found a ciliated epithelium lining the cartilaginous portion, but here there are also numerous mucous glands.

The arterial blood-supply is from twigs of the ascending pharyngeal branch of the external carotid, from the middle meningeal, and from the Vidian arteries. The sensory nerve-supply is from the tympanic plexus and from twigs from the Vidian nerve. The tensor palati (dilator tubæ) is supplied from the otic ganglion, while the levator palati is innervated from the Vidian nerve.

The *auditory ossicles* are three in number, and are united to each other and to the walls of the tympanum by ligaments. They form together a lever of the second order, the weight or resistance being at the oval window.

The *malleus* or *hammer* is about 9 millimetres in length, and weighs 24 milligrammes. It consists of a lower thin portion, the handle, and an upper rounded portion, the head; uniting these is the neck. On the inner and posterior surface of the head is a somewhat oval depressed surface, for articulation with the incus. This surface has two facets almost at right angles with each other, and separated by a sharp edge. The upper facet looks backwards, and the lower inwards (Fig. 23).

Along the external margin of the articular surface is a well-marked ridge. This ridge fits into a corresponding depression on the anvil, and prevents the hammer from being driven too far inwards, while it has comparative freedom in its outward displacement, as will be shown later. The remaining portion of the head is rounded, and looks for the most part forwards, upwards, and inwards.

[1] *Vide* McKendrick and Gray in Schäfer's 'Textbook of Physiology,' vol. ii., p. 1161.

Passing downwards from the head is the neck. It has three surfaces—an inner one, bounded by the processus gracilis in front, and by the surface for the insertion of the tendon of the tensor tympani below and behind. Besides these, there is an external and a posterior surface. From the lower end of the neck two processes take their origin—the long process or processus gracilis, and the short process or processus brevis or obtusus. The processus gracilis leaves the anterior surface of the neck at a right angle, and passes forwards and slightly downwards to the fissure of Glaser, to the sides of which it is attached by fibres or bone. In the adult this process is converted entirely or in great part into fibrous tissue, but in the child it is a thin spicule of bone. In the fœtus it is continued forward into Meckel's cartilage, of which, indeed, it forms a part.

The processus brevis is a small cone-shaped process which arises at the junction of the manubrium and neck of the hammer, and projects outwards against the tympanic membrane (Fig. 21).

The handle or manubrium runs downwards from the neck, forming an angle of about 130 degrees with the latter. In its upper portion it is flattened from before backwards, but at its lower end it is compressed laterally. It is attached to the membrane in its whole length, but most firmly at the tip. A layer of cartilage is interposed between the bone and the membrane. The manubrium varies in length from 4·2 to 5·6 millimetres, and the head and neck together are approximately of the same length.

The *incus* or *anvil* (Fig. 23) is named from its supposed resemblance to an anvil, but it has been compared more appropriately to a molar tooth, with the fangs widely separated, the crown of the tooth being represented by the body of the bone, and the fangs by the two processes. On the anterior surface of the body is a deep saddle-shaped depression, lined with cartilage, for articulation with the corresponding surface of the malleus. It has two facets to fit against the two similar surfaces on the malleus above described. In its outer margin the articular surface is hollowed out to accommodate the spurlike ridge of the malleus (Fig. 23), and prevent an excessive inward movement of that bone, as described by Helmholtz,[1] while it allows of comparative freedom of movement outwards.

The short process of the incus is directed backwards, and is fixed by a ligament to the lower margin of the aditus ad antrum (Fig. 15).

The long process is thin, and projects directly downwards. Its extremity, however, turns sharply at right angles directly inwards, to end in a slight expansion with an articular surface looking inwards, and covered with cartilage. This portion is termed the processus lenticularis or orbicularis; it articulates with the head of the stapes, and in the fœtus is a separate bone. The long process of the incus is nearly parallel with the handle of the malleus; it is 1½ millimetres internal to and behind that structure.

The short process is 3 to 3½ millimetres in length, and the long process 4½ millimetres. The whole bone weighs 24 milligrammes.

The name *stapes* or *stirrup* describes very accurately the third and last ossicle. It consists of a head or capitulum, two crura, and a footplate. The head is directed outwards, and ends in a flat or slightly hollowed surface covered with cartilage and articulating with the processus lenticularis of the incus. Internally the head passes into a short neck, which divides into the two crura, anterior and posterior, and these are again united at their inner extremities by the flat oval footplate. The latter occupies the greater part of the fenestra ovalis, but is nowhere in actual contact with the bone, there being a layer of cartilage all round the footplate, and another round the margin of the oval window. Between these two layers of cartilage is the annular ligament, consisting of dense elastic fibres. The footplate of the stapes is, as above stated, roughly oval, the upper border being more curved than the lower. Over the vestibular surface of the footplate is a layer of cartilage, continuous with that lining the margin of the bone.

Of the two crura, the anterior one is generally the shorter and straighter, but individual bones vary greatly in this respect. Between the two crura there is sometimes found a fine membrane, which is inserted into a groove running along their concave surfaces.

[1] 'Ueber d. Mechanik d. Gehörknöchelchen Wissensch. Abhandl.,' Bd. ii., S. 503, 515.

The ossicles are united to one another and to the temporal bones by ligament, but a synovial membrane is found only in the malleo-incudal joint. The malleus is attached by four ligaments:

1. The *anterior ligament*, broad and strong, passes from the anterior surface of the malleus, at and above the origin of the processus gracilis, to the anterior tympanic wall, in the region of the fissure of Glaser. Some of the fibres arise from the anterior angle of the notch of Rivini or spina tympanica anterior.

2. The *accessory anterior ligament*, which passes from the point of insertion of the tensor tympani to the processus cochleariformis and the surface of the promontory in front of this, and to the arterior wall still farther forwards.

3. The fan-shaped *external ligament*, radiating from the neck of the hammer to the edges of the notch of Rivini.

4. The *superior ligament* is small, and passes from the tegmen tympani to the head of the malleus.

There is but one ligament attached to the incus. It radiates backwards from the tip of the short process to the floor of the aditus ad antrum.

The stapes also is possessed of only one ligament, which unites the footplate in its whole margin to the margin of the oval window. It is known as the *annular ligament.*

There are two *intratympanic muscles*—the tensor tympani and the stapedius(Figs. 21 and 24).

The tensor tympani is a thin pennate muscle arising from the walls of the canal lying above and parallel with the Eustachian tube in its outer part (see p. 32). It is about 15 millimetres in length, and, emerging from its canal just above the opening of the Eustachian tube, it becomes tendinous. It then passes at right angles round the processus cochleariformis, where it is supplied with a bursa, and, crossing the tympanum outwards, is inserted into the inner surface of the manubrium of the malleus at the junction with the neck. It is supplied by a branch of the fifth nerve coming from the otic ganglion, and possessing a small ganglion of its own.

The stapedius is a small muscle hidden in a cavity in the bone of the posterior tympanic wall described above (p. 26). It emerges by a tendon from the foramen immediately behind the head of the stapes, and is inserted into the neck of that bone just internal to the incudo-stapedial joint. It is supplied by a branch from the seventh nerve.

Movements of the Ossicles.—Generally speaking, the ossicles move together as a whole, and only to a slight extent individually. The movement is that of rotation round an axis, extending from the attachment of the short process of the incus to the insertion of the anterior ligament of the malleus at the fissure of Glaser (Fig. 11). Since the whole of the manubrium is below this axis, any inward movement of the tympanic membrane produces an inward movement of the manubrium of the hammer, the long process of the incus, and the whole of the stapes; while the head of the malleus and the greater part of the body of the incus move outwards. A reverse movement happens with an outward displacement of the tympanic membrane. Furthermore, on account of the peculiar formation of the malleo-incudal joint (*vide* p. 34), the incus does not follow the outward movement of the malleus so closely as it does the inward movement. In its inward movement the head of the stapes moves slightly upwards. The stapes revolves round an axis, or hinge, as it may be termed, at the posterior edge of the window.

Since the tensor tympani is inserted below the axis of rotation, it drags in the handle of the malleus and tightens the membrane, at the same time rotating the malleus slightly. The stapedius drags the stapes outwards from the fenestra ovalis by fixing the posterior extremity against the wall of that opening, while the rest of the bone rotates outwards. There is no evidence to support the view that the stapes rotates round a vertical axis passing through the middle of the footplate.

The chain of ossicles as a whole, when moving under the influence of sound-waves, forms a lever of the second order, since the resistance is at the oval window, which is below the fulcrum at the axis of rotation, and above the force applied at the tip of the manubrium. It is not a lever of the first order, as is sometimes stated.

The *mucous membrane* of the tympanum is thin, and greyish-white in colour. It is in some parts closely adherent to the bone, and in others less so. There are a few glands present in some tympana, but possibly not in all. There is, however, a small amount of tenacious secretion always covering the mucous surface. When present, the glands are found in the anterior part of the cavity, near the Eustachian tube. The epithelium covering the mucous membrane is of the columnar ciliated variety in the lower parts of the cavity, and of the squamous type over the upper part, the promontory, the mastoid cells and inner surface of the membrane.

The tympanum derives its *blood-supply* from the tympanic branch of the internal maxillary artery through the fissure of Glaser, and from the petrosal branch of the middle meningeal. Other twigs are derived directly from the internal carotid as it passes through its bony canal. The stylo-mastoid artery accompanies the facial nerve, and supplies it and the stapedius muscle as well as the antrum.

The *veins* of the tympanum carry blood to the external meatus, to the plexus round the internal carotid artery, to the dura mater and superior petrosal sinus through the petro-squamous fissure, and to the temporo-maxillary vein. A small vein also passes from the antrum through the arch of the superior semicircular canal to the interior of the skull.

The distribution of the lymphatics of the tympanum is not well known. According to Rauber,[1] they accompany the bloodvessels.

The *nerve-supply* of the mucous lining of the tympanum is from the tympanic plexus, which lies in grooves on the surface of the promontory (Fig 24). This plexus is formed by the nerve of Jacobson from the petrosal ganglion of the glosso-pharyngeal, the small deep petrosal from the carotid plexus of the sympathetic, a branch arising from the great superficial petrosal near the geniculate ganglion, and the small superficial petrosal from the otic ganglion. Ganglion cells are found in the plexus.

Although the *chorda tympani* does not actually supply the tympanum, it is intimately connected with that cavity (Fig. 92). It arises from the facial close to the exit of that nerve at the stylo-mastoid foramen, and, passing at first upwards, curves forwards and enters the tympanum on the posterior wall at the level of the tendon of the stapedius muscle. It then passes horizontally across the cavity, external to the long process of the incus, internal to the handle of the malleus, and above the tendon of the tensor tympani, to enter a small

[1] *Arch. f. Ohrenh.*, Bd. xv., S. 81.

canal in the bone, the iter chordæ arterius, at the inner end of the fissure of Glaser. After its exit from this canal it passes on to join the lingual nerve. Variations in the course of the chorda tympani have been described by Kelly and Lake.

Recesses and Pouches of the Tympanum.

Owing to their surgical importance, it is necessary to refer to the small recesses and pouches which are found in the tympanic cavity. They are formed in part by the bony walls

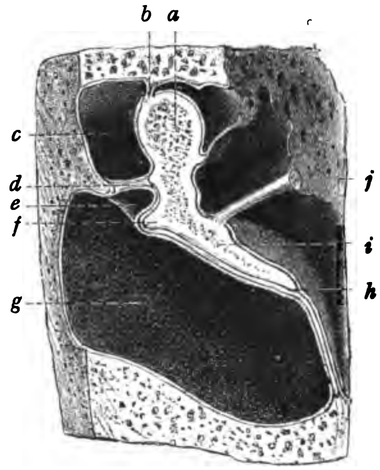


FIG. 25.—SECTION THROUGH THE MALLEUS AND MEMBRANA TYMPANI. (From Quain's 'Anatomy.')

a, head of malleus.
b, superior ligament of malleus.
c, superior lateral pouch.
d, external ligament of malleus.
e, inferior lateral pouch, or Prussak's space.
f, short process of malleus.
g, external meatus.
h, tip of manubrium of malleus.
i, manubrium.
j, tendon of tensor tympani.

of the tympanum, and in part by ligaments and folds of the mucous membrane, etc. (Fig. 25)

The attic, which, as stated above, lodges the head of the hammer and the body of the incus, is divided by these into an outer and inner portion. The inner portion communicates below with the tympanic cavity proper, and behind leads into the aditus ad antrum. The outer attic is divided into two portions, the superior and inferior lateral pouches, the inferior of the two being usually known as Prussak's space. The superior lateral pouch is bounded above by the tegmen tympani, anteriorly by the upper portion of the anterior bony wall of the tympanum, and below by the anterior and external ligaments of the hammer. The inferior lateral pouch, or Prussak's space, lies below, and communicates with the superior lateral space just described. It is separated from the latter, as stated, by the anterior and external ligaments of the hammer.

It communicates behind with the general cavity of the tympanum, but below it is separated from the latter by the short process of the hammer. Externally it is bounded by Shrapnell's membrane. When, therefore, suppuration occurs in Prussak's space, the pus not unfrequently finds exit by the occurrence of perforation of Shrapnell's membrane, which gives a very characteristic otoscopic picture.

According to some writers, the upper part of the tympanic cavity proper—that is to say, the portion above the level of the tip of the manubrium mallei and below the floor of the attic—is also divided into an anterior and posterior pouch by a fold of mucous membrane which encloses the chorda tympani nerve. These two pouches communicate freely below, while above the anterior one ends blindly, but the posterior usually communicates with Prussak's space.

In conclusion, it must be observed that all these pouches are subject to considerable variations, both in size and in the freedom of their communications with each other.

The student must remember that certain variations occur in the temporal bone, and some of these are of great surgical importance. The latter will be referred to in describing the operative surgery of ear diseases. The whole subject of the anatomy of the temporal bone has been investigated very exhaustively by Cheatle, and those desirous of making a more complete study of the subject than is possible within the compass of this volume are referred to his work.[1]

[1] Cheatle, 'The Surgical Anatomy of the Temporal Bone,' Churchill, 1907; 'Infantile Types of the Temporal Bone,' *Lancet*, February 19, 1907.

PHYSIOLOGICAL.

In this section of the subject we proceed to discuss the functions of the various portions of the sound-conducting apparatus.

Whether the auricle has in the human subject the function of reflecting sound into the meatus is very doubtful. It certainly cannot do so to any very great extent, for cases have been recorded in which the auricle has been destroyed without any appreciable diminution of hearing-power; and the stories of Dionysius, Tyrant of Syracuse, and James I. of England [1] may safely be dismissed as mythical.

It was suggested by Mach that the auricle may act as a resonator for the higher notes. Politzer considers that the tragus as well as the concha is concerned in reflecting sound with the meatus, and there is no doubt that if the tragus be bent outwards by a little bent plate the hearing-power is to a slight extent increased. The most important function of the tragus is probably that of protection.

The external meatus may be said to perform two functions—the conduction of sound to the membrana tympani, and the protection of the deeper sensitive structures against violence, cold, and other irritants. It acts as a conductor of sound by simply preventing loss by spherical spread; but, according to Politzer, the various curves are arranged in such a way that the sound-waves are reflected powerfully on to the tympanic membrane, the curve which effects this most being that at the inner end on the lower and anterior surface.

The important function of defence is performed by the meatus, in part by its curves and its length, and in part by its secretion.

Its curvatures tend to prevent foreign bodies finding a straight path to the membrane. And its length, by diminishing the rapidity of diffusion of air, prevents sudden chilling of the deeper parts. Living animals are kept out of the meatus by the essential oil in the cerumen, though occasionally they find entrance. Even when this happens, however, protection is afforded by the rapid production of wax in response to such irritants, and the consequent enforced quiet of

[1] Scott, 'Fortunes of Nigel.'

the intruder. This matter of the rapidity of the secretion of cerumen is interesting, since for long periods the amount produced may be insignificant, while an irritant such as that described above may call for a relatively larger amount in a short time.

The method by which cerumen is extruded from the meatus has not yet been thoroughly explained. Burnett suggested that it is carried out by the epithelium in the same way as a mark on the finger-nail is carried to the tip of the nail. The explanation given by McKendrick and the author is that the movements of the jaw in chewing and speaking gradually work the wax outwards, owing to the downward slope of the outer portion of the meatus, in which portion only is the secretion formed.

Cerumen varies in colour from that of amber to dark brown. Its consistency also varies to a certain extent even in health, and in old age it tends to become dried. Chemically it consists of fats, water, a brown pigment, and an aromatic oil.

When the sound-waves strike the tympanic membrane, they produce vibrations in that structure, which are identical in frequency, phase, and composition with those in the air and the sounding body which produced them. They are not necessarily of the same amplitude—in fact, they hardly could be; but the relative amplitude of one wave in the membrane to another must be, within certain limits, the same as the relative amplitudes of these waves before they strike the membrane. Thus, the vibrations of the membrane are 'forced,'[1] not free. No doubt the membrane has a note of its own. According to König, this note is mi^4 (10,240 v.d.), while according to Politzer it is mi^6 (2,560 v.d.); but the shape and the distribution of weight are so irregular that these 'free' vibrations do not seem to affect the quality of the sound transmitted.

The shape and intimate structure of the membrane offer, according to Helmholtz, a peculiarly delicate means of receiving sound vibrations, and the acoustics of the subject have been worked out mathematically by him.[2] Suffice it

[1] *Vide* p. 12.

[2] 'D. Mechanik d. Gehörknöch. d. Trommelfels.' *Arch. f. d. Ges. Physiol.*, Bd. i., S. 1, and Schäfer's 'Textbook of Physiology,' vol. ii., p. 1154, 1900.

to say here that this delicacy depends upon the outward curvature of the radial fibres of the membrane between the margo tympani and the handle of the hammer.

Mach and Kessel made the interesting discovery that during the positive phase of the sound-wave—that is, during condensation of air in the meatus—the inward movement of the membrane occurs first near the periphery, the central parts being driven in later. During the negative phase this movement is reversed. The same observers noted, that the part of the membrane which underwent the most extensive movement was the posterior quadrant.

The question of the effect of variations in tension of the membrane upon the transmission of sound is rather difficult to answer. It is usually stated, and would *a priori* be expected, that the tighter the drumhead is stretched, the less satisfactory would be its effect upon the transmission of the lower notes, and the more satisfactory its transmission of the upper notes. But it is doubtful if this view has much basis in fact. No doubt in nearly all middle-ear affections the low notes are enfeebled more than the upper notes, but this has been shown by the author to depend upon a different factor altogether.[1] Moreover, the low notes are particularly enfeebled in a class of middle-ear disease, ankylosis of the stapes, in which the membrane is often normal in every respect. On the other hand, the sense of harmony is, so far as we can judge, unimpaired in middle-ear disease, with increased tension of the membrane, provided, of course, the music is heard fairly well. We may conclude, therefore, that increased tension may affect the relative transmission of low and high notes to a slight extent, but not very much. Relaxation of the membrane in pathological conditions undoubtedly affects the hearing unfavourably.

Movements of the Ossicles.—The movements of the membrane are transmitted to the chain of ossicles, which vibrate for the most part as a whole. The exception to this is a slight outward movement which the malleus may undergo independently, on account of the coglike malleo-incudal joint described above. This as well as the more important general movement has been investigated by Helmholtz, Politzer, Buck, Blake, and Burnett. The movement is round an axis

[1] Gray, Glasgow Hospital Reports, 1899.

running from the tip of the short process of the incus to the insertion of the anterior ligament of the malleus near the fissure of Glaser.

The movement has already been sufficiently described in its anatomical aspect (p. 37), and it only remains to make a few remarks upon the movement under physiological conditions—that is, during the transmission of sound.

In the first place, it must be kept in mind that the actual energy applied to the membrane, and thence to the hammer, is never constant in degree during the transmission of sound-waves, but varies according to the sine of an angle representing the time. Thus, the actual energy in the case of a pure tone is greatest when the system is passing through the position of equilibrium, the sine of the angle representing the time being then unity. It then diminishes according to the mathematical law, until the system reaches its limit of movement, when the sine of the angle is zero, and so on (see p. 4).

During the positive phase of the sound-wave, the membrane, the manubrium mallei, the long process of the incus, and the stapes are all driven inwards, and the head of the malleus and body of the incus swing outwards. During the negative phase a reverse action takes place, but as stated above the manubrium may swing relatively farther out than inwards. Helmholtz looks upon this arrangement as a protection to the delicate structures of the inner ear, by preventing the stapes from being driven too far in by the force of loud sounds, etc. The movements of the hammer, and, indeed, of all the ossicles, are limited by the ligaments, particularly the external ligament of the hammer. The movement of the incus has been already sufficiently described, as has also that of the stapes. It should be added, however, that, according to Burnett, there is during the positive phase a slight movement inwards of the membrane and ossicles as a whole—that is, without any rotation. This movement must be very limited if it exist at all.

Since the chain of ossicles under these circumstances constitutes a lever of the second order, it follows that the amplitude of movement at the tip of the manubrium must be greater than that at the oval window where the resistance is; and the power at the oval window will be greater than the force applied at the tip of the manubrium. The numerical relationship has been ascertained by Helmholtz [1] to be :

Force at manubrium : force at oval window : : 1 : 1·5.

Furthermore, since the greater part of the force applied to the membrane by the air is transmitted to the hammer, and thence to the oval window, we must, in order to obtain the sum total of the force applied at the oval window, take into account the relative areas of the tympanic membrane and the oval window. This relationship is approximately 20 to 1. Therefore the pressure exerted by a sound-wave on the membrane is increased thirty-fold at the oval window. This calculation is not, of course, accurate, since it does not allow for the fact that a certain amount of the pressure applied to the membrane is transmitted through that structure to the air in the tympanum ; nor does it allow for friction.

While the description just given may perhaps be considered the orthodox opinion on the method of sound transmission through the middle ear, it must be pointed out that many authorities do not agree with it, and probably it will require modification in the future. The whole subject has been investigated recently by many individuals, both by means of direct experiments and by consideration of clinically observed facts. Unfortunately, the results of these investigations are rarely in agreement with one another.

Hence, while the previously accepted conception described above is obviously insufficient, no other satisfactory explanation of the phenomena has as yet been given. Our ideas of the transmission of sound through the middle ear are in a state of flux.

It is quite impossible, within the limits at our disposal, to consider in detail the various views put forward by many writers, or the reasons which support these views. It may be said in general that they fall into two categories : first, those which deal with the actual media which transmit the sound ; and, second, the way in which these media act.

With respect to the first, the actual media through which transmission takes place, some authorities maintain that the ossicles are not the transmitting media at all, that function being undertaken by the air in the tympanum. From the air

[1] *Op. cit.*

in the tympanum the movements are transmitted to the labyrinth through the round window, the chain of ossicles having but little to do with the matter. This view is held by Lucae and Secchi, although the former admits the possibility of transmission by the ossicles to a slight extent.

Another view is that sound is transmitted directly by the air in the tympanum to the bony wall of the promontory, and through that to the labyrinth. While it is possible that this means of transmission may be applicable to notes of high pitch, it is very doubtful if notes of medium or low pitch can be carried to the labyrinth in this way.

Many authorities consider that sound-waves are transmitted through the middle ear both by means of the air in the cavity and by the ossicles, the former transmitting the notes of high pitch, and the ossicles those of low pitch. It appears probable that this view is more nearly correct than the others.

The second problem in regard to the transmission of sound-waves through the middle ear relates to the magnitude and character of the movements in the media themselves. In the description of the movements of the ossicles given above, it has been assumed that the latter swing, in response to sound-waves, to and fro as a whole, round an axis running from the tip of the short process of the incus to the insertion of the anterior ligament of the hammer. This movement has been termed 'molar.' But it is easy to conceive of the transmission of the sound-waves by means of minute movements of the particles composing the chain of ossicles, while the chain as a whole is fixed. This method of transmission has been termed 'molecular,' but the word 'particulate' gives a more correct conception of the idea. In this case the force is transmitted along the chain of ossicles without any reference to movement of the system round an axis. At present it is not possible to answer this question definitely, and space is too limited to discuss the matter from a speculative point of view.

It may be said, however, that, until more definite evidence in favour of the view of transmission by particulate movements is put forward, the aurist is fully justified in considering the view of molar movement round an axis as being sufficiently near the truth for the practical purposes which he has in view.

Action of the Muscles.—The tensor tympani being inserted into the malleus below, its axis of rotation pulls the manubrium inwards when stimulated, and thus tightens the drumhead. In this case, however, we are dealing with a lever of the third order, and one in which the force is applied close to the fulcrum (the axis of rotation), while the resistance is relatively far below, in the manubrium. The tensor in contracting would therefore cause the tip of the manubrium to undergo a large amplitude of movement, but it would be a movement which could be easily resisted by a smaller force applied at the tip of the manubrium.

This muscle may also have a slight rotating action upon the malleus round an approximately vertical axis.

The stapedius muscle tends to drag the head of the stapes backwards, and rotate the footplate, more particularly its anterior portion, outwards. This movement carries the long process of the incus outwards, and with it the manubrium mallei. Hence, according to Politzer,[1] the tensor tympani and the stapedius are antagonistic. This antagonism may, as suggested by Burnett,[2] serve the purpose of keeping the articular surfaces in close apposition.

In the opinion of the author, the most important function of these muscles is to cause the ossicles constantly to undergo movements more extensive than those produced by sound-waves, and not limited in their energy according to the law of sines (see p. 4). By this means the articular surfaces are not allowed to become stiff, as they might were their movements only produced by the feeble energy of sound-waves.

Although it is probable that some individuals have voluntary control over the intratympanic muscles, the normal physiological stimulus is undoubtedly sound, and the action is reflex. Hensen[3] and Bockendahl investigated this matter very carefully by experiments on animals, and found that the tensor tympani underwent contraction when sound was led into the meatus. The contraction was greater in response to high than to low notes.

Although the normal stimulus in producing contraction

[1] *Wien. Med. Wochenschr.*, Bd. xvii., S. 1657, and Bd. xviii., S. 113.

[2] 'System of Diseases of Ear, Nose, and Throat,' vol. i., p. 87, 1893.

[3] Hensen and Bockendahl, *Arch. f. Ohrenh.*, Bd. xvi., S. 253.

of the tensor tympani is sound, it appears probable from the observations of the author that other stimuli may produce the same effect. Thus, in the case of three adult deaf-mutes, he found that the muscle showed no sign of degeneration. There lies, of course, the possible fallacy in these cases that the deafness may not have been absolute in any of them, since no opportunity occurred of examining the patients before death. The matter therefore requires confirmation, but we may go so far as to say that the hearing may be reduced to negligible limits, and possibly may be abrogated altogether, without causing atrophy or degeneration of the tensor tympani. It is quite possible that contractions of this muscle may occur simultaneously with the others which are supplied by the motor division of the fifth nerve, and this may preserve the functional activity of the muscle even when it does not receive its normal stimulus from sound.

Pollak[1] discovered another reflex of the tensor tympani when he observed that sound led to one ear caused a reflex contraction of the tensor of the opposite ear. This reflex did not occur when the cochlea was destroyed.

The action of the stapedius has already been described, and it only remains to state that, in all probability, the stimulus required for its reflex contraction is also sound; but I know of no investigation bearing upon this subject. Lucae[2] first observed that during violent contraction of the orbicularis palpebrarum a deep humming noise is heard in the ear, and at the same time the power of hearing the deeper and middle notes is diminished and a slight relaxation of the tympanic membrane is observed. These phenomena are attributed by Lucae to the contraction of the stapedius.

Politzer first observed temporary deafness during yawning, and Helmholtz confirmed this, and both writers have attributed it to contraction of the tensor tympani.

Within recent times Lucae has put forward the view that the intratympanic muscles serve the purpose of accommodation in a way somewhat analogous to the intrinsic muscles of the eye. It is difficult either to prove or disprove such a theory, and the most that can be said is that there is but little evidence in support of it.

[1] *Med. Jahrb.*, Wien, 1886.

[2] Lucae, *Arch. f. Ohrenh.*, vol. iii.

Before leaving the subject of the movements of the ossicles, it would not be out of place to make a few remarks upon the extent of these movements.

In the first place, measurements of this kind are apt to be fallacious since the movements are all extremely small, and are always, or nearly always, obtained upon the dead subject. Politzer opened the tympanic cavity in the dead animal, and fixed fine glass threads to the various ossicles. A sound was then led into the meatus, and the movements of the glass threads recorded on a revolving drum. By this means the experimenter found that the tip of the malleus moved through a space of 0·76 millimetre, the tip of the long process of the incus 0·21 millimetre, and the stapes 0·0714 millimetre. These were the greatest amplitudes of movement he could produce.

Burnett, by scattering a few grains of lycopodium in the requisite positions, and observing their extent of movement under a microscope (Lissajous' method), found the extent of movement to be much less than that given by Politzer. Thus, the amplitude of movement at the base of the stapes and at the round window varied from 0·001 millimetre to 0·032 millimetre. Helmholtz gives 0·14 millimetre to 0·18 millimetre as the maximum amplitude of movement of the stapes. With such differences in observations, we may be pardoned for not attaching much importance to any of these measurements. The conditions of hearing during life are quite unlike those under which the experiments are performed.

Of far greater interest, since it appeals to the imagination and at the same time is reasonably accurate, is the calculation of the minimum amplitude of movement at which sound is audible. This has been investigated by Lord Rayleigh,[1] and he finds that vibrations of aerial particles of an amplitude of 10^{-8} centimetres would, under favourable conditions, be audible. Such movements of aerial particles must produce a very much smaller movement in the tympanic membrane—a movement almost inconceivably small. The same mathematician has calculated the energy of sound vibrations of this amplitude in the air, and finds that it is of the same order of magnitude as the energy of vibrations of light

[1] Proceedings of the Royal Society, London, 1877, vol. xxvi., p. 243; and 'Theory of Sound,' vol. ii., p. 435.

which is requisite to produce the sensation of green light in the eye. This calculation is corroborated by Töples and Boltzmann.

Regulation of the Atmospheric Pressure in the Cavity of the Tympanum.—In order that the tympanic membrane and cavity should be in the best possible condition for transmitting sound, it is important that the tension of the structures should be constant. According to Secchi, the air-pressure within the normal tympanum is equal to 4 millimetres of alcohol above that of the surrounding atmosphere. Whether this finding be confirmed or not, the mechanism by which the pressure is kept relatively constant is the same—that is, by the opening at definite intervals of the Eustachian tube. The anatomy of this structure and its adnexa have already been described, and it only remains to describe the opening and closing of it. The opinion held by most anatomists is that the tube is opened during deglutition by the contraction of the levator and tensor palati. Cleland [1] and Luschka [2] state, however, that the tube is open during rest and closed during deglutition. The former of these writers has intimated to the author that he has recently somewhat modified his view, and the latter holds that the tensor opens the tube, and the levator closes it. Politzer states that the firmness with which the tube is closed during rest varies greatly with the individual. Thus, in some people the respiratory current moves the tympanic membrane gently to and fro, showing that Cleland is right in these cases. On the other hand, in a case recorded by me,[3] in which there was paralysis of the muscles attached to the Eustachian tube, the tympanic membrane became indrawn, the hearing impaired, and bone conduction increased, showing that in some cases at least the contractions of these muscles are requisite in order to ventilate the tympanum. It is probable that the Eustachian tube may also have another function, that of draining the tympanum of its secretion. The presence of ciliated epithelium, and the fact that the ciliary movements are directed from the tympanum towards the ostium pharyngeum, lends colour to this suggestion. The fact

[1] *Journal of Anatomy and Physiology*, vol. iii., p. 97.

[2] 'D. Schlundkopf d. Mensch.,' S. 45 and 4; Tübingen, 1868.

[3] Transactions of the International Otological Congress, London, 1899.

that the tube opens above the level of the floor of the drum does not invalidate it, since there is ciliated epithelium in the neighbourhood of the ostium tympanicum.

The particular function of the mastoid antrum and cells is not very obvious in the human subject. Physically, of course, they enlarge the area over which pressure in the tympanic cavity can be exerted, and hence may help to prevent injury to the inner ear through excessive pressure on the round and oval windows; this might result from too forcible injection of air through the Eustachian tube, such as may occur from violent expiratory efforts with closed mouth and nostrils—*e.g.*, blowing the nose. It is doubtful whether these cavities associated with the middle ear are concerned in the resonance of sound.

Sound may be conveyed to the labyrinth by other means than by the chain of ossicles. These means are the Eustachian tube, the air in the tympanum, and the bones of the head. Of these, the first is of no practical importance, but its possibility was first proved by Politzer. The second has already been discussed, and need not be referred to further. The third and, from the aurist's point of view, most important way is by the bones of the head.

Let a tuning-fork be set vibrating, and its stem be placed upon any firm part of the head; the sound will then be heard clearly, and of the same pitch as that at which it is heard when conveyed by the air. The relative intensity of the sound in this case is due to the fact that there is no intervening transmission to the air—a change of the transmitting medium, that is to say, in which much of the energy of the original vibrations is lost so far as their power of producing sound is concerned.

Further, if the vibrating fork be still held in contact with the head, and one ear be closed with the finger, it will be noticed that the sound is heard much more loudly in that ear than in the open one. This remarkable fact was first described by Weber, and is known as Weber's phenomenon. Again, let the stem of the tuning-fork be placed upon the mastoid process of one ear, and held there till the sound dies away; then let that ear be closed with the finger, and the sound will again be heard. This important fact was described by Rinne, and is called Rinne's experiment.

Yet again, let the vibrating fork be set upon some hard portion of the head, and, instead of closing the ear with the finger, let an indiarubber tube be accurately fixed into the external meatus. Now let the air in the tube and meatus be compressed by blowing into the tube, and it will be noticed that the sound loses in its intensity. This phenomenon was originally described by Gellé.

It is beyond the scope of this work to enter into the physical or physiological causes underlying these facts, since the matter has not yet been entirely elucidated. Those who are particularly interested in the matter are referred to the investigation of Lucae, Politzer, Bezold, Gellé, the author and others. The important matter is to remember the facts, since upon them rest several valuable tests used in the investigation of cases of deafness.

CHAPTER III

ANATOMY AND PHYSIOLOGY OF THE INNER EAR OR LABYRINTH

ANATOMY.

THE inner ear or labyrinth lies, as a whole, internal to and behind the middle ear, from which it is separated by a wall of bone except at two small regions, the round and oval windows. It may be said to consist of an outer bony wall or capsule, and an inner membranous portion, moulded so as to follow the bony wall more or less completely.

The Bony Labyrinth (Figs 26 and 27).—The bony labyrinth may be conveniently divided into three portions—an inner and lower part, termed the cochlea; an outer and upper portion, known as the semicircular canals; and a middle cavity uniting the two former — the vestibule. The *cochlea* cannot be described better than by likening it to a snail-shell, from which, indeed, it derives its name. The central pillar is termed the modiolus, and it

FIG. 26.—THE RIGHT BONY LABYRINTH: VIEWED FROM THE OUTER ASPECT. × 2½.

(Sömmering and Quain.)

1, the vestibule.
2, fenestra vestibuli.
3, superior semicircular canal.
4, the external canal.
5, the posterior canal.
6, first whorl of the cochlea.
7, second whorl.
8, apex.
9, fenestra rotunda.
* * *, the ampullæ of the canals.

FIG. 27. — RIGHT BONY LABYRINTH. NATURAL SIZE.

receives the cochlear portion of the auditory nerve. The modiolus lies almost in the horizontal plane, and is directed from behind forwards. From the surface of the modiolus there projects outwards a fine lamina of bone, the osseous spiral lamina (Fig. 28), which partially divides the whorls into an upper and lower portion. The osseous spiral lamina runs spirally from the base to the apex of the cochlea, and between its layers it contains channels for the fibres of the cochlear nerve as they radiate out from the modiolus almost to the tip of the lamina. There they pierce the upper surface of the bone before going on to their termination in the organ of Corti. In the recent condition a fine membranous structure, the basilar membrane, passes from the tip of the osseous spiral lamina to the outer wall of the cochlea, so that the tube is completely divided into an upper portion, the *scala vestibuli*, and a lower portion, the *scala tympani*. These two channels communicate at the apex of the cochlea, by a fine opening—the *helicotrema*.

The spiral tube, of which the cochlea consists, is nearly 4 centimetres in length, and about 2 millimetres in diameter at its widest part, which is that nearest to its opening into the vestibule. There are rather more than two and a half turns in the cochlea. On the floor of the tube, very close to its opening into the vestibule, is the opening of a fine canal (Fig. 28), which passes inwards and backwards, gradually widening until it opens by a triangular orifice into the cranial cavity. This tube is known as the *aqueduct of the cochlea or aqueduct of the perilymph* (Fig. 29), and it enables one of the fluids of the labyrinth, the perilymph, to intermingle with the cerebrospinal fluid. (The endolymph, however, does not pass through this tube.) In the human subject and in the primates the aqueduct of the cochlea is a very fine tube, but in many of the mammalia and reptiles it is much wider. A vein accompanies the aqueduct. At the base the outer bony wall of the cochlea bulges towards the tympanum, and forms the promontory in that cavity, and immediately behind the promontory is an opening from the tympanum into the cochlea, the *fenestra rotunda*, or *round window*. The round window looks backwards and outwards, and in the recent state is closed by a delicate membrane (see p. 23).

The *vestibule* is a somewhat oval cavity which communicates

FIG. 28.—RIGHT BONY LABYRINTH, OPENED IN VARIOUS PLACES: VIEWED FROM BELOW AND IN FRONT. × 3.

(Prepared and photographed by the Author.)

s, superior canal.
f, canal for facial nerve.
h, fovea hemielliptica.
o, osseous spiral lamina.
a, opening of aqueductus cochleæ.
m, fovea hemispherica.
n, fenestra rotunda.

[*To face p.* 54.

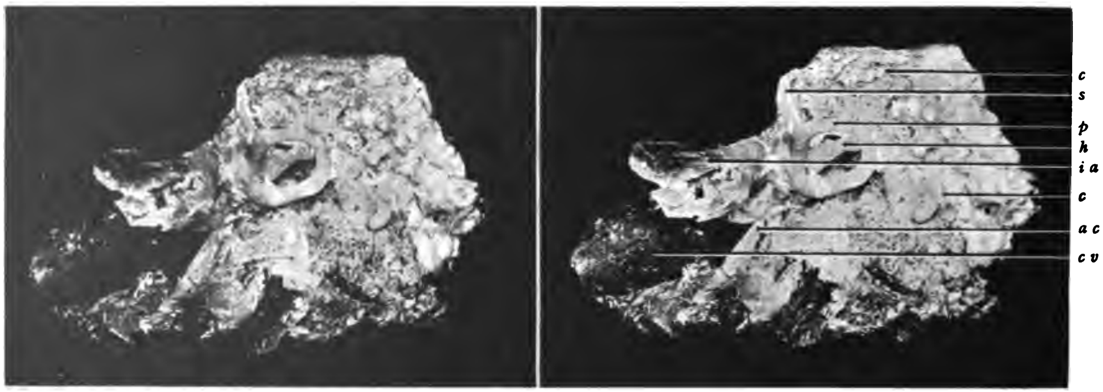


FIG. 29.—CAST OF THE CAVITIES OF THE TEMPORAL BONE: VIEWED FROM THE INNER ASPECT AND BEHIND. NATURAL SIZE.

(Prepared and photographed by the Author.)

c, mastoid cells. *s*, superior canal. *p*, posterior canal. *h*, horizontal canal. *c v*, carotid artery, showing the sharp bend. *i a m*, internal auditory meatus. *a c*, aqueduct of cochlea.

[*To face p.* 55.

FIG. 30.—FOOTPLATE OF STAPES IN POSITION IN OVAL WINDOW: VIEWED FROM THE VESTIBULAR ASPECT. × 10.

(Prepared and photographed by the Author.)

h, opening of horizontal canal. **f**, footplate of stapes.
a, space between footplate and wall of oval window, occupied by annular ligament.

[*To face p.* 54.

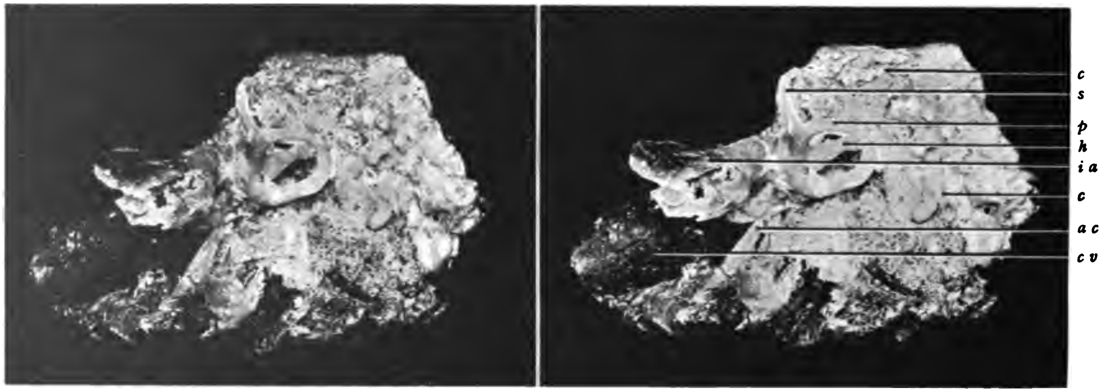


FIG. 29.—CAST OF THE CAVITIES OF THE TEMPORAL BONE: VIEWED FROM THE INNER ASPECT AND BEHIND. NATURAL SIZE.

(Prepared and photographed by the Author.)

c, mastoid cells.
s, superior canal.
p, posterior canal.
h, horizontal canal.
c v, carotid artery, showing the sharp bend.
i a m, internal auditory meatus.
a c, aqueduct of cochlea.

[*To face p.* 55.

Fig. 30.—Footplate of Stapes in Position in Oval Window: Viewed from the Vestibular Aspect. × 10.

(Prepared and photographed by the Author.)

h, opening of horizontal canal. **f**, footplate of stapes.
a, space between footplate and wall of oval window, occupied by annular ligament.

[*To face p.* 54.

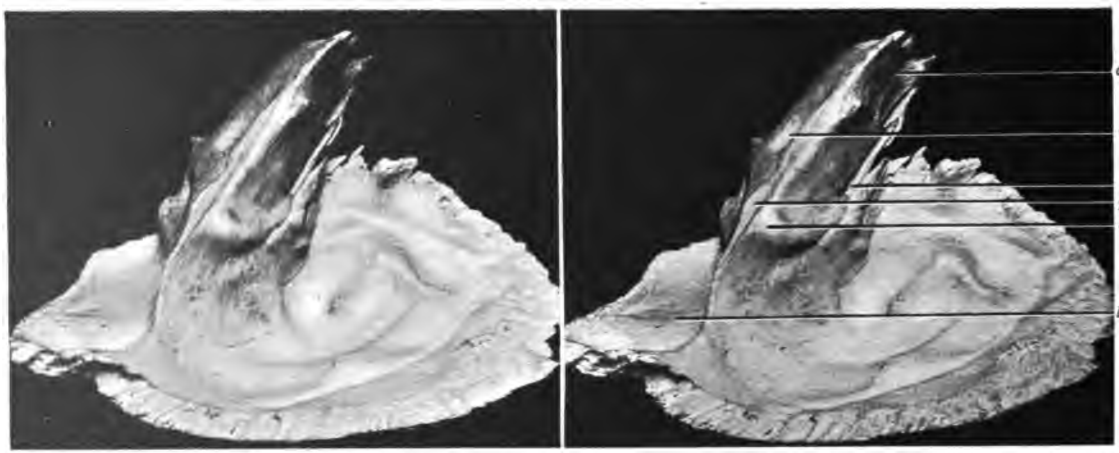


FIG. 31.—RIGHT TEMPORAL BONE: VIEWED FROM ABOVE. $\times \frac{4}{5}$.

(Photographed by the Author.)

c, carotid canal.
i a m, internal auditory meatus.
h, hiatus Fallopii.
p, groove for superior petrosal sinus.
s, prominence of superior canal.
l, groove for lateral sinus.

[*To face p.* 55.

with the cochlea in front, and the semicircular canals externally and behind. Its largest diameter is about 4 millimetres in length. Externally and in front it communicates with the tympanum by means of the fenestra ovalis, or oval window, the major axis of which lies almost in the horizontal plane. In the recent state the oval window is closed by the footplate of the stapes and the annular ligament (Fig. 30). On the inner posterior wall of the vestibule there is a slight ridge, the crista vestibuli, and in front of and internal to this is a rounded depression, the fovea hemispherica (Fig. 28), which lodges the inner wall of the saccule in the recent state. Behind and above the crista is an elliptical depression, the fovea hemi-elliptica, which lodges the inner wall of the utricle. A minute oblique opening is found behind the crista, which passes through the bone upwards, outwards, backwards, and finally downwards. In the recent state it gives passage to the aqueduct of the vestibule. It opens into the cranial cavity in the form of a narrow slit on the posterior surface of the petrous portion of the temporal bone.

The *semicircular canals* (Fig. 29), three in number, open out of the outer and posterior walls of the vestibule. As their name implies, they are semicircular channels enclosed in the petrous portion of the temporal bone. They are termed the superior or superior vertical, the posterior or inferior vertical, and the horizontal or external, and they lie in three planes approximately at right angles to one another. Each canal opens into the vestibule by an opening at each end, but at the same time there are only five openings, because one of the openings is common to two canals—the superior and posterior. Each canal presents, at one of its terminations, a slight bulging, termed the ampulla. The canals are somewhat elliptical in transverse section, and measure about $\frac{1}{20}$ inch in diameter, but the diameters of the ampullæ are about $\frac{1}{10}$ inch in length. The posterior is the longest and the horizontal is the shortest of the canals.

The *superior canal* lies in a vertical plane which runs from in front backwards and inwards, and its ampulla is situated at the anterior extremity. The arch of the canal forms a prominence on the upper surface of the petrous portion of the temporal bone (Fig. 31). The posterior limb of the canal unites with the superior limb of the posterior canal to form a common crus, which opens into the outer and posterior wall of the vestibule. The *horizontal canal* (Fig. 29) lies in the horizontal plane, and its ampullary extremity is in front, immediately below and external to that of the superior canal. The anterior third of the arch of the canal forms a protuberance on the lower and inner wall of the aditus ad antrum, and this is a useful surgical landmark in operations involving the opening of the labyrinth. The facial nerve runs immediately below this portion of the canal, and a little farther forwards separates the ampulla from the upper margin of the oval window (Fig. 14). The posterior limb of the canal opens into the outer and posterior wall of the vestibule after passing under the arch of the posterior canal.

The *posterior canal* lies in a plane passing from within and in front backwards and outwards, so that it lies in the same plane as the superior canal of the opposite ear. The ampulla is at the extremity of the lower crus, and the upper crus of the canal joins the posterior crus of the superior canal to form a common crus as described above (Fig. 29).

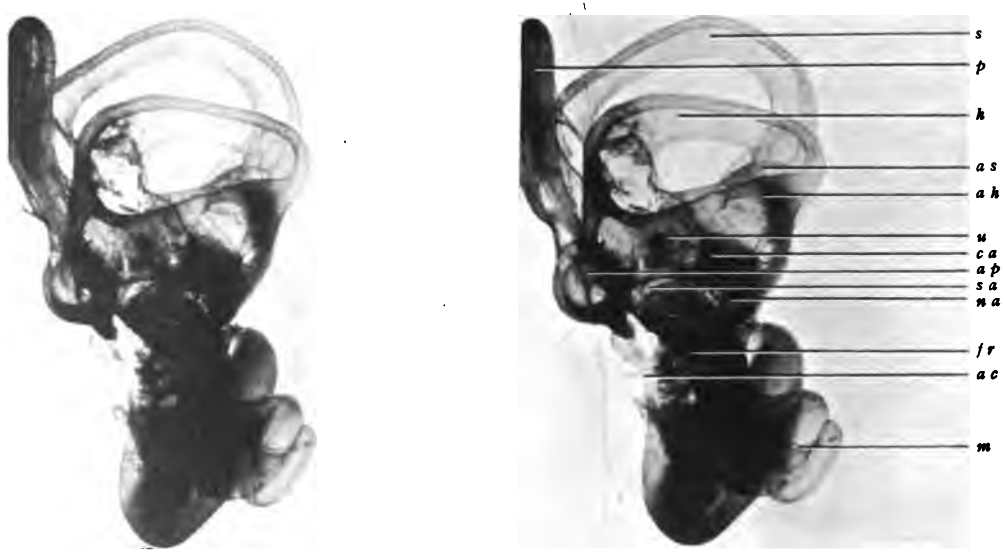
The bony labyrinth is lined inside by an endosteum, which is bathed over almost its whole surface by the perilymph. The membranous labyrinth, properly so called, may almost be said to float in the perilymph, though at some parts it is fixed to the endosteum (Fig. 32). Within the walls of the membranous labyrinth, again, is another fluid, the endolymph.

The Membranous Labyrinth (Figs 32 and 33).—The membranous labyrinth, in the delicate walls of which the neuro-epithelia of the organ are situated, follows fairly closely the outline of the bony labyrinth from which it is, for the most part, separated by the perilymph. It is, however, attached to the endosteum at certain parts—viz., at the convex borders of the semicircular canals, at the cristæ acusticæ in the vestibule, and along the outer wall of the spiral tube of the cochlea. But although the membranous labyrinth follows the contour of the bony labyrinth, the cavity contained by it is much smaller than that contained by the latter, the intervening perilymph space being of considerable size. Indeed, only in the vestibule and ampullæ does the membranous labyrinth even approximately fill the bony cavity. In the canals themselves the membranous canal lies along the convex border of the bony canals (Fig. 32).

FIG. 32.—THE MEMBRANOUS LABYRINTH: VIEWED FROM THE OUTER ASPECT AND BELOW. × 4.

(Prepared and photographed by the Author.)

s, superior canal, showing the perilymph space along the concave portion and the smaller endolymph space along the convex border.
p, posterior canal.
h, horizontal canal.
a s, ampulla of superior canal.
a h, ampulla of horizontal canal.
u, utricle. An air-bubble is seen at the end of the pointer.
c a, fan-shaped termination of the nerves to the maculæ acusticæ of utricle and saccule.
a p, ampulla of posterior canal.
s a, saccule.
n a, nerve to ampullæ of superior and horizontal canals.
f r, position of fenestra rotunda.
a c, position of cochlear termination of aqueduct of cochlea.
m, modiolus.



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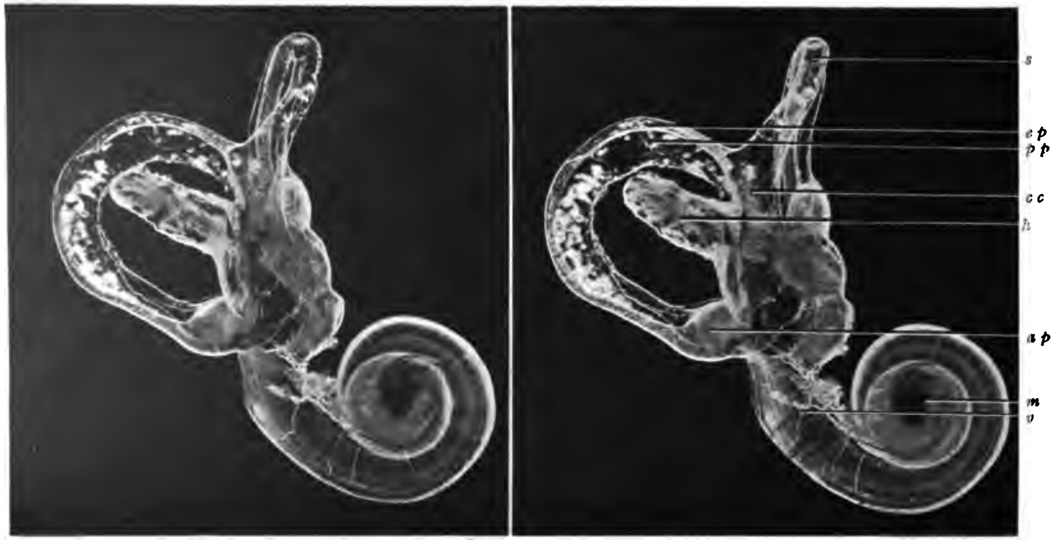

FIG. 33.—THE MEMBRANOUS LABYRINTH : VIEWED FROM BEHIND. × 4 *circa*.

(Prepared and photographed by the Author.)

The preparation is rotated clockwise to a slight extent.

s, superior canal.
e p, endolymph space of posterior canal.
p p, perilymph space of posterior canal. The white deposits are due to insufficient decalcification.
c c, common crus of superior and posterior canals.
h, horizontal canal.
a p, ampulla of posterior canal.
m, modiolus.
v, vein leaving the cochlea along with the aqueduct of the cochlea.

[*To face p.* 57.

In the cochlea the membranous labyrinth is in the form of a small tube triangular in section, and lying between the scala vestibuli above and the scala tympani below (Fig. 35).

For the convenience of description, however, the endosteal lining, the perilymph space, and the membranous labyrinth with its enclosed fluid the endolymph, may all be taken together.

The membranous, like the bony labyrinth, may be conveniently divided into three portions — the vestibule, the cochlea, and the semicircular canals—all of which are more or less indirectly connected with one another.

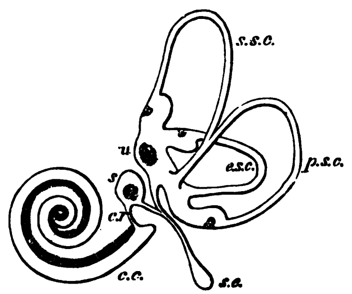

FIG. 34.—PLAN OF THE ENDOLYMPH SPACE OF THE RIGHT LABYRINTH: VIEWED FROM THE INNER ASPECT.

(E. A. Schäfer in Quain's 'Anatomy.')

u, utricle with its macula and the three semicircular canals, *s s c*, *p s c*, *e s c*, with their ampullæ.
s, saccule.
s e, saccus endolymphaticus.
c r, canalis reuniens.
c c, canal of the cochlea.

The Vestibule.—The endosteum of the bony vestibule contains the perilymph, and floating in the latter is the true membranous vestibule. It consists of two portions—the *saccule* and the *utricle*. The *saccule*, according to the investigations of the writer, is the larger of the two, and lies below and in front. It is roughly spherical except on its posterior upper surface, where it is separated by a diaphragm from the utricle. On a portion of the surface of this diaphragm is situated the macula acustica of the saccule, the neuro-epithelium in which the nerve to the saccule terminates. A fine short tube, the canalis reuniens, leaves the saccule below and in front to open out into the scala media of the cochlea. Out of the posterior wall of the saccule there opens another fine tube, which unites at a sharp angle with a corresponding tube from the utricle, to form the aqueduct of the vestibule. The *utricle* is lodged in the upper and posterior portion of the bony vestibule, and is separated from the saccule by the diaphragm described above. On the surface of this diaphragm is the macula acustica of the utricle, a highly specialized neuro-epithelium, in which terminates the utricular branch of the auditory nerve. This surface of the utricle is flat, but the other walls are curved, and the cavity as a whole may be roughly described as a half of a solid ellipse. The utricle receives all the openings of the semicircular canals, the anterior limbs of the superior and horizontal canals opening in front, while the posterior limbs of both these canals and both limbs of the posterior canal open into the posterior portion of the utricle.

Otoliths.—Minute rhrombic or octahedral crystals of carbonate of calcium are found on the maculæ both of the saccule and utricle. These *otoliths* or *otoconia*, as they are called, are suspended in a fine gelatinous envelope, into which project the hairs from the hair-cells below.

The oval window opens into the labyrinth opposite the anterior external wall of the saccule, while the utricle does not lie opposite the window at all.

The *membranous semicircular canals* follow the course of the bony ones, but they are much smaller in diameter, except at the region of the ampullæ, where they occupy almost the whole bony cavity (Fig. 33). The membranous canals run along the convex border of the bony ones, and on their outer walls are adherent to the endosteum, the remaining portions between the membranous and bony canals being occupied by the perilymph. Each canal forms about two-thirds of a circle, and is possessed of one ampulla. In the case of the superior and horizontal, the ampulla is at the anterior end of the canal, just before it opens into the utricle ; in the posterior canal the ampulla is at the inferior extremity. In the horizontal canal an ampulla-like dilatation was also found by the author at the posterior extremity in many examples of the human subject, but in none of these was there any nerve-supply such as is found in the true ampullæ. Little conical ridges are found running along the inner surface of

FIG. 35.—VERTICAL SECTION OF THE COCHLEA, PASSING EXACTLY THROUGH THE CENTRE OF THE ORGAN FROM APEX TO BASE. × 7.

(Prepared by the Author; photographed by Dr. Leslie Buchanan.)

s v, scala vestibuli. *s m*, scala media or ductus cochlearis. *s t*, scala tympani.
m, modiolus containing the cochlear branch of the auditory nerve.

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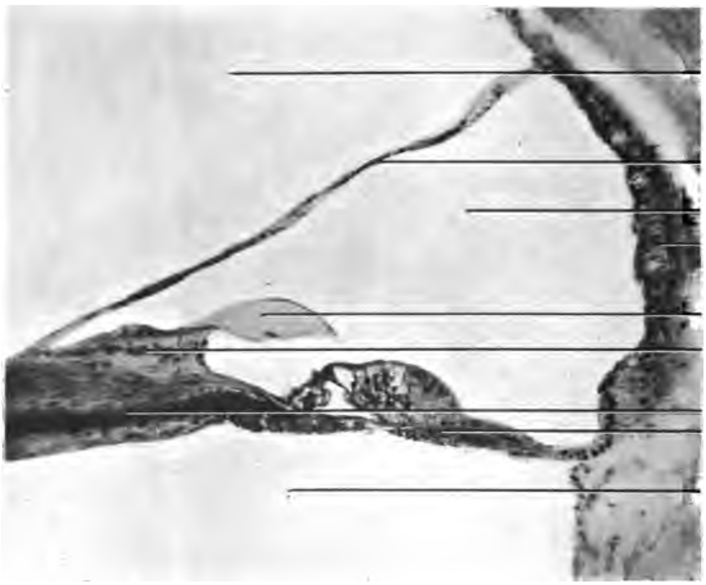


FIG. 36.—SECTION OF THE DUCTUS COCHLEARIS (HUMAN). × 150.

(Prepared by the Author ; photomicrographed by Dr. Leslie Buchanan.)

s v, scala vestibuli.
m r, membrane of Reissner.
s m, scala media, or ductus cochlearis.
v, stria vascularis.
t m, tectorial membrane.
l, limbus.
n, nerve-fibres in osseous spiral lamina running to the organ of Corti.
b, basilar membrane, with the organ of Corti resting on it.
s t, scala tympani.

[*To face p.* 59.

the membranous canals, the significance of which is not known definitely.

On the posterior walls of the saccule and utricle respectively there is found, as was described above, a minute opening in each cavity, which gives exit to a fine tube. The tube from the saccule runs for a short distance upwards, and then joins that from the utricle in a **Y**-shaped junction, with the forks of the **Y** pointing downwards. The single tube, *the aqueduct of the vestibule* (Fig. 34), formed by the junction of the two, runs upwards, outwards, backwards and finally downwards, and ultimately dilates into a small flat triangular sac, which lies in the substance of the dura mater, on the posterior surface of the temporal bone. This sac is known as the saccus endolymphaticus, and it has no channel of communication with the subarachnoid space. The endolymph, therefore, is not in direct communication with the cerebrospinal fluid, differing in this respect from the perilymph which can pass into the cranial cavity through the aqueduct of the cochlea.

The Cochlea.—The cochlear portion of the membranous labyrinth, properly so called, consists of a fine triangular tube, which runs spirally from the base to the apex of the organ, ending blindly at the helicotrema. At the base it is in direct communication with the saccule by means of the canalis reuniens (Fig. 34). The cochlear portion of the membranous labyrinth is called the ductus cochlearis or scala media (Fig. 36); it is bounded below by the *basilar membrane*, which passes from the tip of the osseous spiral lamina to the outer wall of the cochlea. It is bounded above by the delicate *membrane of Reissner*, which passes from the upper surface of the tip of the osseous spiral lamina obliquely to the outer wall of the cochlea. On the outer side it is bounded by the wall of the cochlea itself. The ductus cochlearis contains the endolymph, while the scala vestibuli above and the scala tympani below contain the perilymph. The scala vestibuli leaves the vestibule by a wide opening, and occupies the upper portion of the whorls to the apex of the organ. The scala tympani is closed below by the membrane of the round window, and runs up the cochlea, occupying the lower portion of the whorl. At the apex the scala vestibuli and scala tympani communicate by a fine opening—the helicotrema.

Finer Details of the Membranous Labyrinth.—The chief interest, in so far as the microscopic appearances of the labyrinth are concerned, relates to the neuro-epithelial structures. The structure of the cristæ and maculæ acusticæ in the three ampullæ and in the utricle and saccule are so similar that they may be included in one description. Immediately above the bone is a layer of loose fibrous tissue, in which the bloodvessels break up. Above this is the tunica propria, a clear, glassy layer. The superficial layer is the epithelial lining, and in the region of the cristæ and maculæ acusticæ this layer is specialized according to the following description (Fig. 37). It consists of two types of cells—flask-shaped or columnar—from the free surfaces of which long cilia project into the gelatinous envelope described above. These cilia measure about 25 μ in length. The second type of cell is of an elongated columnar shape, and is attached below to the tunica propria, whereas the ciliated cells just described do not reach so far down. The elongated non-ciliated cells are looked upon by Retzius as merely supporting cells, the true sensory cells being the ciliated ones. The nerve fibres pass through the fibrous layer and tunica propria, and there lose their medullary sheath. The axis cylinders pass into the epithelial layer, and break up to form a network from which other fibrils pass into the columnar cells. Anatomists, however, are not agreed as to the last point, and the matter requires further investigation.

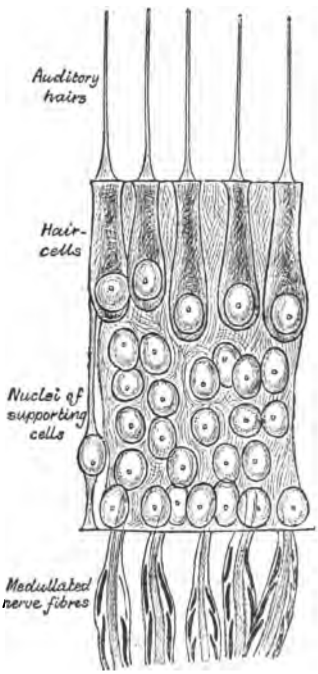


FIG. 37.—SECTION OF EPITHELIUM OF AMPULLA OF LACERTA VIRIDIS. RETZIUS.

The microscopical examination of the cochlea reveals a much more complicated relationship of the structures than that found in the canals and vestibule. The nerve terminates

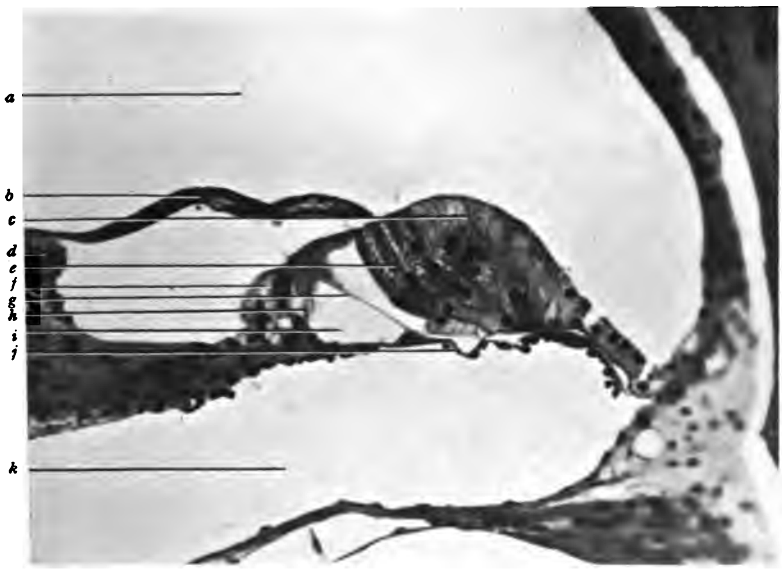


FIG. 38.—SECTION OF THE ORGAN OF CORTI OF THE MOLE. × 350.

(Prepared by the Author; photomicrographed by Dr. Leslie Buchanan.)

a, scala media.
b, tectorial membrane contracted by dehydrating agents used in preparation.
c, cells of Hensen.
d, limbus.
e, outer rows of hair-cells. The hairs are seen at the free surface. The supporting cells of Deiters are seen, cut obliquely, between the rows of the hair-cells.
f, inner row of hair-cells.
g, outer rods of Corti.
h, inner rods of Corti.
i, tunnel of Corti.
j, basilar membrane.
k, scala tympani.

[*To face p.* 60

gular on section and have no hairlike processes. They pass gradually into the cubical epithelium which covers the outer portion of the upper surface of the basilar membrane.

A short distance inwards from the tip of the osseous spiral lamina, the layer of bone becomes thickened in an upward direction, forming the *limbus*, and from the upper corner of the limbus there projects outwards an almost homogeneous gelatinous structure of relatively considerable thickness. This is the *tectorial membrane*, and it runs outward to the outermost point of the organ of Corti, and lies on the upper surface of the latter like a thick cushion, the hairs of the hair-cells projecting into or against it. Considerable misconception has arisen concerning the tectorial membrane, because of the different appearances it presents, according to the method by which the organ is prepared for microscopic section. The real structure is that described above, and is seen in Fig. 39. This is found when the organ is cut in gum, so that the water is not extracted by alcohol. But if the paraffin or celloidin methods are employed, the tectorial membrane undergoes a great change in appearance. It becomes very much contracted in all directions, and dragged up from the surface of the organ of Corti, as seen in Fig. 38.

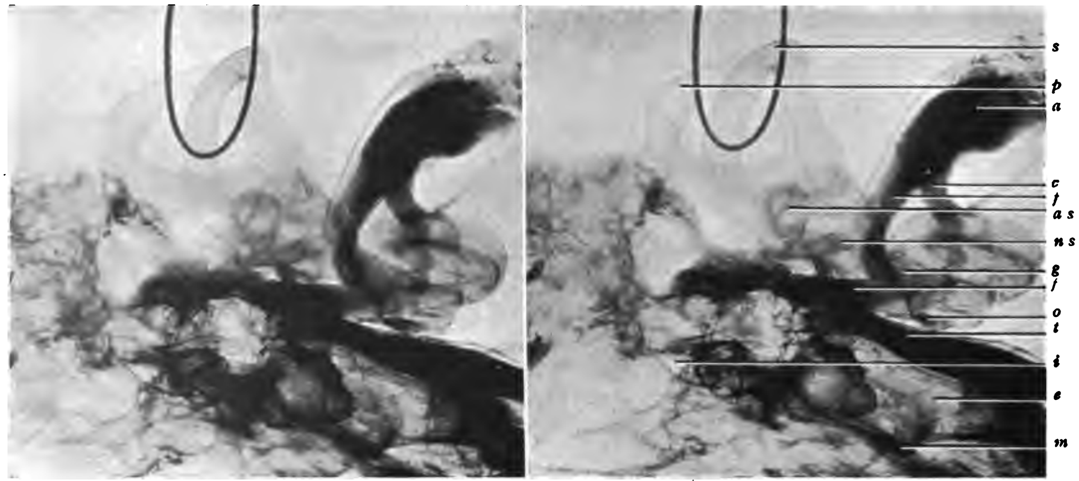
Arising also from the upper surface of the limbus, but farther in than the tectorial membrane, is a very delicate structure, the *membrane of Reissner*. This membrane extends obliquely upwards and outwards, and terminates in the outer wall of the cochlea, so that it shuts off the scala vestibuli from the scala media.

The basilar membrane on which the organ of Corti rests terminates externally in the spiral ligament, and thus shuts off the scala tympani from the scala media. It increases in width from the base to the apex of the cochlea. The spiral ligament runs up the whole length of the outer wall of the cochlea, but diminishes in size and strength from the base to the apex. It consists of fibrous tissue with elastic fibres interspersed, especially in the lower whorls. According to Shambaugh,[1] certain of the epithelial cells of the spiral ligament have a secretory function. On the outer wall of the scala media is a collection of cells, the *stria vascularis*, which

[1] *Archives of Otology*, No. 6, 1908.

FIG. 40.—THE SOFT STRUCTURES OF THE RIGHT MIDDLE AND INNER EAR: VIEWED FROM ABOVE AND SLIGHTLY IN FRONT. × 3. (Prepared and photographed by the Author.)

s, superior canal.
p, posterior canal.
a, auditory nerve.
c, cochlear branch of auditory nerve.
f and *f*, facial nerve.
a s, ampulla of superior canal.
n s, nerve to ampullæ of superior and horizontal canals.
g, geniculate ganglion, with great superficial petrosal nerve cut short.
o, branch from tympanic plexus cut short just before its junction with the great superficial petrosal nerve.
t, tensor tympani.
i, incus; the pointer crosses the head of the malleus.
e, Eustachian tube.
m, bundle of fibrous tissue, formerly referred to as the muscle of Sömmering.



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their medullary sheath, run to the organ of Corti. Those which supply the outer hair-cells pass across the tunnel of Corti on their way, running between the rods of Corti. The method of termination of the axis cylinders is not certainly known. They may actually enter the hair-cells, or they may be distributed about the bases of the latter.

It is important to remember that the ganglion spirale and the other ganglia at the base of the internal auditory meatus, taken together, are homologous with the posterior root ganglia of the spinal nerves. For more detailed description of the various ganglia and nerve-terminations in the labyrinth, the reader is referred to the work of Held,[1] Alexander,[2] Bielschowsky,[3] Retzius[4] and others.

Vascular Supply—Arterial.—The labyrinth is nourished with blood by means of one artery alone, the internal auditory branch from the basilar artery. The vessel passes down the internal meatus along with the nerve, and before entering the labyrinth it breaks up into branches to supply the various parts. The most important of these is the vas spirale, which runs spirally up the cochlea in the basilar membrane beneath the outer rods of Corti.

It is not certainly known whether any anastomosis occurs between the branches of the internal auditory artery and the arteries of the middle ear. The general opinion is that there is no such anastomosis, but some authorities maintain that there is. Since seeing the wonderfully beautiful preparations of Shambaugh, the author is satisfied that fine vascular channels do pass between the middle ear and labyrinth (see article by Shambaugh, *Archives of Otology*, xxxiv., No. 6, 1905).

Venous.—The blood is drained from the labyrinth by a more complex system of vessels than that by which it is supplied. The reason for this probably is that a temporary obstruction to the drainage would be almost more serious than a temporary suspension of the supply, owing to the fact that the labyrinth is almost a closed cavity with rigid

1 Held, *Arch. f. Anat. u. Physiolog.*, 1897.

2 Alexander, *Sitzungsb. d. Wien. Akad. d. Wissensch.*, 1899.

3 Bielschowsky, *Arch. f. Mikrosk. Anat.*, Bd. lxxi.

4 Retzius, 'Das Gehörorgan d. Wirbelthiere,' vol. ii.

walls.[1] There are three channels by which the blood escapes from the labyrinth. The largest of these is by a vein accompanying the aqueduct of the cochlea; the second is by a vessel which passes out through the internal auditory meatus; and the third, and perhaps smallest, is that which accompanies the aqueduct of the vestibule.

For a more detailed account of the venous system of the labyrinth in animals, the reader is referred to the work by the author,[2] and for a complete investigation of the whole subject of the vascular supply of the organ he is referred to the work of Shambaugh.[3]

PHYSIOLOGY.

The physiology of the inner ear is not well understood. It is true that there are certain definitely ascertained facts of a general nature, but the finer processes by means of which the functions are carried out is obscure, and the considerations regarding them are for the most part speculative.

Two entirely different functions are associated with the labyrinth—the sense of hearing, which is altogether confined to the activity of the cochlea; and another sensory function which is performed by the saccule, utricle and semicircular canals. The exact nature of this sensory function is still in dispute, but it appears to be associated with the sense of direction or orientation. According to Ewald, it is associated with the tone of the skeletal muscles of the body, but the evidence in support of this view is slender.

Limits of space prevent the full discussion of the various hypotheses relating to the functions of the labyrinth. Certain of the facts discovered by observation and experiment will be mentioned, and the speculative considerations in regard to the functions of the organ will be referred to briefly.

The Vestibule and Semicircular Canals.—Whatever the exact function of the vestibule and canals may be, there is not a single fact to show that it has any association with the

[1] Gray, 'The Labyrinth of Animals,' vol. ii., p. 85.

[2] Gray, *loc. cit.*

[3] Shambaugh, December publication of the University of Chicago, 1903. See also references to the same author given above.

sense of hearing. When these portions of the labyrinth are irritated or destroyed, certain symptoms appear. These symptoms are giddiness, with consequent staggering gait, nystagmus, and frequently, vomiting. There is general agreement as to the occurrence of these phenomena after injury to the structures, but when the symptoms are considered in detail there is considerable divergence of opinion as to their significance. There can be little doubt that these differences of opinion are largely the result of attempting to compare the results of experiment in one kind of animal with those found in other kinds. Thus, it does not seem to have occurred to some physiologists that to compare the results of experiments made on fishes and birds with those obtained in mammals is to run the risk of making incorrect deductions. The relatively large size of the labyrinth and extremely rich nerve-supply in the former indicate clearly that the vestibule and semicircular canals are of much greater functional importance in them than in the mammal.

Experimental Evidence.—There is no necessity for describing in detail the innumerable experiments which have been undertaken in order to ascertain the functions of the semicircular canals. In general the results obtained are the same; in detail they vary according to the animal experimented upon, the extent of destruction, and the object which the experimenter has in view. Irritation of the horizontal canal produces nystagmus and rotation of the head and body in a horizontal plane, while irritation of the other canals causes similar movements in corresponding planes. Irritation of the utricle and saccule causes movements of a similar nature, but there is no definite plane of movement. Complete destruction of these structures or paralysis by means of cocaine causes similar effects, as described by König,[1] and these results were confirmed by Gaglio.

In 1892 Ewald[2] carried out a most elaborate and careful series of experiments, and from these he drew the somewhat curious deduction that the function of these structures is to

[1] König, 'Contrib. à l'Étude Experiment. de Canaux Semicirc.' Paris, 1897; F. Alcan.

[2] Ewald, 'Untersuch. ueber d. Endorg. d. Nerv. Oct.' Bergmann, 1902.

give tone to the skeletal muscles. No doubt the tone of the muscles does suffer for a certain time after injury or destruction of the organs, but this is probably merely incidental and owing to the fact that the nerve-terminations of the vestibular apparatus in the brain are in particularly close association with the similar terminations of the nerves supplying the muscles. This close connection is, no doubt, owing to the fact that the vestibular apparatus is associated with the sensation of rotation, and therefore with the sense of direction. The latter would naturally be closely associated with muscular movements, since these depend to such a great extent upon the former, in so far as locomotion is concerned. A similar explanation probably holds good for the nystagmus which occurs when the vestibular apparatus is injured, since movements of the eyeball are also closely associated with the sense of direction. No doubt the stimulation of the sensory nerves in general affects the tone of the skeletal muscles, and when the vestibular nerves are stimulated this may be more obvious than in the case of other nerves, for the reasons just given. But it would be a misuse of terms to speak of the function of the canals and vestibule as that of giving tone to the muscles. Further, there is no evidence in support of Ewald's suggestion that the cilia of the cells in the ampullæ or vestibule are in constant motion as a result of stimuli coming from within the cells themselves.

Clinical Evidence.—Of more value in this respect than any of the experiments on animals is the record of a case described by Lake.[1] In this case a patient suffered so severely from deafness, tinnitus and vertigo, that an operation was performed, involving the complete destruction of the labyrinth, first on one side, and later on the other. When the healing process was completely finished, it was found that the vertigo and nystagmus had entirely disappeared, as had also the tinnitus. There was no loss of muscular tone whatever and no affection of equilibration. The only functions in the least degree affected were the hearing, the patient being quite deaf, and the sense of rotation. These important

[1] Lake, *Journal of Laryngology, Rhinology and Otology*, vol. xxiii., p. 496, 1908.

results were confirmed by Professor Schäfer and Dr. G. A. Gibson.

Comparative Anatomy.—The facts revealed by the study of comparative anatomy are extremely valuable in assisting us to form an opinion in this matter. In certain of the mammalian vertebrates the semicircular canals and vestibule undergo remarkable retrograde changes. These changes reach their highest degree in the Cetacea,[1] but are present to a considerable extent also in the Sirenia. Now, in the Cetacea there is a fusion of the cervical vertebræ, which, associated with the rigidity of the overlying tissues, prevents almost entirely any movement of the head upon the trunk. A similar condition, though not so marked, is found in the Sirenia. The author has associated this absence of movement of the head with the retrograde changes in the semicircular canals. These differences in the degree of development of the canals of the animals mentioned may be looked upon as the result of experiments carried out under natural conditions, over very many thousands of years, in unnumbered millions of cases, without injury and with a constant result. Any theory relating to the function of these organs must therefore be in accordance with the anatomical facts.

It would appear, therefore, that, though it is far from possible to speak with certainty in the matter, the function of the vestibule and canals is to furnish the animal with a knowledge of the extent and direction of the movements of the head, whether these be associated with the movements of the body or not. The function cannot be considered a very important one in man, and possibly even in mammals generally the same may be said. In the case of birds and fishes, which undertake long migratory journeys, it may be that this function enables these animals to pursue their course in circumstances, such as darkness and fog, in which vision would be unavailing.

Cochlea.—While it is quite certain that the cochlea is concerned solely with the function of hearing, the process by which the nerve-terminations in the organ of Corti are stimulated by the sound-waves is obscure in the extreme. The value

[1] Gray, 'Labyrinth of Animals,' vol. ii., p. 31. J. and A. Churchill, 1908.

of direct experiment upon the cochlea of animals is insignificant, and considerations as to the function of the organ are for the most part speculative.

With respect to the main question, whether analysis of sound takes place in the cochlea or in the brain, there is no doubt that opinion in recent times is strongly in favour of the view that the analysis takes place in the cochlea. If analysis takes place in the brain, then stimuli exactly corresponding in rapidity and in almost infinitely minute degrees of quality with the highly complex harmonic vibrations of sound must be transmitted with absolute faithfulness by the fibres of the cochlear nerve. Now, there is no reason to suppose that nerve fibres can transmit such stimuli without confusion, and there is every reason to suppose that they cannot do so. Until it is definitely proved that such transmission is possible, the views of Voltolini and Rutherford need not be considered further.

In recent times, therefore, the tendency among physiologists has been to admit that sound is analyzed in the cochlea, in so far as it is analyzed at all.

There is, unfortunately, little agreement as to the process by which analysis takes place. The view of Helmholtz,[1] that each fibre of the basilar membrane vibrates in sympathy with a certain note, cannot, it is true, be accepted in full; for, as was pointed out by myself,[2] it does not account for the difference between noise and musical sounds; and there are also other difficulties in accepting it. But this theory, if modified to a certain extent, does appear to get over these difficulties.

Certain writers have attempted to prove that analysis of sound by sympathetic resonance cannot be accomplished by means of the basilar membrane, but such objections are not insuperable. The usual error in these objections is the ignoring of the change in size and structure of the ligamentum spirale in the different portions of the cochlea. The theory of analysis in the cochlea by sympathetic resonance in the basilar membrane may be wrong, but none of the attempts to show that it is wrong have been successful.

In recent times it has been suggested by Shambaugh and

[1] Helmholtz, 'Tonempfindung.'

[2] Gray, *Journal of Anatomy and Physiology*, vol. xxxiv., p. 324, 1900.

some other investigators that the structure which performs the physical analysis of the sound-waves in the cochlea is not the basilar membrane, but the tectorial membrane. In this case the nerve-terminations would be stimulated by the movements of the tectorial membrane acting on the hair-cells below. This theory, as also that which considers the basilar membrane to be the analyzer, is quite rational, but to it, as to all the theories, there are certain objections. The most obvious of these is in respect to the physical qualities of the tectorial membrane itself. The latter is not, as many physiologists believe, an elastic membrane, but a soft gelatinous structure (see Fig. 39), and the question arises whether it could respond to sound vibrations in such a way as to analyze them.[1]

Although, as stated above, direct experiment upon the cochlea is of little value in helping us to decide upon the way in which the organ performs its functions, exception may be made in respect to the experiments of Wittmaak. This observer caused animals to be constantly subjected for a long time to hearing certain notes, and then killed the animals and examined the cochlea. The examination revealed the fact that in certain portions of the cochlea the organ of Corti and the corresponding cells in the ganglion spirale were damaged. Thus, with a note of 1,024 v.d. the portion damaged was the upper part of the lowest whorl of the cochlea; while with a note of about 256 v.d. changes of the same nature were found half a turn higher up the organ. Siebenmann confirmed these results, and they go a long way to prove that the upper portions of the cochlea respond to notes of low pitch, while the lower portion is sensitive to notes of high pitch. They do not, of course, give us direct information as to the structure which actually responds physically to the notes, and therefore do not enable us to decide whether it is the basilar membrane, the tectorial membrane, the hair-cells, or the rods of Corti, which play the part of resonators. It should be stated, however, that some physiologists do not place much reliance on these experiments.[2]

[1] Shambaugh, *Archives of Otology*, vol. xxxvii., No. 6, 1908.

[2] Wittmaak, *Verhandl. d. Deutsch. Otolog. Gesellsch.*, 1908 and 1909.

For information concerning the theories of Ewald,[1] Max Meyer[2] and Gray,[3] the reader is referred to the works of these authors. For a more detailed description of the physiology of the inner ear he is referred to the article by Professor McKendrick and the author in Schäfer's 'Textbook of Physiology.'[4]

Before leaving the consideration of the physiology of the labyrinth, attention should be drawn to an important matter in this relationship.

It is a curious fact that, amid all the investigation and discussion which has centred round the physiology of the organ, both in regard to the sense of hearing and to that of orientation, or whatever function it may be that is associated with the vestibule and canals, the fundamental quality of the stimulus which is requisite for producing these sensations has not been properly considered.

We have seen that the sensation of sound is called into existence by movements of particles which obey the law of sines, and are therefore never constant in the degree of their energies (p. 5). The nerve-terminations in the cochlea therefore are stimulated by a force which is never constant in intensity, but is always undergoing a change from less to greater, or the reverse. This statement is true whatever the actual structure may be—basilar membrane, tectorial membrane, rods of Corti, or hairlets of the hair-cells—which cause stimulation of the nerve. Similarly, in pathological conditions, whether they be of the nature of vascular interference or of inflammatory activity, the forces acting upon the nerve-terminations cannot, from their nature, be strictly constant in their intensities.

In the case of the vestibular and ampullary structures the same statement is true, although not at first so obvious. Numerous little experiments give proof of this, such as the well-known experiment of rotating the body round an axis

1 Ewald, *Arch. f. Physiolog.*, Bd. xciii., S. 485, 1903.

2 Meyer, 'An Introduction to the Mechanics of the Inner Ear.' University of Missouri, 1907.

3 Gray, *Journal of Anatomy and Physiology*, vol. xxxiv., p. 324, 1900.

4 McKendrick and Gray, 'Textbook of Physiology,' edited by Schäfer, vol. ii., p. 1149.

and producing giddiness. The symptom does not appear so long as the forces acting upon the labyrinth are constant in intensity, but it does appear when the rotation has stopped, because the pressure acting upon the nerve-terminations in the ampullæ and vestibule, which was constant in intensity so long as the rotation at a constant velocity was continued, undergoes a changing degree of intensity as soon as rotation stops, until equilibrium in the pressure of the fluid in the labyrinth in the various directions is again established.

A more conclusive experiment is that which may be observed in a railway train. On waking from sleep under these circumstances, it is usually impossible to tell in which direction the train is going without using either the sense of sight, or else, by an effort of memory, recalling the state of affairs before going to sleep. The same condition may be voluntarily produced by closing the eyes, and, by an effort of will, imagining that we are travelling in an opposite direction. In both these cases it is assumed that the train is travelling with a constant velocity. But the moment the velocity of the train is altered the illusion is dispelled, because the intensity of the pressure in the labyrinth in different directions undergoes a change.

Hence, when we speak of the nerve-terminations in the labyrinth giving us indication of changes of pressure in the labyrinthine fluid, the term is ambiguous, and is usually misunderstood. We are only conscious of a change in the pressure when it is actually passing from a greater to a less intensity or the reverse. We are not aware of the change in pressure so long as it is maintained at a constant degree of intensity, whether this be above or below the normal.

These brief remarks upon the quality of the stimuli which call into activity the functions of the labyrinth have been made for two reasons. The first reason is to try to remove a very common misconception as to their nature. The second and more important reason is, that they appear to foreshadow in a dim way what the author believes will ultimately be found to be a universal law of all sensation—viz., that, in order to evoke any given sensation, the stimulus applied must be such that its intensity is constantly varying in degree. In the case of light and sound the truth is obvious from the nature of the forces which call forth the sensation; and in the case of the functions of the semicircular canals and vestibule we have seen that the law also holds true.

In regard to the sensory functions of the skin, we may go so far as to say that the heat sense comes under the same law. It is possible therefore that, when the matter has been properly investigated, all sensation may be found to obey this law.

CHAPTER IV

METHODS AND PRINCIPLES OF INVESTIGATION

THE methods employed in making complete the diagnosis of diseases of the ear may be divided into two classes: (1) Those in which we employ direct observation, and (2) those which, by the use of experiment, give us certain data from which we draw corresponding conclusions. In addition to these there is, of course, the ascertaining of the family history, the previous history of the case, and the general condition of the patient.

In contradistinction to the method employed in ordinary medical cases, the student is well advised to use the method of direct inspection first, the reason of this being that in not a few cases direct investigation will frequently reveal the presence of wax or pus in the meatus, which must, of course, be removed before the other methods of investigation can be used to any purpose.

Direct Inspection.—This is carried out by means of a reflecting concave mirror and a speculum. The mirror may either be fixed to the forehead by a band or spring round the head, or held in the hand by a suitable handle. The speculum may be made of metal or of vulcanite, and of these several kinds may be employed. No particular advantage is possessed by any of these, and the aurist will in general come to prefer that which he has most accustomed himself to use. The light used may be either diffuse sunlight or artificial light. In this country, with its sombre sky, the latter is more frequently employed. If sunlight be used, the examiner must be careful not to focus the direct rays of the sun into the meatus, as has sometimes happened. Personally, I attribute more to the brightness of the light than most authors, and I find that the rays of the incandescent gas mantle, concentrated by a large lens, give a very brilliant light, and one of suitable spectroscopic composition. The light of ordinary gas contains too many of the yellow and red rays. Limelight gives an excellent illumination, but is somewhat cumbrous. Finally, it should be mentioned that the light from the electric glow-lamp is perhaps worst of all.

For the purpose of examination, the patient is seated with the light behind or in front of him, according to the ear which is to be examined. The light should be about the level of the examiner's forehead, and should be directed toward him. With the mirror the examiner reflects the light on to the patient's ear, and notes anything of mark on the auricle or the adjacent parts. The speculum (Fig. 42), held by the forefinger and thumb of the left hand, is then gently inserted into the meatus with a slight rotating motion,

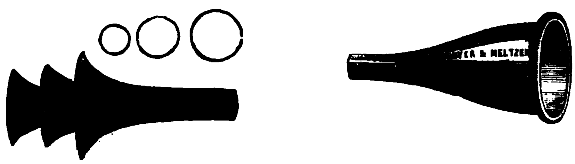

FIG. 42.—AURAL SPECULA.

the auricle at the same time being displaced upwards and backwards by the ring and middle fingers of the hand holding the speculum. The speculum must not be inserted so far as to cause any pain.

By this means the deeper parts of a normal meatus are seen, provided there is no pus or wax present, and if hairs or other substances do not obstruct the view. The condition of the meatus should be noticed, the colour of the membrane, the appearance of the reflex, the inclination of the handle of the hammer and its outline, the prominence of the short process, and of the posterior and anterior folds, the presence or absence of perforations, atrophic patches, calcareous deposits, etc. At present only the normal appearance of the drumhead need be described in detail.

Normal Appearance of the Membrane.—The amount of the membrane visible varies in individual cases, on account of the variations in the extent to which the anterior inferior wall bulges into the lumen of the meatus. In favourable cases the whole membrane may be seen, while in some only a portion behind the malleus is visible; and there are, of course, cases in which, on account of exostoses, it does not appear in the field at all. In order to get as complete a view as possible, the speculum should be rotated in different planes.

Colour and Form.—The normal drumhead (Fig. 61) is pearly and lustrous in appearance. Its colour varies from bluish-grey to greyish-white, the central region partaking more of the grey, and that at the circumference becoming more white and opaque. It appears roughly elliptical in shape, but the major axis of the ellipse is not much greater than the minor axis.

For the sake of convenience, the membrane is described as being divided into four quadrants in the following manner. The line of the handle of the hammer is continued until it cuts the tympanic ring above and below; then at right angles to this imaginary line is drawn another, passing through the tip of the handle of the hammer. The four so-called quadrants thus formed are termed the posterior superior, the posterior inferior, the anterior superior, the anterior inferior. Owing to the plane in which the membrane lies (see p. 21), the posterior superior quadrant is the nearest to the observer, while the anterior inferior is most remote. This oblique position produces the appearance of foreshortening, and when operating the surgeon must remember the obliquity.

The most noticeable object on examining the normal membrane is the handle of the hammer, with the short process of that bone at the upper extremity. At the lower extremity of the handle is the umbo, which presents a yellower colour than the rest of the handle, owing to the presence of cartilage cells. The short process (Fig. 61) is white, and stands out in relief from the surrounding membrane. Passing upwards and forwards and upwards and backwards, respectively, from the short process are the anterior and posterior folds of the membrane. Passing downwards and forwards from the umbo appears a cone of light, the apex of the cone being at the umbo. This is known as the light reflex, and it owes its existence to the fact that over this area the plane of the membrane is at right angles to the shaft of light which passes through the speculum. The light is therefore reflected directly back to the eye of the observer

The transparency of the membrane varies considerably even in healthy ears. It appears to be greatest in the posterior quadrants, and in favourable cases a faint view of the long process of the incus and the crus of the stapes is thus obtained, and below these the round window is sometimes seen as a dark crescentic shadow at the posterior margin of the membrane. In many individuals the outer region of the membrane is less transparent than that nearer the centre, on account of the increasing number of circular fibres.

Variations in Position of the Malleus.—Variations occur to a large extent in normal drumheads, and the student is carefully warned against attributing these to pathological changes. The most frequent error is the assumption that the membrane

FIG. 43.—BRUNTON'S OTOSCOPE.

is pathologically depressed because the handle of the hammer approaches the horizontal more than usual. Perfect hearing may coexist with an almost horizontal position of the manubrium. Further pathological appearances will be found described in subsequent pages.

Other Aural Specula: Magnifying.—Various attempts have been made to improve upon the ordinary method of examining the tympanic membrane. These have chiefly been in the direction of producing an instrument to give a magnified image of the structure, and have proved of no particular value. Thus, Brunton has designed an instrument (Fig. 43) by which light is reflected from an obliquely-placed mirror with a perforation in the centre and a convex lens behind, but its weight and the fact that instruments cannot be satisfactorily passed into the meatus through it have prevented it from coming into general use. Other similar instruments have been designed. I have, however, frequently found that a magnified image of the membrane may give valuable information with regard to the condition of the bloodvessels and the finer details. For this purpose I use an ordinary ophthalmoscope and a very bright light. The convex lenses of the ophthalmoscope magnify the membrane considerably, but the eye must be brought close up to the aural speculum. The aural speculum most useful in this case is a large one, brightly polished on the inner surface, so that as much light as possible is thrown into the meatus.

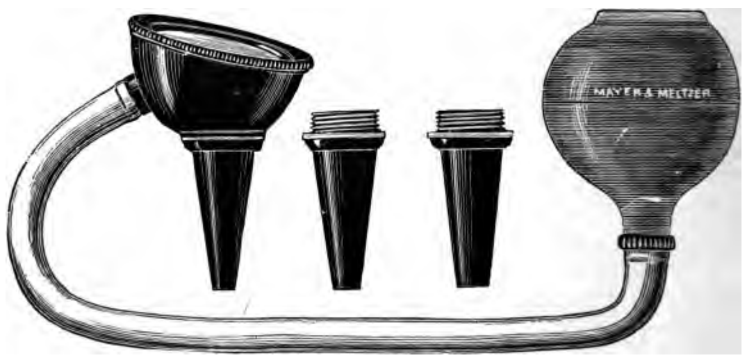

FIG. 44.—SIEGLE'S SPECULUM.

Siegle's Speculum.—It is sometimes desirable to ascertain the degree of tension of the membrane, and its mobility in various parts. For this purpose Siegle has designed a speculum by means of which the air in the meatus is rarefied, in consequence of which the air within the tympanum presses the membrane out. The glass window in the speculum enables the examiner to see the membrane while the rarefaction takes place (Fig. 44). The general mobility is gauged by the change in appearance of the light reflex, and the points of attachment of any adhesion that may be present, as known by the fact that such points do not move in response to the rarefaction of the air. In using this speculum, care must be taken that the rarefaction is not too great, or hæmorrhages in the membrane may occur.

Testing the Hearing-Power.—Having obtained all the information possible by means of direct inspection, the hearing-power should next be examined. Now, there is no completely satisfactory method for testing the hearing-power in general, and this for several reasons: (1) There is in Nature no uniform sound or combination of sounds that may be used as a standard—nothing, that is to say, like white light for testing vision; (2) the hearing-power for one part of the scale may be seriously impaired, while that for another part is hardly affected; (3) there is no satisfactory means of measuring the actual intensity of sound—that is to say that, while we are able to measure the amount of energy in the vibrations which produce a given sound (see p. 4), we cannot accurately measure the loudness or intensity of the effect which these vibrations will produce upon our consciousness. In spite of these difficulties attempts have been made by Gradenigo, Politzer and others, to construct acoumeters, as they are termed, for testing the hearing-power. Politzer's[1] acoumeter consists of a hammer of a given weight falling upon a steel cylinder. Schmiegelow[2] measures the hearing-power by means of tuning-forks of a certain construction, but Bezold and Edelmann[3] deny the correctness and practicability of the method. Gradenigo also uses the tuning-fork, but employs an optical method of ascertaining the power of hearing in this way. To the end of a prong of a deep-toned tuning-fork is attached a well-marked figure—*e.g.*, an inverted **V**. When the fork is set vibrating, there appear two fields, a field of single image and a field of double image, the latter being distinctly marked out from the former, owing to the fact that the images are superimposed. The greater the amplitude of vibration, the greater the field of double image. By noticing the extent of the field when the patient ceases to hear the tuning-fork, an estimate of his hearing-power is obtained. This method is extremely ingenious, simple and scientific, but is only applicable to the investigation of the hearing-power for the deeper tones.

The Watch.—The watch is a useful test in that it is convenient, but that is perhaps its only recommendation. Its

[1] Politzer, *op. cit.*, p. 128.

[2] Schmiegelow, *Arch. f. Ohrenh.*, Bd. xlvii., S. 164.

[3] Bezold and Edelmann, *ibid.*, Bd. xlix., S. 8

great fault is that the tones which go to compose the tick are high in pitch, and these are not the tones which are really most important to man as employed in the spoken voice. The method of testing with the watch is to put the normal hearing distance as the denominator, and that of the subject under examination as the numerator of a fraction. Thus, if a watch is heard by a healthy ear at a distance of 200 centimetres, while an affected ear hears it no farther than 60 centimetres, the hearing-power is expressed by the fraction $\frac{60}{200}$.

The Voice.—The most commonly used standard for testing the hearing-power is the voice, both conversational and whispered. To understand conversation is undoubtedly the most important function of the human ear; therefore, in general, the voice may be considered the best test. The difficulty lies in the obtaining of a constant loudness of the voice. But this difficulty is not so great as at first appears, for by practice the aurist learns to give to his voice the constant degree of loudness which is required. There are usually recognized two standards, the 'whispered' and the 'conversational,' and each of these is by some divided into a gentle and a loud. The method followed is to test first with the whispered voice, noting how far from the ear various words are heard. The words chosen are usually numerals, such as eighty-five, sixty-two, four, five, nine, etc. It should also be noted what numerals are confused with one another, one of the most common errors being of mistaking the five for nine. The acoustic composition of the various vowel-sounds has been investigated indefatigably by Helmholtz, Donders, McKendrick, Lloyd, Böke and others;[1] but the subject is too large to be discussed in these pages, and indeed, the matter is by no means settled. The acoustic analysis of the consonants has also been attempted by Lloyd, Blake and others, but the value of their results has not yet been ascertained.

If the patient is so deaf that the conversational voice is not heard, then a bell should be tried. If the examiner should happen to be possessed of a siren, then it may be used. The

[1] McKendrick and Gray, 'Textbook of Physiology,' edited by Schäfer.

value of the instrument lies in the fact that with it notes of various pitch may be produced as desired.

Bone Conduction.—It was explained on p. 51 that sound may be conveyed to the auditory nerve by way of the bones of the head, and it was further stated that under certain circumstances (*e.g.*, with the finger in the meatus) the sound so conveyed is heard better than when the meatus is left open. Now, a somewhat similar anomaly occurs in many cases of ear disease, the affected organ perceiving the sound by bone conduction better than a healthy one. Upon the existence of this phenomenon are founded several methods of testing the hearing. The most important of these is that known as Rinne's, and it is carried out as follows:—A tuning-fork of a pitch of about 256 v.d. (or lower) is struck, and held immediately in front of the ear of the patient until he ceases to hear it. The stem of the instrument is then placed on the mastoid process of the same ear, and, if the sound is again heard by him, the time during which it is now heard is noted. This is spoken of as 'Rinne's test negative of so many seconds.' Thus, if the patient hears the fork by bone conduction for ten seconds after he has ceased to hear it when held in front of the ear, it is expressed: Rinne $= -10$. If, on the other hand, the patient hears the instrument for, say, five seconds longer when held in front of the ear than when placed on the mastoid process the result is expressed: Rinne $= +5$.

Now, this method of expressing the results is not very satisfactory, because it takes no account of the differences in forks of different construction. Thus, a massive tuning-fork might be heard for sixty seconds by air conduction, and sixty-five by bone conduction, the difference being five seconds; while a light fork of the same pitch might be heard for ten seconds by air, and fifteen seconds by bone. In both these cases the result would be written: Rinne $= -5$; but it would convey a totally wrong impression, because in the second case it is obvious that the relationship of air to bone conduction is much more disturbed than in the first case.

The method of expressing the result of Rinne's test in the form of an equation is the best. Let A represent air conduction, and B bone conduction; then the ratio of the times during which the fork is heard by both ways is expressed by a fraction. Thus, in the first case cited: $\frac{A}{B}=\frac{60}{65}$; in the second case: $\frac{A}{B}=\frac{10}{15}$. From this expression the test may be expressed, if so desired, in the usual way by subtracting the lesser from the greater, and prefixing the sign + if air conduction preponderates, and the sign − if bone conduction preponderates.

Forks used for Rinne's test must not be too high in pitch, and it is sometimes instructive to try several, all of them below 440 v.d. In general it may be said that in middle-ear affections the bone conduction is relatively prolonged, while the air conduction is diminished. Furthermore, Bezold has pointed out that this difference in the relationship of air conduction to bone conduction is more pronounced the deeper the tones employed.

Schwabach's test depends upon the same principle as Rinne's, but he eliminates duration by air conduction altogether. A vibrating fork is placed upon the mastoid process of the examiner, and the time noted during which it is heard. The same is then done on the mastoid process of the patient. In middle-ear disease the patient will hear it longer than the examiner, and in disease of the inner ear or nerve he will not hear it so long. The two objections to this test are: First, the fork may not be struck with the same degree of force on the two occasions; and, second, the bone conduction in different individuals with quite normal hearing may vary. The first objection is not so serious as might be supposed, for the rate at which the sound of a tuning-fork dies away after the first few seconds does not depend much upon the violence with which it is struck, but upon its pitch and construction.

If a vibrating tuning-fork be placed upon the skull, and the air in the meatus be compressed by means of a Siegle's speculum, it will be found that in normal ears the sound is heard less powerfully than before. The same diminution in hearing will occur, according to Gellé, if the middle ear is normal and the inner ear affected; but if the middle ear is affected, then the intensity of the sound will remain unchanged.

According to Politzer, this test is only applicable to cases with a high degree of deafness, and even then only when it gives positive results.

Weber's test is only satisfactorily applied to those cases in which one ear is normal, or nearly so, while the other is considerably affected. It is carried out as follows: The stem of a vibrating tuning-fork is applied to the middle line of the head—*e.g.*, the incisor teeth. If the middle ear is affected, the sound will be heard best in the diseased ear; while if the nerve structures or inner ear be affected, then the ear which is less deaf will hear the fork best.

On account of its limited applicability, Weber's test loses considerably in value, for when both ears are affected to any approximately equal degree it gives ambiguous results.

The acoustic principles underlying the tests by bone conduction have not been properly ascertained. According to Politzer, the sound-waves do not so readily obtain exit from the tympanum in middle-ear disease as in normal conditions, and are therefore reflected inwards against the stapes and round window, and thus act more energetically upon the inner ear than under normal circumstances. Bezold holds, and apparently more correctly, that the increased tension of the ossicular chain which exists in middle-ear disease is the cause of the increased bone conduction in these cases. From my own experiments, I have been led to the view that the increased tension in the chain of ossicles, and also the increased tension in the radial fibres of the tympanic membrane, are the causes of increased bone conduction. The probability is that several factors go to produce alterations in the intensity of bone conduction, but that differences in tension and rigidity of the parts are the most important factors. Diminution of bone conduction is found in old people even when there is no appreciable deafness.

Hearing-Power for Notes of Different Pitch.—Among the valuable tests for hearing are those by means of which we ascertain the hearing-power for notes of different pitch. This subject has been studied with the greatest care and patience by Bezold.

The instruments most suitable for the purpose are tuning-forks for the lower notes, tubes closed at one end for the middle notes, and Galton's whistle for the higher notes.

Tuning-forks (Fig. 45) are the only suitable instruments for testing the lower notes, for reasons explained on p. 15. On the other hand, various instruments may be used for examining the higher notes—*e.g.*, König's cylinders, or the same modified by Blake, or flat metallic plates. If Galton's whistle be employed, the more recent pattern designed by Edelmann of Munich should be used, as the ordinary instrument shown in Fig. 46 does not give very accurate results.

FIG. 45.—TUNING-FORK, WITH CLAMPS.

The tuning-forks must have clamps attached to them, and the various notes marked upon them at correct intervals. They should be struck by a hammer, covered by chamois leather, and, after the examiner has ascertained that the overtones have died away, should be held immediately in front of the meatus. The various tuning-forks should cover the scale from the lowest note audible (16 v.d.) up to those of about 1,000 v.d. Beyond this the covered pipes should be used, and for the highest notes Galton's whistle or König's rods.

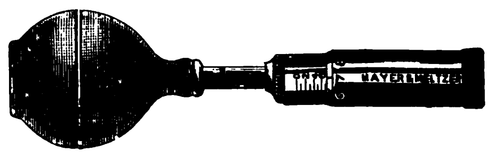

FIG. 46.—GALTON'S WHISTLE.

In general it may be stated that the hearing-power for the lower notes is most affected in diseases of the middle ear, while that for the higher notes is most affected in diseases of the inner ear. The reason for the loss of the lower notes in middle-ear disease has been explained by the author. Since the intensity of the sensation of the sound is, for the lower portion of the scale, in proportion to the energy transmitted to the labyrinth, then the amplitude of movement of the stapes must become greater the lower we go in the scale, in order to produce a sound of equal intensity with those produced by smaller amplitudes higher in the scale (see p. 5).

Testing the hearing-power for the high notes does not give such valuable results as that for the low notes. It should always be carried out, however, in cases where there is any doubt as to the condition of the inner ear. Further, loss of hearing for the high notes is, in my experience, the first indication of the deafness which occurs in the aged. Indeed, old people are quite frequently unaware of the fact that they are deaf at all, and even their friends may not have noticed it until it is revealed by some chance, such as when listening to the singing of birds and other high-pitched notes. On examining such subjects, a considerable portion of the upper part of the scale will be found to be inaudible to them, while the lower notes are heard perfectly. This loss of hearing for the upper notes in old people precedes the real deafness for conversation by many years, and in a considerable number of cases the affection frequently ceases to progress if the health remains otherwise good. It is important to remember this, since a grave prognosis might entail much mental suffering.

The cause of this loss of hearing-power for the high notes in elderly people is not certainly known. If the Helmholtz theory, or my own modification of that theory, be accepted, then it may be explained anatomically on the ground that the portion of the basilar membrane and ligamentum spirale nearest to the round and oval windows undergoes degenerative changes and becomes unable to fulfil its function.

In examining deaf patients it is sometimes found that, while the patient is deaf to most of the notes of the scale, there remains some hearing-power for certain portions of it. These portions are termed 'islands of hearing.' Their occurrence is interesting, and their existence indicates disease of the internal ear or auditory nerve.

The Air-Douche.—The forcible propulsion of air into the cavity of the tympanum gives more information, both as regards diagnosis and prognosis, than any other part of the examination of a deaf patient. It is, moreover, in many cases of ear disease by far the most important element in treatment, and the methods employed to carry it out must therefore be practised very thoroughly by the student.

Valsalva's Experiment.—The simplest method of forcing air into the tympanum is to hold the mouth shut and close the nostrils with the finger and thumb, and then attempt to force the breath through the nose. In most healthy individuals this will cause a sense of pressure in the tympanum. It may also succeed, but it will be more difficult to accomplish, in those who suffer from disease causing swelling of the mucous membrane in the region of the naso-pharynx or of the Eustachian tube. It is not a procedure which is of much value from the diagnostic point of view.

Politzer's Method.—A more satisfactory method is that introduced by Politzer. The patient is told to take a mouthful of water and hold it in the mouth for the time being. The nozzle of an india-rubber air-bag (Fig. 47), made for the purpose, is then introduced into one nostril. Both nostrils are then compressed by the finger and thumb of the left hand of the surgeon in such a way that no air can escape. The patient is told to swallow, and just as the act of swallowing occurs the surgeon compresses the air-bag rapidly with the right hand. The patient should be told to keep the lips very tightly closed during the operation, else the water will be blown out of the mouth. It is advisable for the surgeon to stand at the side of the patient in view of this contingency. A modification of this method may be mentioned. Instead of causing the soft palate to shut off the naso-pharynx from the mouth by the act of swallowing, the same end may be attained by directing him to say ' hook ' or ' huck,' the air-bag being compressed while the hard guttural *k* is sounded. There is yet another way of giving the air-douche. The patient is directed to blow hard through the almost closed mouth, and the air is driven by the bag through the nostrils, held as described above, while the patient is blowing.

FIG. 47.—AIR-BAG.

Of the three methods, perhaps that described first is the surest, though not always the most cleanly, since unintelligent patients do not always grasp the importance of keeping the mouth tightly closed while they swallow.

In children who refuse to assist the surgeon in any of the ways described above, the act of crying enables the object to be attained, since it necessitates the shutting off of the naso-pharynx from the pharynx, and therefore directing the pressure up the Eustachian tube.

Intelligent patients usually recognize at once when air has passed into the tympanum, by the sense of pressure in that region.

The Eustachian Catheter.—Should none of these means suffice, then air must be forced into the tympanum by means

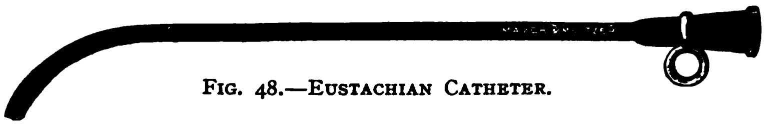

FIG. 48.—EUSTACHIAN CATHETER.

of the Eustachian catheter (Fig. 48). This instrument consists of a thin tube of vulcanite or metal. The distal end or beak of the tube is curved, and the proximal end is expanded into a trumpet-shaped orifice, to allow of the insertion of the nozzle of an air-bag. To the collar of the proximal end is fastened a ring, the plane of which coincides with the plane of the curved beak, and thus gives an indication of the direction in which the latter is pointing even when not seen.

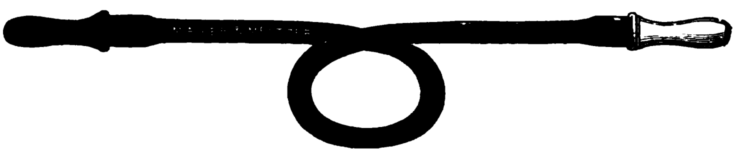

FIG. 49.—AUSCULTATION TUBE.

Before proceeding to pass the Eustachian catheter, it is advisable to examine the nose, in order to ascertain whether any obstruction exists, and if so, to avoid it when sliding the instrument along the inferior meatus.

The importance of knowing whether the air is really passing up to the tympanum is so great that the statement of the patient should not be relied upon. The aurist can, by means of the auscultation-tube, make sure of the matter (Fig. 49). This instrument is simply a rubber tube with a nozzle at each end. One of these is inserted into the ear of the patient, and the other into the ear of the surgeon who will hear the sound caused by the rush of air into the tympanum.

With the patient seated directly in front of him, the surgeon puts the ends of the auscultation-tube into his own and the patient's ears as described, and then proceeds to pass the catheter. The tip of the nose is tilted slightly upwards, and the beak of the instrument, with its concavity downwards, is slid gently backwards along the floor of the inferior meatus until it reaches the posterior wall of the naso-pharynx. It is then brought forward towards the surgeon until the curve of the beak is felt to be hooked against the hard palate. With the left hand resting upon the bridge of the patient's nose, and the fingers and thumb of the same hand holding the instrument, the latter is rotated until the plane of the beak points approximately to the outer canthus of the eye of the same side as the ear which is to be inflated. The ring fastened to the proximal end of the catheter indicates this, for its plane coincides with that of the beak. By following these directions, the beak of the catheter will in most cases come to lie in the funnel-shaped orifice of the Eustachian tube. Another method of passing the catheter is to direct the instrument onwards till it strikes the posterior wall of the naso-pharynx, then rotate it through a quadrant of a circle in such a way that the beak points horizontally inwards; next draw it forward till the curve catches on the posterior edge of the septum, and then rotate it a semicircle, so that the beak is now pointing outwards and is lying in the orifice of the Eustachian tube. A third method is to pass the instrument backwards as before till the tip touches the posterior wall of the naso-pharynx, rotate through a quadrant of a circle in such a direction that the beak points horizontally outwards, and draw it forwards over the tuberosity of the posterior lip of the Eustachian orifice, when the tip of the instrument will come to lie in the orifice itself.

There is no need to dilate on the supposed advantages of these methods. Frequently where one fails another will succeed, and only constant practice will enable the student to achieve the desired result in every case.

Presuming that the tip of the instrument lies in the Eustachian orifice, the surgeon, still holding the catheter steady with the left hand, inserts the nozzle of the air-bag into the mouth of the catheter with the right hand. On compressing the bag, air will be driven into the tympanum, provided the instrument is properly inserted and there is no obstruction in the Eustachian tube. If he has been successful, the surgeon will know at once, as the air rushing into the cavity of the drum makes a noise which is easily heard through the auscultation-tube. Should he not hear this noise, then the catheter must be gently manipulated, as described previously, until there is no doubt about the passage of air into the tympanum.

The sound of the air entering the cavity varies in different cases, both in intensity and in quality. Thus, if there be fluid in the drum the sound may be of a bubbling character, whereas if the cavity is comparatively dry it will be of a somewhat harsh, fricative description. Too much importance must not be attached to the quality of the sound, since it varies in healthy individuals, and furthermore, unavoidable conditions may lead to error.

Although it is true that only practice will enable the student to pass the catheter with precision and without pain, yet there are one or two hints which he would do well to remember when learning. The first of these is not to cause pain. No doubt the passing of the instrument is attended with discomfort, but this should not amount to actual pain. Force must therefore never be used. If there be any obstruction in the nose, such as a deflected septum, enlarged turbinated bodies, or polypi, they may be avoided by turning the beak of the catheter in different directions, by selecting a smaller instrument, or by passing the catheter through the opposite nostril, and then turning the beak in the direction desired. In the latter case the beak should be longer and more curved than in the ordinary catheter. If, however, it is quite impossible to catheterize, then the obstruction in the nose must be so pronounced that it requires removal in any case.

Cocaine is only rarely needed to enable the operator to succeed, but it should be employed if the procedure be found impracticable without. The drug may be assisted, or even replaced, by the application of adrenalin chloride.

Finally I would refer the reader to a paper by Dundas Grant,[1] in which he will find some valuable hints on the subject under discussion.

[1] *Journal of Laryngology*, etc., 1901, p. 453.

Certain accidents may occur when employing the catheter. Of these, the most important is the occurrence of emphysema in the tissues about the naso-pharynx. It indicates an injury, though a slight one usually, to the mucous membrane. At the moment of occurrence the patient is aware of pain and a strange feeling of tension, usually in the region of the palate, and on examination the characteristic appearance of the presence of air subcutaneously may be observed. Inflation must of course be stopped as soon as the accident is discovered. In mild cases the emphysema is limited to the region of the palate, but in more severe cases it may extend to the pharynx, the cheek, the neck, and even down to the thorax. Its course is almost invariably favourable; so far as I am aware, no fatal case has ever been recorded. Should, however, symptoms of suffocation occur, owing to bulging of the tissues over the opening of the larynx, punctures should be made in the swollen parts with a sharp needle. If left, the imprisoned air is very soon absorbed.

Rupture of the drumhead occasionally occurs, both as a result of the air-douche in the ordinary way, and, less frequently, when using the catheter. The accident rarely, if ever, happens when the membrane is healthy. Its occurrence is accompanied by an audible crack, and the hearing is usually made worse for a day or two. The rent heals without treatment, provided the over-enthusiastic surgeon does not prescribe antiseptic or other instillations, in which case suppuration will probably occur. The correct treatment is, to keep a small plug of cotton-wool in the ear and avoid using the air-douche or any other application for two or three weeks.

It should be stated that rupture usually occurs in cases where there is calcareous deposit in the membrane, and the surgeon should exercise gentleness in using the air-douche or the catheter in these cases.

Other accidents which may occur as a result of the air-douche or the passing of the catheter are fainting, vertigo, and convulsions. None of these are common, and apparently they are never serious.

Slight injuries to the mucous lining of the nose may occur, but if the operation be carried out gently they need not be inflicted.

Occasionally it is necessary to ascertain if there is an obstruction in the Eustachian tube. This is done by the passage of a bougie. The procedure is carried out by first passing the Eustachian catheter, and when the surgeon has satisfied himself that it is in the correct position, a fine pliable bougie (Fig. 50), made of whalebone, celluloid, or gum-elastic, is passed through the catheter, and directed by the latter up the Eustachian tube. The bougie is marked at certain points, in order that the surgeon may know how far the distal end is from the proximal orifice of the catheter. The bougie should not be passed more than 1 inch up the Eustachian tube. Its passage is usually associated with the sensation of pain in the ear.

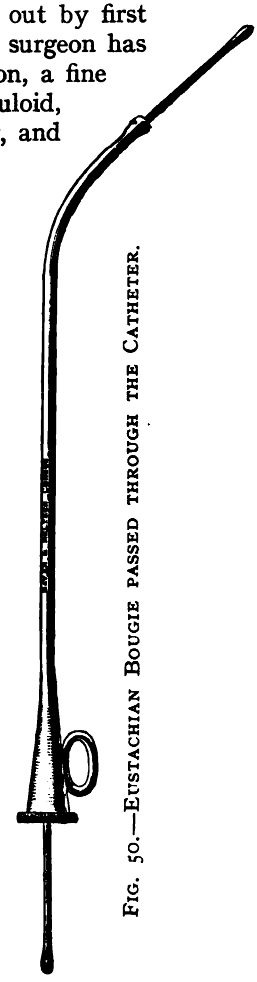

FIG. 50.—EUSTACHIAN BOUGIE PASSED THROUGH THE CATHETER.

There remains to be described a method of investigation which is of peculiar interest, though of limited practical value. It was discovered by Lermoyez[1] that the inhalation of nitrite of amyl produced in some deaf patients a marked, though very fleeting, increase in the hearing-power, associated in some cases with the temporary cessation of the distressing tinnitus which frequently accompanies the condition. Lermoyez attributes the improvement to the increased flow of oxygenated blood to the internal ear, and infers that the deafness is due, to a certain extent, to anæmia of that portion of the organ of hearing. It is to be noted that he does not say that improvement of hearing during the inhalation indicates internal ear disease. All he says is that it indicates anæmia of that organ, an anæmia which may be, and, to judge from my investigations, frequently is, associated with disease of the middle ear, particularly in cases of fixation of the stapes in the oval window.

Electrical Investigation.—In an age when electricity is tried for every purpose imaginable, it may be supposed that the ear has not escaped the attention of enthusiasts. Fortunately, though practically no benefit has ever accrued from

[1] *Annal. d. Malad. d. l'Oreille, du Larynx*, etc., 1896, No. 7, p. 28.

its application, it must in fairness be admitted that the damage inflicted upon the organ of hearing has also been but slight, though temporary disagreeable symptoms have occurred.

Attempts have been made to find out a reaction for the auditory nerve in response to the passage of the electric current. Brenner[1] maintained that, with the negative pole in the region of the ear, and the positive pole in contact with the skin at a distance from the ear, there is in the normal ear a sensation of sound during the passage of the current; whereas with the poles in a reversed position there is only a faint sound heard, and that only at the moment of opening the current. If the current be weak, the sound is of a buzzing character; if strong, it partakes of a more musical quality. This last statement is disputed by Kiesselbach,[2] who holds that the sound perceived by the subject is the proper tone (Rezonanzton) of the sound-conducting apparatus.

Pollak and Gärtner[3] hold that the healthy auditory nerve gives no reaction at all to the electric current, and that the sounds perceived take their origin in the sound-conducting apparatus.

Gradenigo,[4] from careful investigation, comes to the conclusion that in the normal ear the auditory nerve reacts only with difficulty to the electric current, but that in certain conditions both of the organ of hearing and of the cranial contents a reaction is very readily obtained. These conditions are, acute and chronic inflammations of the middle ear and internal ear, disturbances in the blood-supply of the labyrinth, brain tumours, meningitis and other intracranial affections. No relationship exists, according to Gradenigo, between the hearing-power and the electric reaction of the nerve. It must be admitted that the testing of the electric reaction of the auditory nerve has not come into general use in the diagnosis of affections of the ear.

Nystagmus Tests.—The physiological relationship which has long been known to exist between the vestibule and

[1] 'Untersuch. u. Beobacht. a. d. Gebiet. d. Elektrotherap.' Leipzig, 1868 and 1869.

[2] *Pflüg. Arch.*, xxxi. 95.

[3] *Wien. Klin. Wochenschr.*, 1888.

[4] *Annal. d. Malad. d. l'Oreille, du Larynx*, etc., 1899, No. 3.

semicircular canals on the one hand, and the muscles of the eyeball on the other, has in recent times been investigated with particular care by von Stein and Barany, with the result that certain tests have been devised by these otologists in order to assist in the diagnosis of some affections of the ear.

The two methods are von Stein's or the rotation test, and Barany's or the caloric test. The first depends upon stimulation of the vestibular structures by rotating the patient on a specially-constructed chair, and the second upon stimulating the structures by means of syringing hot or cold water into the meatus. Both methods are of value, but the caloric test is the more easily carried out, and has the further advantage of being applicable to one ear at a time.

In the *caloric test* the temperature of the water employed should be 42° C. in the case of hot water, and 24° C. in the case of cold water. In the normal individual, when the cold water is syringed into the meatus, the nystagmus is towards the opposite ear. For example, if the left ear be syringed, there will be a rapid movement of the eye to the right, followed by a slow return. This is termed nystagmus to the right. If hot water be employed, the converse happens, and there will be nystagmus to the left—that is, towards the ear syringed. It is to be noted, further, that in the case of nystagmus due to labyrinthine disease the amplitude of the movement is increased on looking towards the side to which the nystagmus is directed. Thus, if there is nystagmus towards the left, it will be increased on looking to the left. This feature was at first supposed to be characteristic of vestibular nystagmus, and no doubt it generally is. The author, however, knows of one case where this feature was present, but in which the nystagmus was due to an ocular condition, the ear being quite normal.

Now, for the purpose of clinical investigation, it is necessary first to find the normal physiological activity of the nystagmus. Barany's original method was to syringe a given amount of fluid at a given temperature into the meatus, and then note the duration of the nystagmus. McKenzie[1] has modified the test by employing a standard amount of water at standard temperatures (42° C. for hot and 22° C. for cold

[1] *Journal of Laryngology*, December, 1909.

water) and at a standard pressure. He then measures the period of time requisite to induce the nystagmus. Using this method, McKenzie found that this induction period in a healthy ear varies from between 20 to 40 seconds, in hyper-excitable conditions of the labyrinth from 5 to 15 seconds, and in cases of lowered excitability from 50 to 120 seconds; and when there is no excitability in the labyrinth nystagmus does not occur at all.

In certain cases of middle-ear disease also the nystagmus tests may be of practical use. Thus, if the air-pressure in the meatus be increased by fitting into it tightly the nozzle of an air-bag, and gently compressing the latter, nystagmus may be very readily induced if there is a fistula leading from the middle ear or antrum into the vestibule or canals. This is termed fistula nystagmus. With these exceptions, the nystagmus tests are not of any practical value in middle-ear disease. In otosclerosis Pike found hyperexcitability of the vestibular structures, but McKenzie found the excitability sometimes increased and sometimes diminished, and not bearing any relationship to the degree of deafness.

Rotation nystagmus does not lend itself so readily to the formulation of practicable tests as does caloric nystagmus. It may, however, be applied in the following manner. The patient is seated on a turnstool and rotated ten times in twenty seconds, and the duration of the nystagmus thus induced is measured in seconds. In employing this test it is desirable that the patient should wear smoked glasses; otherwise he may influence the duration of the nystagmus by fixing his eyes upon some adjacent object.

The nystagmus tests are of undoubted value in the diagnosis of labyrinthine affections. Like many other novelties, their importance and value have been considerably exaggerated; and the reader is advised, in regard to their application, to accept as evidence only well-marked deviations from the normal, and on no account to rely upon them too much, but to look upon them only as an addition to other methods of clinical investigation.

In spite of the short time that has elapsed since these tests were introduced, the literature of the subject is considerable. The reader who wishes to investigate the subject further is referred to the work of Barany[1] himself, and to papers by McKenzie,[2] Pike,[3] Scott,[4] Moure and Cauzard,[5] Lake[6] and others.

General Considerations.—In all cases of affections of the organ of hearing, the history of the case and the general constitutional condition of the patient as well as his habits and family history, should be inquired into. The temperament of the individual can be studied during this part of the examination, a study which is both of great practical value as well as of philosophical interest to the thoughtful physician. In many cases the way in which the patient relates the history of his trouble, and gives the description of his symptoms, is of more value than the actual history itself. This is particularly true of those cases in which tinnitus and vertigo are among the symptoms from which relief is sought.

It is of the utmost importance to ascertain the patient's previous history. The history of syphilis, inherited or acquired, will in some cases clarify the whole subject to the mind of the physician, and the same may be said of leukæmia, arterio-sclerosis, diabetes, anæmia, etc. It is hardly possible to exaggerate the importance of this part of the examination.

In cases of deaf-mutism and otosclerosis the family history should be inquired into with especial care.

1 Barany, 'Physiolog. u. Patholog. d. Bogengangapparat.' Leipzig, 1907.

2 McKenzie, *Journal of Laryngology, Rhinology, and Otology*, February and December, 1909.

3 Pike, *Journal of Laryngology, Rhinology, and Otology*, November, 1908.

4 Scott, Proceedings of the Royal Society of Medicine, vol. ii., No. 6.

5 Moure and Cauzard, *Bull. et Mém. d. la Soc. Franc. d'Otolog., Rhinolog., et Laryngolog.*, tome xxv., prem. part, 1909.

6 Lake, 'Otological Section, Royal Society of Medicine,' December 4, 1909.

CHAPTER V

GENERAL SEMEIOLOGY AND THERAPEUTICS

SEMEIOLOGY.

UNDER the term semeiology are included those symptoms of disease which lead a patient to seek relief at the hands of the surgeon or physician. In the case of ear affections these symptoms are deafness or dulness of hearing, pain and itching in the ear, noises in the ear or tinnitus, painful hearing or hyperæsthesia acustica, giddiness, disturbances of equilibrium, sensations of fulness or pressure in the ear, discharges from the ear and others.

Deafness.—Deafness varies greatly in degree and character. It may be absolute so that no sound, however loud, is heard, though such a condition is very rare. On the other hand, it may be so slight that the patient may not be aware of it, having come for relief from some other symptom, such as tinnitus. Furthermore, the loss may only be for certain sounds or tones.

The extent to which deafness varies in the same individual under different circumstances should be noted. Thus, damp weather, exhaustion, the catching of colds and other circumstances affect the hearing of some deaf patients, while they leave unchanged that of others. There is one condition of great interest which should always be inquired into—that is, the effect of loud noises upon the hearing-power of the patient for other sounds and particularly conversation. It has long been known that many deaf patients hear much better when, for example, in a cab, a railway-carriage, or in a noisy street than they do in a quiet room. The fact has no doubt been noticed from time immemorial, but it was first carefully studied by Willis[1] in 1676, and the phenomenon has come to be termed paracusis Willisii.

Paracusis Willisii.—Some authorities deny the real existence of the phenomenon, and attribute the apparent improvement in hearing to the fact that in a noise the speaker instinctively raises his voice. But this is in reality no explanation, since it is only a limited number of deaf individuals who experience the condition, and many hear much worse if conversation is carried on in the midst of a noise. It is, besides, far too obvious to be explained away in all cases, and finally, not only is the voice heard better in a noise, but other sounds of constant intensity may be heard better under these conditions.

The view that a loud noise shakes the ossicles loose to a certain extent, and thus enables them to transmit the finer vibrations, which in the absence of the louder noise they are unable to do, may, in a sense, be said to be correct. But it is a vague and unscientific way of explaining the phenomenon, and the meaning of the statement does not appear to be properly understood by most of those who use it. Consequently, the significance of paracusis Willisii in diagnosis has not been appraised at its true value, and no apology therefore is needed for explaining the subject more fully.

When a system, such as the chain of ossicles, is to a certain extent inhibited from performing its full amplitude of movement, there is a corresponding diminution in the kinetic energy of the harmonic vibrations which it is called upon to transmit, and consequently, in the case of hearing, the intensity of the sound is diminished. Further, as was shown on p. 5, this diminution in intensity affects the low notes more than the high ones. This resistance to the transmission of harmonic vibrations of low frequency may be to a considerable extent overcome, provided the amplitude of the vibrations of the low note be greatly increased—that is to say, by making the sound loud. It may even be achieved by employing vibrations which are below the actual limit of hearing, but in this case the amplitude of the vibrations must be increased to a still greater extent. But it is to be observed that, in order to obtain this result satisfactorily, two conditions are requisite—first, that the inhibiting mechanism is not too

[1] Willis, 'De Anima Brutor,' *Rust's Magazine*, No. 35, p. 504.

massive, and, second, that its degree of elasticity is comparatively high. If these conditions are not fulfilled, a large proportion of the energy is transformed, not into movements of the ossicles obeying the law of sines, but into heat, in accordance with the laws of elasticity.

Now, suppose these conditions have been fulfilled, and that, by employing a note of low frequency but great amplitude, we cause the ossicles to undergo oscillations which are strictly harmonic in character and of considerable amplitude. If, upon this series of vibrations of the ossicles, we now superimpose another series, in which the vibrations are of much smaller amplitude, the result is as follows. In the regions of extreme displacement (see p. 4) the second series of vibrations will not to any great extent affect the kinetic energy, because at these points the inhibiting mechanism is exerting its greatest influence, and the movement of the system in response to the first series is least. On the other hand, when in response to the first series the system is passing through the position of equilibrium, the kinetic energy is greatest, and the resistance of the inhibiting mechanism is least. In this region, therefore, the second series of vibrations can act upon the movements of the ossicles, accelerating or diminishing their velocity according to the relative phases of the two series of vibrations, and in strict accordance with the law of sines. The energy of the second series of vibrations is therefore, under these circumstances, transmitted to the labyrinth with far less loss than when, acting alone, it has to overcome the resistance of the inhibiting mechanism.

The subject is not very easy of explanation to those who have not studied these problems from the mathematical point of view; but if the reader has followed the explanation of paracusis just given, he will see the importance of the matter in relation to diagnosis, and, to a certain extent, of prognosis. We have seen that, to permit of the occurrence of paracusis Willisii, the inhibiting mechanism must not be too massive. We should not, therefore, expect it in cases in which the whole pelvis of the oval window was filled with a large mass of new-formed bone, completely incorporating the stapes in its substance, nor where a cholesteatomatous mass filled up the pelvis of the oval window. Again, since the occurrence of paracusis Willisii postulates a fairly high degree of elasticity in the inhibiting mechanism, we would not find it in cases in which the middle ear was filled with fluid, as in acute inflammation or serous middle-ear catarrh. For the same reason the symptom is not present in suppurative disease of the middle ear in which the dulness of hearing is due to the presence of granulations or swollen pulpy mucous membrane interfering with the movements of the ossicles. It is conceivable, however, that paracusis Willisii might occur in suppurative middle-ear disease in which the discharge is slight in amount. In such a case, the discharge might come from an ulcerated surface sufficiently far distant from the ossicular chain that the inhibiting mechanism consisted, not of the swollen mucous membrane, but of tightly stretched adhesions, the result of previous inflammatory activity.

On the other hand, the symptom may be present when the inhibiting mechanism is itself of such a nature that it is readily capable of performing harmonic motion when the exciting vibrations are of sufficient amplitude. That is to say, the inhibiting mechanism must not be too massive, and must have a considerable degree of elasticity. Hence we find it sometimes in cases of tightly stretched adhesions binding the ossicles, particularly the stapes. Such may occur as the result of previous inflammatory activity, suppurative or other, but these cases are not very common. By far the most frequent cause of the symptom is the existence of delicate bony trabeculæ and bridges passing from the footplate of the stapes to the edges of the fenestra ovalis, and thus replacing in part the annular ligament. This condition is common in otosclerosis (Fig. 112).

The occurrence of paracusis does not necessarily indicate that the cochlea and cochlear portion of the labyrinth and nerve are quite healthy, but it does prove that, if disease is present in these structures, the lesion is comparatively slight.

In respect to prognosis, the explanation of paracusis just given will enable the reader to understand why the symptom is, as a rule, of bad omen. It indicates that the inhibiting mechanism is not due to a swollen mucous membrane or fluid within the tympanum, either of which may be affected by treatment. New-formed bony tissue or tight adhesive bands binding down the stapes do not, with a few exceptions in the case of fibrous adhesions, permit of satisfactory treatment.

The author has purposely referred to this matter rather fully, because he has felt that the significance of paracusis Willisii has not been properly understood, and it has not therefore been appraised at its true value in diagnosis. In the light of this explanation, the occurrence of this symptom enables us to estimate with remarkable accuracy the position and nature of the lesion.

Giddiness.—Giddiness is a symptom not uncommonly complained of by patients who suffer from ear affections. There seems to be little doubt that, apart from intracranial complications, it is always produced by irritation of the maculæ and cristæ acusticæ in the labyrinth. This is not to say that these neuro-epithelia are necessarily diseased, since in various conditions fluid in the labyrinth may be made to undergo such changes that the cristæ are stimulated to an abnormal degree. A good example of such a condition is that which occasionally occurs during syringing of the ear with hot or cold water, when vertigo sometimes results.

Theoretically it would be expected that the patient might describe the sensation of giddiness in two ways: first, that, while he felt himself to be steady, objects around him appeared to move in a definite plane; second, that he felt himself to be rotating round an axis in his own body. As a matter of fact, the patient is seldom so explicit, but the surgeon should endeavour to elicit as much information on the subject as possible, and to ascertain in particular in what direction and plane objects appear to move.

The giddiness may come on only at intervals, and be merely evanescent, or it may be called forth by some particular incident. Its relationship in point of time to meals or hours of the day, and so forth, should all be noted. It varies in degree from a transient sensation to a sensation so strong as to cause the patient to fall.

Nystagmus.—Frequently associated with the symptom of giddiness is nystagmus. It is usually in the horizontal plane, and corresponds with the giddiness. Its nature should be observed (see p. 93), as well as the condition of the pupil at the time.

Staggering Gait.—Another symptom associated with giddiness, though not so common as the latter, is a peculiar way of walking. In his attempts to walk, the patient tries to catch hold of objects with his hands, in order to steady himself. It may be likened to the walk of a drunken man.

These three symptoms — giddiness, staggering gait and nystagmus—owe their existence to disturbances of the normal physiological functions of the labyrinth and auditory nerve.

Subjective Sensations of Sound.—One of the commonest and most troublesome symptoms of aural affections is the sensation of sound in the ears or head. The sounds so heard are in some cases due to contractions of the muscles of the ear or the Eustachian tube, but these are not properly termed subjective, since they have an objective existence and may frequently be heard by others than the patient. Such sounds are, moreover, usually fleeting and cause no great distress.

The subjective sounds, properly so called, are likened by sufferers to almost every conceivable sound in Nature. They may be rushing, whistling, hissing, beating, hammering, rustling, clanging. The patients occasionally state that they hear voices or melodies, though in both these cases there is usually an associated condition of mental instability. The most famous example of hallucination of hearing is that of Jeanne d'Arc, a case in which genius was apparently closely allied to insanity. The sounds may be continuous or intermittent, or they may be intermittent at first, to become continuous afterwards. In the majority of cases they are associated with or preceded by deafness, and are usually of sinister significance when very pronounced. Occasionally the sufferer complains of hearing two sounds, of which sometimes the one predominates and sometimes the other. As regards position, it is remarkable that in most bad cases the patient does not locate the trouble in the ear so much as in the head, and, except at first, is not deceived as to their subjective nature.

Varying bodily states or external conditions generally affect the tinnitus either for good or evil, though this is not always the case. Exhaustion either of the mind or body is perhaps the most potent evil influence, while damp, cold, raw weather, and especially east winds are also unfavourable conditions. Differences in the position of the body may effect changes in the intensity of the sound. Thus, lying down sometimes diminishes and sometimes increases its loudness.

This accounts for the fact, which the author has frequently noted, that on waking in the morning after a refreshing sleep, when it might be expected that the patient would not find the sound so distressing, the reverse has been actually the case. Alcohol, tobacco and many drugs certainly influence tinnitus unfavourably. Unfortunately, there is none which may be depended upon to act in the reverse manner.

The discomfort which sufferers experience from tinnitus varies greatly in individual cases, and depends largely upon the personal temperament and the state of health. Children rarely complain of tinnitus: according to Bezold, only 2·4 per cent. of the cases occur in children, the remaining 97·6 per cent. in adults.

Tinnitus may sometimes be favourably affected by stimulation of various nerves. Thus, pressure upon the tragus has been known to stop tinnitus temporarily; and conversely, the removal of irritation from certain nerves, particularly the fifth, may affect the condition favourably. Thus, the extraction of a carious tooth may bring about the cessation of a distressing tinnitus. It is extremely rare to find that the symptom is agreeable to a patient. Such cases have, however, been recorded by v. Tröltsch and Burnett.

Etiology of Tinnitus.—The etiology of tinnitus is very obscure. Naturally, some cases have an obvious explanation, such as those in which the sound is generated by the contraction of an adjacent muscle, etc., or by the existence of an aneurism. Many objective noises, 'entotic' as they are called, are produced by contraction of the intratympanic muscles, or those of the Eustachian tube, etc., and are thus easily explained. But there remains a large majority, and unfortunately, it is a majority which includes the worst cases, that cannot be accounted for in such obvious ways. It is the etiology of such cases that I propose to discuss now.

By far the commonest pathological change found in diseases of the ear associated with tinnitus, is fixation of the stapes in the oval window. It may be added further, that these are the cases in which the symptom assumes its most distressing form. The physiological explanation of this fact has never been properly revealed, though there has been much speculation on the subject. At first sight the most obvious explanation is that the symptom indicates a coincident lesion in the cochlea or auditory nerve. It is remarkable how readily this view has been accepted by many whose scientific training should have taught them to be suspicious of the obvious unless supported by demonstrated fact. As a matter of actual experience, post-mortem examinations in a considerable number of cases of tinnitus associated with fixation of the stapes have revealed no lesion in the cochlea or auditory nerve,[1] so that the explanation just referred to is insufficient in many cases. Some authorities have suggested that increased tension in the labyrinth is the cause of tinnitus in cases of fixation of the stapes, but it is difficult to see how such increased tension can last for more than a few moments. The fluids in the labyrinth can readily find exit into the cranial cavity, the perilymph directly through the aqueduct of the cochlea, and the endolymph by the same channel, after having first diffused through its membranous wall into the perilymph. An explanation of tinnitus more in accordance with the known pathological changes in otosclerosis is that which refers the symptom to fluid veins formed in the vascular channels in the bone, which become dilated at one period in the osseous changes.

Another possible explanation has occurred to the author, which is as follows. At each systole of the heart the blood-vessels of the labyrinth will be relatively more full, and at each diastole a little less full. There would therefore be a constant slight change in the tension of the labyrinthine fluids, but for the fact that the pressure may find relief at the round and oval windows, and to a less extent, on account of their very fine calibre, through the two aqueducts. If, therefore, one or more of these means of relief be removed, the constant changes in pressure are exerted upon the intra-labyrinthine structures and stimulate the organ of Corti, thus causing the subjective sensation of sound.

It must, however, be admitted that all the views in regard to the physical and physiological factors in the causation of tinnitus in cases of fixation of the stapes are purely speculative, and none are really satisfactory. What is definitely known is that the symptom, particularly in its worst manifestations, is most commonly associated with bony fixation

[1] Panse, 'D. Schwerhörig. durch. Starrheit. d. Paukenfenst.,' S. 166, 1897.

of the stapes, and probably few of such cases escape the symptom altogether.

Other affections of the ear may be associated with tinnitus. Thus, in acute inflammation, whether suppurative or not, subjective noises may be complained of; and even in Eustachian and chronic middle-ear catarrh they may be present, but they do not cause so much distress as when associated with fixation of the stapes.

In cases of disease of the labyrinth and auditory nerve unassociated with middle-ear disease or fixation of the stapes, it is a very curious fact that tinnitus is rarely included in the list of prominent symptoms. But to this statement exception must be made in respect to cases of sudden onset. In these, of course, the sudden change from normal conditions invariably causes severe tinnitus; but it is remarkable even in these circumstances how comparatively quickly the symptom disappears or becomes insignificant in degree. When the onset is gradual the deafness usually progresses without much complaint of tinnitus. Thus, in cases of tumours in the tract of the auditory nerve in the encephalon causing deafness, Siebenmann found that only 18·3 per cent. suffered from tinnitus, and even in these the symptom was not severe in degree, and was transient.

Certain drugs and poisons may cause tinnitus, which is sometimes associated with deafness to a greater or less extent. Quinine and salicylic acid and its compounds are the most familiar examples of these, but alcohol and tobacco are not uncommon causes of the symptom. The author has seen a case in which the administration of thyroid extract in rather large doses caused tinnitus of considerable severity, but on stopping the drug the symptom passed off.

Diseases of the vascular system frequently cause tinnitus, but in these cases deafness is not observed, or is present only in slight degree. Aortic incompetence and arterio-sclerosis are particularly associated with tinnitus, but the various forms of anæmia are also frequently the cause of the symptom. The surgeon should be particularly careful, when dealing with cases in which tinnitus is not associated with deafness, to ascertain the condition of the heart and vascular system. Under these circumstances the subjective sensation of noise is not to be looked upon as indicating any lesion in the ear, but as significant rather of a heart long overburdened and staggering towards the end.

Tinnitus can be temporarily stopped in most patients by compression of the carotid artery. This is true of the cases in which the symptom is associated with local lesions of the ear independent of changes in the circulatory system, such as arterio-sclerosis or valvular heart disease.

Pain.—Pain is a noticeable feature of several forms of ear disease. Its position and character should be noted.

In the great majority of cases, pain in the ear is obviously due to a local lesion in the organ, and consequently deafness is associated with it. But pain may occur in the ear without deafness, and then the surgeon must make a particularly careful examination before giving an opinion. Sometimes the pain is of the nature of neuralgia, and no lesion can be found anywhere. But in many cases it is a reflex sensation, and may be due to carious teeth, spurs and deflections of the nasal septum, etc. But there is one condition which must always be looked for with especial care—malignant disease of the pharynx or larynx. Pain in the ear is frequently the first symptom of cancer in these regions, and it is a serious mistake not to recognize the condition at once.

A sense of fulness or pressure in the head, particularly in the region of the ears, is not an uncommon complaint of patients. It usually indicates more or less occlusion of the Eustachian tube, but I have noticed the symptom to be present in cases in which no apparent obstruction was present.

Reflexes.—Various symptoms due to the stimulation of certain nerves in the region of the ear are undoubtedly of a reflex nature. Of these, perhaps cough is the most common. It occurs in many subjects on the introduction of the aural speculum ; sometimes it is very severe, but more often slight. Cerumen in the ear may cause the same symptom. Closely allied to the cough reflex is the sneezing reflex which sometimes, but more rarely, occurs.

Convulsions are reported to have occurred as the result of wax in the ear, but they must be rare in this connection.

Facial Paralysis.—Facial paralysis is sometimes associated with diseases of the ear. It is usually the result of present or past inflammatory processes in the tympanum, but in rare cases is due to lesions involving the auditory nerve or the medulla. It is associated with paralysis of the sense of taste on the corresponding side of the tongue, due to coincident involvement of the chorda tympani. Paralysis of the sense of taste, however, may occur in ear disease, owing to involvement of the last-mentioned nerve without facial paralysis.

Vomiting and Nausea.—Vomiting and nausea are sometimes symptomatic of ear disease, and are due to disturbance of the maculæ and cristæ acusticæ in the labyrinth. They are associated, therefore, with such symptoms as giddiness, nystagmus and staggering gait.

Fever, headache, malaise and rigors may be indicative of ear affections or of the intracranial complications resulting from otorrhœa, and various disturbances of vision are sometimes the result of these complications.

Facial Expression.—The appearance of an individual frequently undergoes slight changes as the result of deafness in both ears. When the symptom first makes its appearance, the expression is apt to become strained, owing to the increased mental effort which the patient makes in order to hear conversation. If tinnitus be present, the strained appearance is apt to be more pronounced. When, however, the deafness increases and the tinnitus becomes less irritating or disappears, the face gradually assumes an expression of placid serenity. The dulness of hearing can no longer be compensated for by increased attention, the effort to listen is gradually and unconsciously given up, and the patient resigns himself to his condition. Since his social intercourse with his fellows becomes more limited with the increasing deafness, the emotions are less frequently stimulated, and the facial muscles consequently do not undergo that unconscious but constant exercise which occurs in daily intercourse. This change in expression, subtle as it is, may easily be recognized by the observant physician ; but it must be remembered that the existence of distressing tinnitus will naturally prevent its appearance.

Otorrhœa.—There remains to be described one very common and important feature of many ear diseases. This is otorrhœa, or discharge from the ear. The amount of discharge may be large, or it may be so insignificant that the patient is unaware that there is any. It is usually purulent or mucopurulent, but sometimes is serous, and occasionally is tinged with blood. Its odour may be of the sickly sweetish character of ordinary pus, or it may be very offensive.

Milligan[1] has carefully investigated the cytological and bacteriological character of the discharge from cases of otorrhœa, with the object of ascertaining to what extent the presence of certain organisms influences the course of suppurative ear disease. He found that in all chronic cases the infection was mixed, and many saprophytic organisms were present in addition to the pathogenic ones. Of the latter, the staphylococci proved to be the least, and the streptococci and diplococci the most, virulent. Tubercle bacilli are present in some cases, but are difficult to find. They are more common in the discharge from the ear of a child than from that of an adult. Other organisms occasionally found are Löffler's diphtheria bacillus, the meningococcus, the gonococcus and the pneumococcus.

THERAPEUTICS.

A few general remarks should be made in regard to the common methods employed in treating affections of the ear. Special methods will be discussed when the affections in which they are employed come under consideration.

The method of employing the catheter, the air-douche, and Valsalva's experiment, have already been described, and it is not necessary to say anything further on that subject.

Syringing.—Syringing is employed in order to remove wax, pus, or foreign bodies from the ear. Needless to say, the meatus should invariably be inspected before using the syringe. The water should be as warm as can be comfortably endured by the patient. The syringe should have a relatively fine nozzle ; and there is no need to employ guarded syringes, such as are occasionally recommended.

The auricle of the patient should be drawn gently upwards and backwards with the left hand, the right hand directing the syringe. The nozzle should be placed just inside the meatus and along its upper wall, and the syringing should be carried out steadily and, if necessary, repeatedly.

In the case of hard, dry cerumen, a little warm olive-oil dropped into the meatus night and morning for a few days previously facilitates the removal of the substance. The

[1] *British Medical Journal*, October 12, 1907.

same end is achieved by employing a saturated solution of bicarbonate of soda in equal parts of glycerin and water. In certain cases it is desirable to employ special methods of syringing out the cavity of the middle ear. These will be described in the chapter devoted to the consideration of suppuration in the middle ear.

Cleansing.—The drying out of secretion from the meatus and middle ear is necessary in all cases of suppurative ear disease. Fine pledgets of cotton-wool are wrapped round the end of a probe (which must not have a bulbous tip). The cotton-wool should project beyond the end of the probe, so that the hard metal does not actually touch the sensitive tissues of the middle ear. On withdrawing the probe, the moist cotton-wool is slipped off the end and another dry pledget wrapped round it. The process is repeated until the cotton-wool comes dry out of the ear.

Instillations.—A favourite method of applying medicaments to the ear is in the form of drops. Applications of this nature should in general be warmed, the exceptions being those solutions or mixtures into which alcohol, anilin, or peroxide of hydrogen enter. The patient should be seated with the head inclined to the side in such a way that the affected ear is uppermost. The fluid is poured into the meatus, and the tragus is then pressed inwards, in order to drive the liquid into the deeper parts.

Gelatin Bougies.—Some aurists, for the sake of convenience, order the drug which they desire to be applied, to be made up with gelatin in the form of a bougie. The gelatin melts at the temperature of the body, so that when inserted into the ear it runs down to the deeper parts. The author is of opinion that this is one of the least effective ways of applying a medicament locally. Gelatin has very little power of penetrating the tissues, and it is this penetrating quality which in the majority of cases is most desirable in the vehicle we employ for the local application of drugs.

Insufflation.—Powders are frequently insufflated in the treatment of suppurating middle-ear conditions. The profession is indebted to the late Professor Bezold, who introduced this method (Fig. 51). The powders employed are boracic acid, iodoform, salicylic acid, iodol, etc. This method is not suitable for all cases, but in the majority it is very useful. The contra-indications will be referred to when considering suppurative middle-ear catarrh.

Applications through the Eustachian Tube.—Medication by way of the Eustachian tube has been attempted with more or less success in some conditions of the middle ear. The object is supposed to be attained, if the drug is a volatile one, by inhaling it into the mouth and nostrils, and then performing Valsalva's experiment. The best feature of this method is that it almost certainly does no harm, for the good reason that the quantity which reaches the tympanum could have but little effect either for good or evil.

A more satisfactory method is the propulsion of the drug up to the middle ear, either by means of the air-douche or through the catheter. In the former the drug must be volatile; in the latter it need not be. In employing the air-douche for this purpose, the nozzle of the air-bag, with the bag itself com-

FIG. 51.—POWDER INSUFFLATOR.

pressed, is inserted into the mouth of the bottle containing the volatile substance (*e.g.*, iodine gently warmed). The bag is then released, and it sucks in air impregnated with the medicament. The air-douche is then employed in the usual way.

To drive any given substance definitely into the middle ear, the only satisfactory method is through the Eustachian catheter. The catheter employed should be wide, and should have a well-curved beak. After making sure that the beak of the instrument is engaged in the Eustachian tube, a few drops of the medicament are injected into the outer end of the catheter by a small syringe; the nozzle of the air-bag is then again inserted into the catheter, and the fluid is (perhaps!) blown into the middle ear in the form of a fine spray. The amount of the fluid which reaches the ear must be very small, and probably its therapeutic effect is insignificant in so far as the middle ear is concerned.

Applications may, however, be made direct to the Eustachian tube, and these may have a beneficial effect in catarrh of that channel. The applications are made as follows. The beak of a catheter is dipped into the fluid which the surgeon wishes to apply to the Eustachian tube. The instrument is then passed in the usual way, and air driven through it. A bougie of whalebone is then passed through the catheter into the tube, and carries some of the medicament with it. Glycerin solutions are easily applied in this way. A similar method may be employed for the application of ointments, care being taken that the preparation is not so stiff in consistency as to prevent the passage of the bougie through the catheter.

Other local methods of treatment will be described in the chapters dealing with the special diseases with which they are concerned.

General Therapeutics.—Besides local treatment, it is very frequently necessary to apply general measures to patients suffering from aural troubles. This is particularly the case with those forms of ear affection which are the result of anæmia, syphilis, tuberculosis, etc., and, less commonly, rheumatism. It behoves the surgeon, therefore, to ascertain carefully the presence or absence of these conditions, and to direct his treatment accordingly.

Climate.—Change of climate is sometimes effective in bringing about an improvement which skilled medical attention could not achieve. The author has been struck with the frequent remarks of soldiers who were in South Africa during the war, with regard to the pronounced improvement which took place in their hearing in the high and dry atmosphere of the Transvaal.

Residence at a high altitude is particularly noticeable for the improvement in hearing which it may bring about. This improvement may be due to the diminished pressure upon the surface of the body. A little consideration will show that it cannot be due to drawing out of the tympanic membrane, as has been suggested by some. On the other hand, it may be due to the increase in hæmoglobin which takes place in all —even healthy—individuals when passing from a low to a high altitude. It is, unfortunately, the fact that in many cases the improvement in hearing passes off when the patient returns to lower regions.

Baths, etc.—Turkish, Russian and hot baths are sometimes of use in the treatment of aural troubles.

Cold Bathing.—While referring to the effect of baths upon aural affections, it is desirable to make a short statement upon the use of cold baths in diseases of the ear. In this country, where the cold morning bath on rising out of bed is such a regular institution. there is no doubt it is indulged in too indiscriminately. It is true, of course, that very many people—perhaps the majority—can rise from their beds and immediately take a cold bath, not only without harm, but with distinctly beneficial results. But to obtain these results it is necessary that the vascular system should not only be healthy, but it should be vigorous and quickly responsive. Further, if there be any condition of chronic congestion in the deeper organs, these will not benefit from the stimulus of the cold water, though the other organs may. It must be remembered that on waking in the morning the heart is beating feebly, and may not always respond to the sudden stimulus of the cold water. If, on the other hand, a short but quick walk be taken to increase the activity of the circulation, the bad effects of the cold bath may be avoided.

Patients, therefore, who suffer from ear affections, and particularly those in whom the trouble arises from catarrhal affections in the nose, the Eustachian tubes and the middle ear, should not take the morning tub without having exercise before it, and in many cases they are wise to avoid cold bathing altogether. Those who suffer from suppurative ear disease or have a perforation in the drum membrane should always, before entering the water, insert into the meatus a plug of cotton-wool saturated with lanoline or vaseline.

When cold baths are ordered as a tonic, salt water is far more valuable for the purpose than fresh.

Habits.—Various habits exercise an influence upon many of those who suffer from ear affections. Tobacco-smoking is, in general, bad for the deaf, particularly if their list of symptoms includes tinnitus. It is probable that smoking influences the ear trouble in two ways. First by the absorption of nicotine, and the effect of the poison upon the auditory nerve, the bloodvessels and intratympanic muscles. The other and (as I believe) subsidiary effect is produced by its local irritating action upon the pharynx, and more especially the naso-pharynx.

Alcohol.—Alcohol is as bad in its effects upon aural maladies as is tobacco, and the deleterious results manifest themselves in the same cases—viz., those in which the disease is associated with tinnitus.

In patients suffering from those aural affections which are associated with tinnitus in particular, the use of alcohol and tobacco should be very strictly limited, or forbidden altogether.

ANÆSTHESIA.

1. *Local anæsthesia* is sometimes sufficient for minor operations on the ear, but where the procedure involves the removal of bone, general anæsthesia is to be preferred.

For the production of local anæsthesia of the tympanic membrane or cavity, special methods are necessary, since the instillation of watery solutions of cocaine are valueless.

There are three methods by means of which local anæsthesia may be employed in the ear:

(1) Bonain's method, in which a mixture of pure carbolic acid, menthol and cocaine are applied to the circumscribed area. This gives a satisfactory anæsthesia for incision of the membrane, removal of granulations, etc. The objection to it is that it is apt to produce a change in the appearance of the parts, so that the surgeon does not see exactly what he is doing.

(2) The author's method is to instil into the meatus a 15 per cent. solution of cocaine in equal parts of rectified spirit and anilin. This gives a satisfactory anæsthesia for incision of the membrane, removal of granulations, etc. The objection to this method is that anilin, if used carelessly, may be absorbed through the skin of the meatus and cause toxic symptoms. It is necessary, therefore, to say a few words as to the method of use. Fifteen to twenty drops of the solution are instilled into the meatus, the head being held well over to the side and resting on a table, so that the affected ear is uppermost. The solution is left in for about ten minutes, and is then very carefully dried out, so that none of it remains. The operation is then proceeded with, and it will be found that either there is no pain at all, or at most it is insignificant in degree. Used in this way, there is no possible

fear of toxic effects from anilin—at any rate in adults. In young children a few drops of the solution may be put on a pledget of cotton-wool, which is then passed down the meatus until it lies against the membrane.

Both Bonain's solution and the author's should be made up fresh every month or so.

It is a curious fact that neither of these methods is very efficacious where there is *acute* inflammatory activity, and they are therefore not of much use for the incision of furuncles in the meatus, or for the incision of the drumhead in acute middle-ear inflammation. In order to prevent completely the pain of incision in these cases, a general anæsthetic is requisite.

(3) Schleich's infiltration anæsthesia has been warmly recommended by Neumann even for some of the major operations upon the ear, such as the various forms of the mastoid operation. The use of this method for such purposes should, however, be limited to those cases in which a general anæsthetic might be dangerous on account of cardiac, vascular, pulmonary, or renal complications. For the excision of small exostoses in the meatus, and for the removal of the outer attic wall and ossicles, however, the method may be employed. The fluid used for the purpose is a 1 per cent. solution of cocaine in sterilized water, preferably with the addition of a minute trace of adrenalin (1 part in 3,000). If the operation is confined to the region of the meatus, the fluid is injected into the upper posterior wall at the junction of the cartilaginous with the osseous meatus. If, in addition, the mastoid process is to be attacked, another injection over its surface is also requisite.

2. *General Anæsthesia.*—As stated above, however, for major operations on the ear a general anæsthetic is very much to be preferred to a local one however carefully carried out. The anæsthetist should be very thoroughly experienced, and with such it is remarkable how much the surgeon may be assisted at the various stages of the operation by the skilful employment of ether and chloroform, without endangering the safety of the patient. A skilful anæsthetist seems to know instinctively at what stages it is necessary to have the field of operation almost bloodless by employing chloroform, and at what stages this is not of such great importance, and when ether may therefore be used.

CHAPTER VI

RELATIONSHIP OF NASAL AND PHARYNGEAL AFFECTIONS TO DISEASES OF THE EAR

THE intimate physiological and anatomical relationships which exist between the ear and the upper respiratory passages are paralleled by the interdependence of the two regions under pathological conditions. It is, therefore, desirable to make some remarks in regard to the methods of examination of the nose and throat, in so far as they are necessary for a proper understanding of pathological changes in the ear, and as indications for treatment.

Anterior Rhinoscopy.—In order to inspect the anterior portion of the nasal passages, the forehead mirror is employed in the same way as for the ear. But in the case of the nose artificial light is almost a necessity. The nostril is dilated with one of the many types of nasal specula, one of the most useful of which is seen in Fig. 52. One of the most prominent objects which meets the eye is the rounded anterior end of the inferior turbinated body. The condition of this should be noted. It may be of a normal pink colour or congested and swollen, and if it be in contact with the septum the condition is certainly abnormal. The septum itself is then inspected, and any prominent deflection or spur should be noted. It must be remembered, however, that the septum may be deviated to a considerable extent without necessarily producing any symptoms requiring treatment. The middle turbinated body runs parallel with, but on a higher plane than, the inferior turbinated body; that is

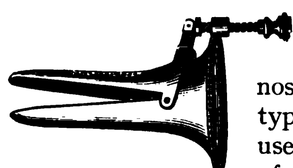

FIG. 52.—NASAL SPECULUM.

to say, they both run approximately horizontally backwards. The space between these two turbinated bodies should be carefully inspected for pus or for polypi, the latter being easily recognized by their translucent grey colour.

The width of the nasal passages varies considerably within perfectly healthy limits, but the peculiarly wide condition found in atrophic rhinitis is very characteristic, and should receive careful attention when present.

Before proceeding to examine the posterior nares and the naso-pharynx, the mouth should be inspected, the teeth and the arch of the palate examined, as well as the region of the fauces, tonsils, and pharynx.

Posterior Rhinoscopy.—Posterior rhinoscopy is carried out by means of the forehead and pharyngeal mirrors and artificial light. If the pharyngeal region is very sensitive, it may be painted with a 15 per cent. solution of cocaine, but this is not usually necessary. The light is reflected into the pharynx,

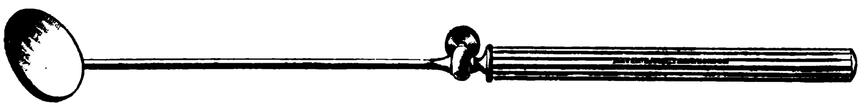

FIG. 53.—RHINOSCOPIC MIRROR.

and a small rhinoscopic mirror (Fig. 53) is passed carefully back until it lies behind and below the soft palate. It is then turned so that its reflecting surface looks upwards and forwards, and the various portions of the naso-pharynx and posterior nares are brought into view by turning the mirror in different directions. In this way the posterior surface of the uvula and soft palate are seen, as well as the posterior termination of the septum, which is almost always free of any deflection in this portion.

By the slight movements of the mirror, as described above, other parts may be brought into view, such as the posterior ends of the inferior and middle turbinated bodies, the opening of the Eustachian tube, the fossa of Rosenmüller and the vault of the naso-pharynx. Attention should be directed to the general colour of the parts and the presence and nature of secretion.

The posterior ends of the middle and inferior turbinated bodies are of a translucent grey colour, with sometimes a faint tinge of light brown. They are not pink in the normal condition. The other portions of the mucous membrane are pink in varying degrees of intensity, though small areas in the region of the Eustachian tube are sometimes of a dirty white colour. The normal relationships of the parts may be studied in Fig. 22, and there is therefore no necessity for a detailed description.

Before passing on to consider the affections of the upper respiratory passages, it is necessary to emphasize the fact that it is only intended to discuss these in so far as they are related to diseases of the ear; and even in this respect a detailed description is forbidden owing to limits of space.

Acute Rhinitis.—The symptoms of a common cold—or, as it is more ponderously termed, acute rhinitis—are so well known that no description is required. The subject is only referred to because it occasionally happens that acute inflammation of the middle ear results from a common cold.

The treatment is expectant, the patient being guarded against adverse conditions by remaining in one room at a constant temperature. The author has never found any benefit from the numerous specifics which have been vaunted as cures for a cold. The local application of mild alkaline sprays sometimes gives temporary relief. In recent times the vaccine treatment of acute rhinitis has been attempted, and according to some reports, with success in so far as it may materially shorten the course of the disease. It is too early to give a definite opinion on the value of this treatment.

Chronic Rhinitis.—The symptoms of chronic rhinitis are increase in the amount of nasal secretion and a certain degree of obstruction, though in so far as the latter symptom is concerned, it is sometimes so slight that the patient is hardly aware of it. Frequently stringy mucus collects above the soft palate or in the inferior meatus of the nose and trickles down into the pharynx. On examination, the inferior turbinated body is seen to be swollen, and the middle turbinated body is also usually affected more or less. The swelling may be due to congestion merely, or to true hypertrophy. In the former case it disappears on the application of a dilute solution of adrenalin. On examination of the posterior nares with the rhinoscopic mirror, the inferior turbinated body is seen to be enlarged, and may in severe cases fill the choanæ to a great extent. In colour it is of a translucent pearly grey, but occasionally a pink tint is present.

Treatment.—The only satisfactory treatment of chronic rhinitis is surgical, and there is no need to waste time upon describing the use of douches and sprays. In the majority of cases the swollen tissues can be reduced to normal dimensions by repeated applications of the electric cautery, or by the use of crystals of chromic acid fused on to the tip of a probe or chromic acid applicator. It is important to dry the surface both before and after the application of the acid, and care should be taken in the use of either method that the septum is not touched, for fear of causing adhesions between it and the turbinated body.

When the hypertrophied tissues will permit, their reduction is more rapidly effected by means of removal by the snare, either cold or hot (Fig. 55). This is particularly serviceable in the case of enlargement of the posterior end of the inferior turbinated body. The operation, however, is not always easy and frequently requires patience. In some cases removal by means of the spokeshave is demanded, but when possible this should be avoided.

In these operations the parts should be previously anæsthetized by the application for a few minutes of a 10 or 15 per cent. solution of cocaine, and if a little adrenalin be added the anæsthetic effect is increased. In the case of removal by means of the spokeshave, a general anæsthetic is perhaps better, unless the patient is possessed of considerable courage.

Adenoid Growths.—Of all the diseases of the respiratory tract that are apt to affect the ear, adenoid growths in the naso-pharynx are the most important. The condition is one of hypertrophy of the pharyngeal tonsil which occupies the roof and posterior wall of the naso-pharynx. It is most frequent in childhood, and accounts for a large percentage of the deafness and other ear affections which occur at this period of life ; but it is also sometimes found during adult life.

There is no single cause known to which the disease can be definitely ascribed, but it is possible that the tubercle bacillus may be present in all cases. Adenoid growths are certainly more common in those who have a tendency to tuberculosis, but they are not uncommonly present in others who show no weakness in this direction.

The growth appears as an irregular rounded mass depending from the roof and posterior wall of the naso-pharynx, and frequently hiding the upper portion of the posterior termination of the septum. It is pulpy to the touch and pink in colour.

Symptoms.—The symptoms to which adenoid hypertrophy in the naso-pharynx gives rise are numerous and vary in degree. Nasal obstruction, with consequent mouth-breathing, is frequently present, and in many cases the disease can be recognized by a glance at the face of the patient. When the obstruction is marked, all the evil consequences of mouth-breathing may be produced — the ill-shaped chest, the V-shaped palate and resultant malformed and displaced teeth, the constant catching of colds, with catarrhal laryngeal complications, and general delicacy and ill-health.

One of the most serious consequences, however, is the deafness which so frequently results from the disease. In many cases suppurative disease of the middle ear also occurs, and all the dangers of that condition are added. Of the disagreeable but less serious symptoms, noisy respiration, snoring at night, and the flat, muffled voice, may be mentioned.

It must not, however, be supposed that adenoid hypertrophy, when present, necessarily produces all these symptoms. Indeed, it is remarkable how great the hypertrophy may be when the symptoms may not be very pronounced, and deafness may be the only important manifestation that has brought the patient under the notice of the medical attendant.

Diagnosis.—The diagnosis is easy, but it must be remembered that other conditions may simulate adenoid hypertrophy in so far as the symptoms are concerned. Where rhinoscopic examination is possible, the growth can be recognized directly, and in cases where this is not possible the post-nasal space should be examined with the finger. The condition will then be recognized by the sense of touch, the growths giving the sensation of 'touching a bag of worms.' There is almost always a slight amount of bleeding, no matter how gently the digital examination may have been carried out.

Adenoid growths tend on the whole to undergo atrophy to a greater or less extent after puberty, but this should not be allowed to influence treatment, unless the symptoms are present in the mildest degree and the patient nearing the period mentioned. For, although the growths themselves may disappear, the changes they produce are apt to be permanent. Above all, deafness or suppurative middle-ear disease calls for active interference.

Treatment.—The only satisfactory treatment is surgical, and it may be added that the sooner the growths are removed the better.

Operation.—As regards the anæsthetic to be employed, opinion is not unanimous. Personally, the writer prefers ether or chloroform, according to the age of the patient. Many operators prefer a short anæsthesia, such as that afforded by nitrous oxide, chloride of ethyl, or bromide of ethyl. In the case of the first of these latter there is no doubt that greater safety is assured than with chloroform, or even than with ether; but as regards chloride and bromide of ethyl, it appears to be doubtful if they are really safer than the old-

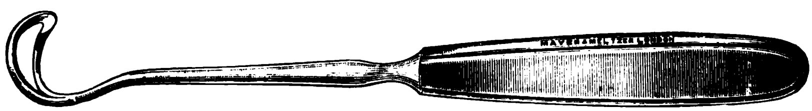

FIG. 54.—GOTTSTEIN'S CURETTE.

established anæsthetics. The longer anæsthesia enables the operation to be done more thoroughly, and when, as is often the case, the faucial tonsils also require removal, chloroform and ether are, in the writer's opinion, the most satisfactory. With a skilled anæsthetist and the patient in the proper position, the danger is insignificant.

When the patient is sufficiently anæsthetized in the recumbent position, the head is allowed to hang well over the edge of the table, from which it is protected by a soft pillow. In this position safety is increased, both in respect to the general effect of the anæsthetic and in regard to the possible entry of blood into the windpipe. The mouth is then held open by a gag, and a Gottstein's curette (Fig. 54) is passed up behind the palate, hugging the posterior termination of the septum. It is then pushed firmly backwards along the vault of the naso-pharynx, and then equally firmly down the posterior wall. After sponging, the finger is passed into the naso-pharynx, and any remains of the growth in Rosenmüller's fossæ or elsewhere are crushed or removed by further application of the curette. It is important to see that all trace of the diseased tissue is removed, and it may be necessary to apply the curette several times, the blood being sponged out constantly by sponges fitted on to suitable holders. If the growths are tough, they may be removed by means of Löwenberg's forceps, but this method is rarely necessary. Hæmorrhage is free, especially if ether is employed as the anæsthetic; but it very soon stops, and is never alarming in degree. The fear of excessive loss of blood should never be allowed to influence the operator in respect to the thoroughness of the removal of the growths, and the surgeon who prides himself on performing the operation with the 'loss of scarcely a teaspoonful of blood' may be assured that he has not done the work properly. It need hardly be added that, if the tonsils are enlarged, these should also be removed; and unless the enlargement is excessive, it is perhaps better to do this after, and not before the removal of the adenoids.

The after-treatment consists of confining the patient to bed for twenty-four or forty-eight hours, and ordering a bland and pulpy or liquid diet, such as sago, custard, milk, etc. The patient should also be advised to blow the nose as seldom and gently as possible, for fear of driving the secretion up the Eustachian tube and causing inflammation in the middle ear. Above all, the use of sprays and douches to the nasal passages must be avoided. Their employment is apt to cause middle-ear inflammation. In the course of about a week the patient may be allowed to go out of doors if the weather is suitable.

The removal of adenoids is one of the ugliest but most satisfactory operations in surgery. It is practically free from any danger, and the results are most beneficial in every way. Sometimes the accompanying deafness requires a little after-treatment with the air-douche or catheter, but more frequently, especially in children, the deafness disappears without further interference.

Mucous Polypi.—One of the common affections of the nose is mucous polypus, but it is, perhaps, not quite such a frequent cause of deafness as might be expected, considering the almost complete obstruction to nasal breathing which the growths frequently entail.

The growth consists of œdematous mucous or granulation tissue, and is not to be regarded as a neoplasm properly speaking. It is frequently associated with pus formation in one of the sinuses of the nose.

The symptoms of which the patient may complain are nasal obstruction, a constant tendency to running at the nose which is aggravated on catching cold, sneezing, sometimes associated with asthmatic attacks, headaches, and occasionally deafness.

The condition is easily recognized on inspection; the characteristic grey, translucent colour and absence of any special tendency to bleed will prevent the mistaking of polypi for malignant growths.

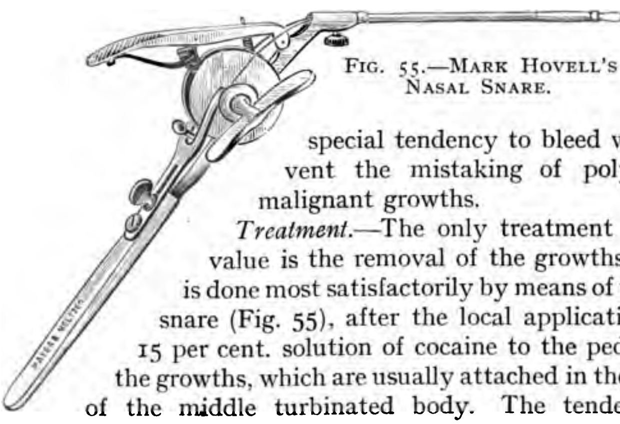

FIG. 55.—MARK HOVELL'S NASAL SNARE.

Treatment.—The only treatment of any value is the removal of the growths. This is done most satisfactorily by means of the cold snare (Fig. 55), after the local application of a 15 per cent. solution of cocaine to the pedicles of the growths, which are usually attached in the region of the middle turbinated body. The tendency to recurrence may perhaps, to a certain extent, be diminished if the raw surface left after removal be touched with the electric cautery or chromic acid.

Sinus Disease.—If there be any accompanying disease of the nasal sinuses, this should be treated appropriately. But we must carefully understand what is meant by the term 'appropriately.' It must not be presumed that in every case of polypus associated with sinus disease the affected sinus should be subjected to destruction by curetting and removal of its walls. Each case must be judged upon its merits, and the surgeon who is determined to open every sinus that is the seat of suppurative disease will have a fatality sooner or later, and, moreover, will not, in a considerable proportion of cases, stop the suppurative process. The first thing to come under consideration is whether the operation is not more dangerous than the disease. It is impossible to give full instructions applicable to every case, but a few general remarks may save a young and too enthusiastic operator from grave mistakes which may damage his reputation very seriously.

So far as the *antrum of Highmore* is concerned, operations are quite free of danger; but in not a few cases, even with the most complete operations, they are not entirely successful in stopping the suppurative process. Still, in all cases the improvement is great, and the risk so insignificant that it is well to advise the patient to have the cavity opened through the canine fossa or through the inferior meatus of the nose, or through both together.

With respect to the *frontal sinus*, operative procedures are uncertain in their results; they are by no means free of danger, and frequently leave ugly deformities. They should only be undertaken if there is reason to fear intracranial complications from the passage of infective material through the wall of the sinus.

Suppuration from the *ethmoidal cells* is a common cause of polypus, and it is very difficult to decide when to advise operation. Perhaps the best line to pursue is to remove the polypi completely and note how long the period of relief lasts. If the patient is free of trouble for several years, as is very frequently the case, then he is well advised simply to return and get the polypi removed when he feels the necessity. If, however, the return of the growths is rapid, and the nose is again obstructed in the course of a few months, it is better to remove the middle turbinated body and very carefully curette the ethmoidal cells. In no case is it advisable to use the hot wire snare in the upper portions of the nasal cavities, but the cold snare, cutting forceps, scissors and hooks should be employed.

Sphenoidal sinus disease may exist without causing any symptoms of which the patient is aware, except the passage of a muco-purulent secretion into the throat. Even this symptom may be comparatively slight in degree, and there is no doubt that, as Tilley has pointed out, the condition is frequently mistaken for uncomplicated naso-pharyngeal catarrh. On the other hand, the symptoms may be very troublesome, and include pain (which may be localized in various parts of the head), drowsiness, proptosis, diplopia, optic neuritis, and general ill-health. Like the corresponding affections of the ethmoidal and frontal sinuses, intracranial and pyæmic complications may result. But such cases are, on the whole, rare. When one considers the vast numbers of individuals who suffer from nasal polypus, resulting from sinus disease of various sorts, it is remarkable that more do not die of intracranial disease.

It must be observed that very frequently more than one of the sinuses is the seat of suppurative disease, and that, if the operation for relief is to have a satisfactory result, all the diseased cavities should be opened.

In warning the reader to be careful about operating on the nasal sinuses, the author does not wish to give the impression that the operations are often dangerous to life. But it is necessary to remove an impression which is conveyed to the reader—unconsciously, no doubt, on the part of several writers on rhinology—that these operations are quite free from danger. To judge from some descriptions, one would imagine that such undertakings may be approached with the same sense of security that a surgeon feels when called upon to perform the radical mastoid operation. Now, such is by no means the case, except in respect to the antrum of Highmore; and even if it were, the danger of leaving a suppurating ear unrelieved is greater than in permitting a suppurative nasal sinusitis to continue.

In cases in which the patient or the surgeon decide against operation for sinus disease, it will naturally be understood that the parts are to be cleansed by suitable douches or sprays, and the growth of polypi is to be kept down as far as possible by removal, etc.

Deflections of the Septum.—Deflections of the nasal septum are occasionally the cause of deafness, but not so frequently, perhaps, as might be expected. When they are so marked as to cause appreciable nasal obstruction or other symptoms, they should be removed, whether deafness is present or not. When, however, in addition to the obstruction deafness is the only symptom, the surgeon should be guarded in advising operation, in so far as it will affect the hearing. In these cases the hearing does not always improve after even complete removal of the obstruction, and when such improvement does take place it is not always very pronounced.

The operation selected should be one of the submucous type which have become so much the fashion in recent years. As is the case with most new operative procedures, submucous resection of the septum was ridiculously overdone when first introduced; but, fortunately, saner views now prevail--at least, amongst intelligent surgeons.

Local infiltration anæsthesia is to be preferred to a general anæsthetic, and adrenalin should be added to the cocaine. The preparation known as 'codrenine' is very suitable for the purpose, and it should be injected beneath the mucous membrane on both sides of the septum. An incision is made from the most prominent point on the convex surface of the deflection until it reaches some distance forwards over the cartilaginous septum. In this latter portion the incision is carried right through the cartilage to the under-surface of the mucous lining of the concave side of the septum. The muco-periosteum and muco-perichondrium are then raised freely on both sides of the septum, and the cartilage and bone removed by forceps, chisel and hammer or other instruments, according to the requirements. The mucous membrane is then folded back into position, and one or sometimes two stitches introduced to keep the edges of the wound together. The nostrils should be lightly plugged with gauze for twenty-four hours and the patient kept indoors for a day or two.

Other intranasal causes of deafness are *malignant* and, more rarely, *innocent growths*, *atrophic rhinitis*, *paralysis of the muscles attached to the Eustachian tube*; and in rare cases other affections of the nose and naso-pharynx affect the ear secondarily. These are to be treated in accordance with the requirements of the case.

Limits of space prevent further discourse on the relationship of nasal to aural affections. It is necessary, therefore, to emphasize the importance of carefully ascertaining in every case of deafness whether any intranasal disease is present, and if so, to find out the relationship of cause and effect when such exists.

CHAPTER VII

INJURIES AND DISEASES OF THE OUTER EAR

INJURIES.

On account of its position, the outer ear is frequently subject to injury. Fortunately, by reason of its pliability, the auricle may undergo considerable changes of shape without harm being done. Injuries, however, do sometimes occur, especially among those whose work or play entails distortion of the auricle ; of these, football players and boxers are most common.

Cutting and stabbing wounds of the auricle in general heal well, though in the case of old people the prognosis is not quite so favourable as in others. A portion of the auricle and even the whole structure, when actually cut off, may be stitched on to its place of attachment and union occur, although several hours may have intervened between the injury and the surgical attendance. Contused and lacerated wounds of the auricle, on the other hand, are sometimes followed by perichondritis, necrosis of cartilage and subsequent deformity of the auricle.

Treatment.—The wound should be carefully cleansed and the edges united. It is important to remember that, should the wound extend to both surfaces of the auricle, the skin wounds on both sides should be united by separate rows of stitches, and not by one row passed right through the auricle. Stitches should not be passed through the cartilage.

Inflammation after Boring for Earrings.—The boring of the lobule for the support of earrings is sometimes followed by tedious inflammation. The risk of this habit of displaying jewellery in the ear is not ended when the wound produced by boring is healed. Occasionally the ornaments are torn from the lobule by accident, and a painful wound results. These wounds are treated on general surgical principles.

Injuries to the Meatus.—The external meatus may suffer injury from the accidental impact of pointed implements, or from unskilful attempts to extract foreign bodies. Although such wounds usually heal satisfactorily, disastrous results occasionally occur, such as periostitis, with consequent stenosis of the meatus or necrosis of the walls of the canal.

Fracture of the bony meatus very rarely occurs from direct violence. Indirect violence, such as blows on the occiput or vertex of the skull or upon the chin, is the usual cause of such fractures.

Frequently, though not invariably, the fracture of the meatus is only a portion of a much larger fracture extending into the base of the skull. In such cases the tympanic membrane is invariably torn.

Fractures of the walls usually cause hæmorrhage from the meatus, and the flow is sometimes profuse. In rare cases the epidermis is not broken, and then the hæmorrhage remains subcutaneous.

According to Jacobson,[1] fractures of the anterior and inferior walls of the meatus heal well, though there is danger of subsequent stenosis. In fractures of the upper wall the prognosis must be guarded, on account of the proximity to the cranial cavity.

Treatment.—It is, in general, unwise to syringe the meatus in cases of fracture. The blood should be mopped up with antiseptic wool or gauze; should the bleeding be profuse, a tampon may be required. When it has ceased, the meatus should be plugged with gauze, or considerable quantities of boracic acid or iodoform powder may be insufflated. If, however, a history of preceding suppurative middle-ear disease is obtained, then frequent though gentle douching with carbolic solution should be employed.

Injuries to the soft tissues of the meatus must be treated on general surgical principles. The insufflation of dry powders, such as boracic acid and iodoform, is very suitable for these injuries. Should periostitis or perichondritis occur, the pus should be evacuated at once.

[1] *Op. cit.*, p. 376.

Prognosis.—If the base of the skull is not involved, the prognosis as regards life is favourable; but it must be born in mind that stenosis of the meatus, with subsequent deafness, may result from injury, should periostitis occur or if the injury be extensive.

MALFORMATIONS.

Apart from what may be termed real malformations, the shape of the auricle is held by some authorities to afford an indication of certain mental or moral characteristics in the subject. This matter has been particularly considered in regard to criminal tendencies. A marked deficiency or absence of the lobule is supposed to be an important clue which the auricle can give to the investigation of natural criminal tendencies. The Italian criminologists have paid particular attention to the subject.

Anomalies of Shape and Size.—The shape and size of the normal ear vary within very wide limits. When extreme, the variations in size are termed microtia and macrotia auriculæ. Occasionally the auricle is entirely absent, and, except when the condition has been produced by injury, it is frequently associated with absence of the meatus and the tympanum, the labyrinth being only very rarely absent.

Supernumerary auricles are not uncommon, and, indeed, there may be more than one of these. They present the appearance of protuberances of various shapes, and are usually situated below and in front of the proper auricle.

A much rarer and more interesting malformation is that in which the cartilages are congenitally absent while the remaining soft tissues of the auricle are fully developed. The curious appearance produced by this abnormality is shown in Fig. 56. The upper portion of the auricle droops like that of some terrier dogs.

Fistula Auris Congenita.—An interesting condition is that of fistula auris congenita. It consists of a small blind canal of varying depth, which is usually situated above and in front of the auricle. A thin yellowish or whitish secretion exudes from it, and, should stenosis occur, a retention cyst may be formed. In rare cases an abscess has been known to occur, and in such circumstances the pus must be evacuated. Otherwise the anomaly may be left alone.

Congenital Atresia.—A much more important malformation of the outer ear is that of congenital atresia or stenosis of the meatus. The obstruction may be membranous, fibrous, or bony. The condition is frequently associated with defect of

FIG. 56.—CONGENITAL ABSENCE OF THE CARTILAGE OF THE AURICLE.

(From a case of the Author's; photographed by Dr. D. O. McGregor.)

the auricle, the ossicles of the middle ear and abnormalities of the Eustachian tube.

Treatment.—In very young children no operation should ever be undertaken in these cases of congenital stenosis, because it is not possible to make absolutely sure that the deeper parts are unaffected.

In older children, if the obstruction is simply a thin membrane, it may be excised and a tent be introduced from time to time until healing has occurred. But the surgeon must make sure that the patient has hearing-power in the affected ear before undertaking the operation.

Operations for congenital atresia, other than that just described, are usually doomed to failure by reason of the fact already mentioned, that the tympanum itself is so frequently malformed in these cases. There is reason to believe, however, that the tympanum may be comparatively unaffected in a few patients. For example, in a case described by Tod,[1] on using the catheter air seemed to pass into the tympanum. Furthermore, the hearing-power is sometimes so good that we cannot associate the atresia with any very marked deformity in the middle ear. But even in these cases operation is inadvisable, since the artificial meatus closes in spite of all attempts to keep it open.

Cerumen accumulating in the ear is a frequent cause of dulness of hearing. The method of removal has already been described (p. 107).

SKIN AFFECTIONS.

Eczema.—Many forms of skin disease occur in the outer ear. Of these, by far the most common is eczema.

Eczema manifests itself in the acute and the chronic forms. It does not present any particular modifications from the disease as found in other parts of the body, and its pathology need not be discussed. It should be mentioned, however, that the distinction between the acute and the chronic form is rather a matter of the anatomical changes which are in progress than of chronology, and consequently that therapeutic measures should be directed accordingly. Clinically the disease is recognized by the redness and swelling of the parts associated usually with serous or purulent discharge. In its acute form the parts are intensely itchy, but pain is absent except in cases where erosions have occurred, these being frequently the result of scratching with hairpins or other objects.

In cases of long duration the meatus may become so narrow and obstructed as to lead to dulness of hearing, and if a suppurating middle-ear catarrh is present the discharge may be pent up in the tympanic cavity and lead to serious mischief

[1] *Journal of Laryngology*, 1901, p. 105.

in the antrum and even within the cranial cavity itself. Such a case was observed by the writer, who was compelled to perform the radical mastoid operation after a fistula had formed, leading from the antrum to the outer wall of the mastoid process. In this case the discharge, which had lasted for more than fifty years, had established the eczema.

Eczema of the auricle is frequently associated with the appearance of the disease elsewhere on the scalp or the face. On the other hand, eczema of the meatus is commonly the only manifestation of the disease.

Etiology.—In many cases no cause can be discovered, but a rheumatic or gouty tendency underlies some forms. Locally the most common discoverable causes are a suppurative catarrh of the middle ear, and the accumulation of hard, dry cerumen. In the latter case I have observed that the cerumen is usually paler than normal, but whether there is any causal relation between that fact and the occurrence of the eczema I am not prepared to say.

Course and Treatment.—The disease, if unattended to, may last indefinitely, but under proper treatment it usually subsides sooner or later. It need hardly be said that any local or general condition which may be the cause of the eczema must be treated. Thus, gout, rheumatism, and diabetes, should either be excluded from the diagnosis, or if present, should be treated suitably.

Locally, suppurative catarrh of the middle ear is the commonest factor, and the eczematous condition will subside when the discharge ceases. Certain applications are occasionally the cause of eczema of the meatus; of these, boracic acid powder and iodoform are most likely to be the disturbing agents. The use of anilin causes eczema in some individuals, and cannot be used in the treatment of middle-ear suppuration in these subjects.

It is a general rule that water should not be applied to eczematous areas, and this is true of the disease as it occurs in the outer ear. In the acute stage a dusting-powder, frequently applied, dries up the secretion—*e.g.*:

℞ Bismuth. subnit.	.. ..	5–10 parts.
Pulv. amyl.	.. ..	ad 100 parts.

Misce. Sig. Dust over the parts frequently.

For the heat and itching Jacobson recommends ice-cold olive-oil applied on linen cloths. When the secretion is slight in amount or absent, various ointments may be used. Of these, perhaps the most useful ingredient is salicylic acid, its value depending upon its keratolytic action—*e.g.*:

℞ Acid. salicyl.	.. .. ..	gr. 10–20.
Vaselin. / Ung. zinc. ox. }	.. .. ..	āā ℥iii.
	Misce.	

To this ointment unguentum picis liquidum may be added. This increases the efficacy of the application, but gives it a disagreeable colour.

By many writers oil of cade is highly extolled. Whatever preparation is used it will naturally be understood that scabs and scales should first be removed by strips of gauze soaked in olive-oil and applied to the part for twenty-four hours or longer.

Actual erosions should be painted over with a 2 to 5 per cent. solution of nitrate of silver, or a 2 per cent. solution of chloride of zinc or other astringent.

In stubborn cases of dry scaly eczema, Haug[1] recommended painting with—

℞ Acid. salicyl.	.. .. ..	1 part.
Glycerin.	.. .. ..	30 parts.
Alc. abs.	.. .. ..	ad 100 parts.
	Misce.	

Should the eczema be associated with suppuration from the middle ear, the latter should be treated by what is known as the dry treatment—that is, by carefully drying out the secretion with pledgets of absorbent cotton-wool without previous syringing with water.

It need hardly be said that arsenic is recommended internally in this disease. Those who believe in its efficacy may try it in very chronic cases. It should be avoided in all acute forms.

Psoriasis.—In comparison with its frequency elsewhere, psoriasis may be considered rare in the external ear. It does, however, sometimes occur and may even lead to dulness of hearing through the accumulation of the epithelial scales in the meatus. The writer has seen such a case, and, though the process disappeared on the administration of arsenic it

[1] *Klinische Vorträg.* No. 1.

rapidly returned on relinquishing the use of the drug. Psoriasis of the external ear is almost invariably associated with the existence of the disease elsewhere, and its treatment is the same as in ordinary cases. Thus, arsenic, in large doses if necessary, should be given, and an ointment containing chrysophanic acid or oil of cade applied locally. Hutchinson is opposed to the internal administration of arsenic, on account of a tendency to cause cancer at a later date. Some physicians, however, do not consider that the occurrence of malignant disease is associated with the administration of arsenic. According to Byrom Bramwell, thyroid extract exercises a beneficial influence upon psoriasis, and it should therefore be tried. Judging from my own experience, it is not of much value.

FIG. 57.—HERPES OF THE AURICLE.

(From a case of the Author's; drawn by A. K. Maxwell.)

Herpes. — Herpes sometimes appears on the auricle. It may occur in the region supplied by the great auricular nerve on the surface of the auricle, or in that supplied by the auriculo-temporal branch of the fifth nerve in front of the tragus and on the anterior wall of the meatus. The eruption of the vesicles is preceded by neuralgic pains in the affected region. Its appearance is shown in Fig. 57.[1]

For the relief of the pain, belladonna may be applied locally as an ointment:

℞ Extr. belladonnæ	..	..	1 part.
Lanolin. ..	..	..	10 parts.

Misce.

[1] In very rare cases of herpes of the external ear facial paralysis accompanies the other symptoms. The condition, therefore, indicates the geniculate ganglion as being the nerve-centre of the disturbance. Such cases are apt to be confused with those in which facial palsy results from middle-ear disease. In the case of herpes, however, deafness is absent or insignificant in degree, and the soft palate is usually paralyzed.

Should this fail, morphia may be given by the mouth or subcutaneously, if the pain is very severe.

Certain other diseases of the skin may affect the outer ear, but are rare in that region; and as their treatment is conducted on the same lines as when they attack other parts, they need not be referred to at length. Such are *acne, seborrhœa, pityriasis, ecthyma.*

FIG. 58.—LUPUS OF THE AURICLE.
(From a case of the Author's; photographed by the Author.)

Lupus.—Lupus of the auricle is not very uncommon in this country and on the continent of Europe, but it appears to be rare in America. It usually invades the auricle from neighbouring parts, and perhaps on this account the lobule is the portion usually affected. At first it causes considerable swelling, but in the later stages it destroys the tissues and may, as in a case seen by the writer, leave no vestige of the auricle at all. The spread of the disease is sometimes so slow that, even after twenty or thirty years, the deformity may be comparatively slight. Such a case is illustrated in Fig. 58, in which the affection had lasted for thirty-three years.

Treatment.—If the nodules are few and discrete they should be scraped away and the raw surface cauterized with the electric or other cautery. If the affected part is more extensive, the method of light treatment introduced by Finsen is frequently, though not always, satisfactory. In some cases the vaccine treatment introduced by Wright appears to succeed where all other means fail, but in not a few this method of treatment also gives but little relief.

Syphilis.—In rare cases syphilis manifests its existence in the tertiary stage in the form of an ulcer in the wall of the meatus. It is, on the whole, more common in those who are affected at the same time with suppurative discharge from the middle ear. The diagnosis is made from the dirty yellow or greyish secretion, the thickened edges, rapid growth, and from general evidence of syphilis. Primary chancres in this situation have been recorded, as also have condylomata.

Treatment.—Internally, mercury and iodide of potassium or sodium must be given. Locally, the most rapid healing is obtained by painting the ulcer, after very careful drying, with two to five drops of a saturated solution of iodoform in anilin. Care should be taken to remove the excess of the solution.

Erysipelas.—Erysipelas commencing at the ear is by no means uncommon, as may well be understood when it is remembered that excoriations, due to scratching or to irritating discharges, must frequently exist.

The disease has been known to spread down the meatus, involve the tympanic membrane and cause a suppurative middle-ear catarrh.

The course of the affection varies within wide limits. In mild cases the localized and sharply defined redness and swelling are almost the only evidences of its presence, the constitutional disturbance being insignificant. In severe cases marked fever and signs of cerebral irritation may be present, and even fatal cases have been reported.

For some time after the disappearance of erysipelas, the skin of the ear appears to be liable to suffer from constant desquamation and the formation of furuncles.

Treatment.—The affected part should be painted over with a protective or antiseptic covering, but water is inadmissible as a vehicle. A good pigment is:—acid. carbol. 1 part, turpentine 30 parts, care being taken that the solution does not get into the eyes. Collodion flexile makes a good protective covering and is free from the disadvantages which affect carbolic acid. In all cases it is wise to keep the affected part warm with cotton-wool or gamgee tissue.

Beyond a gentle purge at the beginning of the disease, internal medication is, I believe, valueless, though the tincture of the perchloride of iron in large doses has been recommended. Should an abscess form, it must be opened at once.

Epithelioma.—Malignant disease appears in the external ear in the form of epithelioma, and in the auricle is easily recognizable from its rather slow growth and warty surface. It frequently first makes its appearance in an innocent papilloma of the skin. In the auricle it is most common in the upper portions, and appears first as a small, hard nodule, which after a long period ulcerates. A less common form is that in which it occurs from the first as a hard, flat ulcer, with thickened edges, and covered with a purulent discharge. Its progress, if allowed to continue, is not resisted by any tissue, and it may perforate the cranial wall. The lymphatic glands are affected relatively late in the disease. Malignant disease of the ear is rare. Senf found that it constituted 0·048 per cent. of all ear affections, and Connal found only 10 out of 15,000 cases of ear disease.

In the meatus, where epithelioma is primarily less common than in the auricle, it runs a more rapid course, is more painful, and the glands are affected sooner. In many cases there is a history of long-continued suppurative discharge from the middle ear, and there appears to be little doubt that the irritation caused by the discharge is the determining factor in the occurrence of the more serious disease. It must be remembered, however, that in some cases the malignant trouble has extended from the middle ear itself, and it is not always possible to ascertain the point of origin of the new growth.

Diagnosis.—The diagnosis of epithelioma of the meatus is, in contradistinction to that of the auricle, frequently difficult. In the early stages pain is, according to Kuhn, usually absent, and occurs when the deeper tissues, and particularly the cartilage, are involved. The same writer lays particular weight, in framing a diagnosis, on the occurrence of granulations, which recur quickly after removal, the significance being still more ominous if the granulations arise from the anterior wall. Further, free hæmorrhage from the granulations occurring spontaneously or on very gentle manipulation, is also a suspicious sign. These signs appearing in one who is neither deaf nor the subject of suppurative discharge from the middle ear should suggest malignant disease. The interpretation is more ambiguous if there is suppuration from the middle ear, since the granulations which frequently accompany the discharge occasionally present the same features as those described above.

One symptom, not hitherto recorded, but upon which personally I lay considerable weight, is the occurrence of pain on chewing, and to say the least, this should at once excite the surgeon's suspicion.

Microscopic investigation is frequently of service in the diagnosis, but care must be taken that the piece removed for examination is characteristic, and further, that the sections are cut perpendicular to the surface.

Finally, it should be remembered that age is an important consideration in the diagnosis of epithelioma of the outer ear. It is extremely rare under the age of forty.

Treatment.—The affected part should be excised without delay, and if this be done when the disease is in the auricle, and not extensive, the prognosis is fairly good; indeed, the auricle is one of the least serious situations for cancer. A large area of healthy tissue surrounding the growth should be excised with the latter, and no risk must be run for the sake of gaining a good cosmetic effect. So important is this that it is open to question whether in all such cases the whole auricle should not be removed. A good prothetic appliance may look better than an auricle in which even a successful plastic operation has been performed.

In the meatus the matter is not so easily decided, since even in an early stage it may be impossible to remove the whole diseased portion.[1]

The later stage of patients suffering from carcinoma of the

[1] In some cases, however, of endothelioma of the meatus, removal of the diseased portion may prove quite satisfactory. Thus, Wagget (Transactions Otological Society, vol. vi., p. 45) has recorded a case in which the patient was free of the disease two years after operation.

ear is pitiable in the extreme. Pain, which may have been absent at the beginning, invariably supervenes, and is constant and agonizing. For this morphia is required, and must be administered with a free hand. Orthoform should be dusted over the raw surface, but, unfortunately, it cannot reach the deeper parts. The remarkable absorbent properties of turf-moss make it a good dressing material, as the amount of secretion is frequently considerable.

The duration of the disease has been estimated to be, on an average, from ten months to a year and a half, and the end is brought about by exhaustion, or, if the cranial cavity has been invaded, by meningitis.

Sarcoma.—Sarcoma of the auricle is rare. Asch[1] describes it as having a lengthy and more or less innocent stage, followed by a short ulcerating period. The growth in the first stage appears as a small nodule of either soft or hard consistency, and growing so slowly that its increase in size may be imperceptible. This stage may last twenty years. In the second stage the growth is very rapid and ulceration occurs. A profuse purulent discharge comes from the surface, and the patient rapidly loses weight; but the neighbouring lymphatic glands are practically never enlarged, thus distinguishing the growth from epithelioma. Sarcoma of the meatus is still rarer than that of the auricle. It occurs for the most part in the bony meatus as a small, tough, whitish nodule. It grows rapidly, and soon ulcerates, bleeding readily and discharging a large amount of pus. The lymphatic glands and neighbouring tissues become enlarged, in contradistinction to the absence of this condition in sarcoma of the auricle. Pain may be entirely absent or extremely severe. Microscopic examination of a removed fragment may reveal the nature of the neoplasm.

Treatment.—The treatment is the same as for epithelioma.

Exostosis and Hyperostosis.—Bony growths may in very rare cases occur in the auricle, but interest chiefly attaches to those occurring in the meatus. They may be divided into two classes—exostoses which are circumscribed, and even occasionally pedunculated; and hyperostosis, in which a general diffuse thickening of the bony walls takes place.

Several hypotheses have been framed to explain the occurrence of these growths. Prolonged suppuration appears to

[1] Inaugural Dissertation, Strasburg, 1896.

be the underlying factor in many, but judgment must be reserved in this matter, when we remember that a large number of individuals may have these growths without causing any symptoms, and therefore without being recorded. On the other hand, most individuals suffering from suppurative trouble will be examined and the exostoses recorded. A truer result would be arrived at if a comparison were instituted between the number of individuals suffering from other aural troubles and possessing exostosis, with those suffering from suppurative disease and also subject to these growths. The supposed pathogenesis in the cases where suppuration from the middle ear is present, is that the long-continued irritation has produced a chronic periostitis, with resulting deposit of bone.

According to Virchow,[1] exostoses may owe their existence to a developmental disturbance occurring in the annulus tympanicus. Lucae points out that this explanation is particularly apt in those cases in which the exostoses are found to be symmetrical in both meatuses. Toynbee and Pritchard consider exostoses to be manifestations of gout, rheumatism and syphilis, and in regard to the last of these diseases they are supported by the observations of Triquet. Field attributes their occurrence to frequent cold bathing, and in support of this view is the fact that the South Pacific Islanders, many of whom lead an almost amphibious life, appear to be particularly prone to them. It is somewhat remarkable that rickets is not recorded as being the cause of exostosis in the meatus, though it is a common cause of those found elsewhere.

Hyperostoses and exostoses are usually composed of compact bone, rarely of cancellous bone. They are seldom found in children.

In size exostoses may vary from that of a pin's head to that of a bean (Fig. 62). If not inflamed, they appear as white or yellow swellings, with but a thin covering of epidermis, and feel hard when touched with a probe. Most frequently they are found in the posterior and upper walls of the osseous meatus close to the membrane, and not uncommonly several are present.

The diagnosis of the condition is not difficult when the cutaneous covering is not inflamed, and even in the latter case careful examination with the probe will reveal the nature of the growth.

[1] 'Sitzungsb. d. Kgl. Preuss. Akad. d. Wissensch.,' 1885.

Many exostoses remain stationary and cause no symptoms. Some, and, unfortunately, particularly those occurring in the course of chronic suppurative middle-ear catarrh, continue to increase in size, and may fill the whole lumen of the meatus. In such cases the deafness increases, and is frequently associated with tinnitus. Naturally, the most serious cases are those in which the exostosis prevents the free exit of pus from the middle ear. Such a condition may bring about dangerous sequelæ, as mastoid abscess, cerebral abscess and other intracranial complications.

Neuralgic pains in the region of distribution of the fifth nerve have been recorded as resulting from the presence of exostosis without other complications.

Treatment.—The treatment of exostosis and hyperostosis depends upon the size of the growth and the complications which may be present. If they threaten, even remotely, the free outlet of pus, they should be removed without delay. The same operation should be undertaken if the hearing be affected in both ears, or if tinnitus be distressing.

Operation.—Great care must be exercised, in the removal of an exostosis, that the membrane and tympanum are not injured. Jacobson[1] recommends the operator to chisel gently at the base of the growth, so as to form a fissure. This fissure is gradually deepened until the exostosis only adheres to the wall of the meatus by a thin pedicle of bone, when it can be snapped off and removed.

When the exostosis is deeply seated, Schwartze[2] recommends an incision behind the auricle, and separation of the membranous wall of the meatus in its posterior portions. These soft structures are turned forwards and the removal of the exostosis proceeded with as above.

Many operators deprecate the use of the chisel, and advocate the use of a drill or burr driven by an electric motor. There is no doubt that this is a safer procedure, but it may be very tedious, as the growths are sometimes of ivory hardness.

Another method which has been employed is as follows. A strong steel rod, with its distal end formed into a screw, is bored firmly into the growth, and with a lever movement the growth

[1] *Op. cit.*, p. 157.

[2] *Arch. f. Ohrenh.*, Bd. xviii., S. 64, 1882.

is then snapped off. This method is only applicable to those growths which have a narrow pedicle.

The reaction after these operations for the removal of exostosis is frequently severe, and the after-treatment must be directed accordingly. The meatus should be carefully, but not too firmly packed with iodoform gauze, and a bandage applied. Should there be no suppurative middle-ear complication and no sign or symptom of pus formation, the dressing may be left on for three or four days. If, however, the wound becomes inflamed and if pus be present dressing should be undertaken every day, the raw surface being very carefully cleansed and dried. With this treatment the wound will heal with rapidity.

In conclusion, it must be clearly pointed out that the removal of exostosis and hyperostosis should not be undertaken lightly. Very good reasons must be given, such as deafness in both ears, hindrance to the exit of pus, or distressing tinnitus. In syphilitic cases iodide of potassium should be given before attempting removal, unless urgent symptoms due to the retention of pus are present.

When it is decided that the removal of an exostosis is not called for, the patient should be informed that deafness may sometimes occur, owing to the collection of wax. This may be removed by the syringe after several days' previous softening with warm olive-oil night and morning, or after the instillation of such a solution as that mentioned on p. 108.

Stenosis of the Meatus.—Stenosis of the meatus may be produced by exostosis as described above, but there are other conditions which may bring it about. Eczema of long duration is one of these, as also are cicatricial contractions after ulceration the result of syphilis, lupus, injuries, or burning, and the application of too strong reagents, etc. In elderly people the upper cartilaginous wall of the meatus sometimes sinks and causes stenosis. This sinking is due to relaxation of the supporting fibres which pass from the osseous wall to the cartilage.

Should the walls of the meatus be ulcerated, the stenosis may result in actual atresia, due to the gluing together of the opposing surfaces.

The stricture may exist along the whole length of the meatus, or may be present only at one portion of the tube. In those which result from the irritation of prolonged suppurative discharge, the stenosing tissue is usually composed of both bony and soft structures.[1] Sometimes the obstruction is merely a thin membrane presenting appearances very similar to the drumhead, from which it may be distinguished by its proximity to the opening of the meatus and the absence of the malleus.

Treatment.—The treatment of stenosis of the meatus must depend upon the conditions present in each individual case. The most important of these conditions is the presence or absence of suppurative discharge from the middle ear. Stenosis in suppurative cases must never be allowed to go untreated. If the stricture is marked, and any signs of retention of pus present, then it is wise to do the radical mastoid operation at once (see p. 287). On the other hand, if time and circumstance permit, an attempt may be made to dilate the meatus by the insertion of laminaria tents, the middle-ear condition being treated thoroughly at the same time. The tents should always have a thread attached before being inserted, and should be left in till a slight degree of pain occurs. By these means the suppurative process in the middle ear may be brought to an end, and the danger to life disappears even if the stricture gradually closes, as it sometimes does.

The reason for thus treating such cases by dilatation, instead of at once proceeding to perform the radical mastoid operation, is that, even after that procedure, a permanent opening cannot be guaranteed however well the operation may be carried out. At first sight this may appear difficult to explain, but it must be remembered that the condition of the soft tissues of the meatus is usually not so good as in cases where there is no stenosis. Hence, when the radical operation is done for the relief of serious disease in the mastoid, no difficulty is usually experienced in making the cavity permanent, but when done to relieve a stricture of the meatus the cicatricial tissue tends to contract. In spite of these difficulties, however, it may become necessary to perform the radical operation in order to cure the suppurative disease, after which re-formation of the stricture may cause deafness, but not danger to life if the suppurative process has been cured.

In cases of stricture uncomplicated by middle-ear disease, the matter assumes a different aspect. The most important

[1] Schwartze, *Arch. f. Ohrenh.*, Bd. xlviii., S. 261, 1900.

indication is the condition of the hearing-power in both ears. If the hearing-power in either ear is good, then the stricture should be left alone. If there is marked deafness in the unobstructed ear, and *at the same time good evidence that the middle ear of the stenosed organ* is functionally active, then an attempt may be made to remove the stricture. To accomplish this end, various methods have been devised, and of these most are tedious, painful and unsuccessful. The simplest is the introduction of laminaria tents of increasing thickness until the desired calibre is obtained. Thereafter the patient must continue to wear a vulcanite tube of suitable thickness for a very long period, lasting even for several years. Schwartze has devised the following operation. The auricle, together with the membranous meatus, is separated from the bony structures as though for the radical mastoid operation (see p. 287). The stenosed portion of the meatus is then excised, and layers of bone are chiselled away from the posterior upper and lower walls of the meatus in a concentric fashion, until a wide bony meatus is formed. The remains of the membranous meatus are then stitched to the upper and lower angles of the wound, and the latter is packed with gauze from the external opening of the meatus. The wound behind the auricle is closed with stitches. The after-treatment is very important, and consists in carefully destroying exuberant granulations with chromic acid as they appear, and firm packing with gauze. The healing of the raw surface may be hastened by skin-grafting.

From the description given above, it will readily be understood that the surgical treatment of stenosis of the meatus requires some skill and great patience, both on the part of the surgeon and that of the patient. The operations may, even in the best hands, prove a failure, and should only be undertaken after mature consideration.

Perichondritis.—Inflammation of the perichondrium results usually from injury, either accidental or as the sequence of surgical procedures. It may, more rarely, occur spontaneously or follow frost-bite. When the point of origin is in the cartilaginous meatus, it may be mistaken for furuncle, but as the process extends outwards the nature of the case becomes more evident.

In its early stages there is swelling and pain, but the skin appears normal; as the disease progresses, however, a purplish appearance replaces that of the normal skin, and irregularities are observed on the surface. The parts feel warm to the touch, and before long the sensation of fluctuation can be obtained. The outer surface of the auricle is that usually affected, and the swelling may reach the size of a pigeon's egg.

The course of the disease is slower than might be expected, lasting usually for several weeks or months and may extend over a year. Furthermore, the affection, according to Haug,[1] is sometimes tubercular in its nature, and according to the same writer these cases are characterized by the doughy consistency of the swelling, and, after the opening of the abscess, by the occurrence of pinkish or yellow granulations and the presence of occasional tubercle bacilli in the scanty, discoloured discharge. The lymphatic glands in the neck are more likely to be enlarged in the tubercular than in the ordinary form of the disease.

Treatment.—Except in the tubercular form of the disease, an attempt should be made to bring about absorption of the fluid before resorting to incision. With this object, the ice-bag should be applied to the part, and uniform pressure by a well-applied dressing should be made, associated with gentle massage.

When fluctuation is clearly present the fluid must be allowed to escape. This should be done by a long incision through all the soft tissues. The fluid is usually clear and straw-coloured, but may be purulent. To allow of its continuous escape, a small drainage-tube should be inserted. If the cartilage is necrosed, it is well to excise it, and during the subsequent treatment granulations must be kept in check.

After the inflammatory action has passed off, the auricle may recover its normal shape, but this can by no means be depended upon. It is therefore the duty of the surgeon to inform the patient of the possibility of disfiguring shrinkages. These might perhaps be remedied by the method of paraffin injections, but at present I am not aware of any such attempts to rectify these deformities of the auricle. On account of the irregular shape of the structure, a good result would be more difficult to obtain than in the case of deformities of the nose.

Frost-bite.—Cold may produce pathological effects in the auricle, varying in degree from simple chilblains to actual

[1] *Arch. f. Ohrenh.*, Bd. xxxiv., S. 154.

gangrene. Fortunately, the latter condition is very rare. The swollen parts appear purple, and ulceration may occur, or vesicles containing blood-stained serum may form on the surface. In rare cases the vesicles may become pustules.

Treatment.—The parts should be kept warm and dry. If ulceration sets in, the raw surface should be painted over with a 10 per cent. solution of nitrate of silver, which should be repeated when the scab is thrown off, until healthy granulations make their appearance. When gangrene occurs no attempt should be made to excise the necrosed tissue until a well-marked line of demarcation is present.

In the way of preventive treatment of chilblains, 20 to 30 grains of chloride of calcium, freely diluted with water, should be taken twice or three times daily. This drug, suggested by Wright, certainly appears to give good results in the majority of cases of chilblain.

Othæmatoma.—The effusion of blood between the perichondrium and the cartilage of the auricle gives rise to a peculiar form of swelling which is termed othæmatoma, or hæmatoma auris. In some cases the effusion takes place in the cartilage itself.

The pathogenesis of this affection is somewhat obscure, for while there is no doubt that injury plays a part in most, if not all cases, yet it is equally true that even severe injury will not produce the condition in most individuals.

There seems to be a general consensus of opinion among German aurists that a preceding degeneration of the cartilage, associated with a widening and new formation of bloodvessels, has existed before the injury occurs. This view is certainly supported by the facts that the injury is frequently very insignificant, and that children rarely suffer from it. It is even possible that the condition may arise spontaneously without injury at all. Repeated slight injuries or irritations of the auricle, such as rubbing the ear against objects held upon the shoulder, may produce the trouble.[1]

Othæmatomata are relatively common among Rugby football-players and the insane. This does not, however, permit of the inference that the mental faculties in both are on a par, but only that trauma is common in football-players.

The swelling appears as a smooth, rounded, purple tumour

[1] Laubinger, *Arch. f. Ohrenh.*, xlvii., Bd. 1 and 2, p. 135, 1899.

on the outer surface of the auricle. It may obstruct the entrance to the meatus, and is doughy or fluctuant to the touch. It may involve the whole auricle except the lobule. When incised, its contents are bloody if of recent origin, but in old-standing cases they may consist of slightly blood-stained serum. Subjective symptoms are frequently absent, but there may be some itchiness and sense of tension, which in rare cases may amount to a considerable degree of pain.

The recognition of the condition is not difficult, as its development is so rapid. In a few hours the swelling may reach the size of a pigeon's egg.

The prognosis is for the most part favourable, as the fluid tends to undergo absorption. In a small proportion of cases some crumpling and deformity of the auricle takes place. Suppuration is very rare.

Treatment.—In recent cases no treatment is required unless pain is complained of, in which case a small incision may be made, with careful aseptic precautions, to allow the escape of the blood.

In old-standing cases it is necessary to make a moderately large incision in order to allow of the extrusion of clots which may be present. A less heroic measure is the daily practice of very gentle massage for a period of a quarter of an hour. The fingers of the masseur and the skin over the swelling should be well greased before massage, in order to prevent further rupture of bloodvessels and consequent effusion. Laubinger[1] recommends the injection of a few drops of a weak alcoholic solution of iodine into the swelling, if the case is a painless one.

Furunculosis.—The skin of the meatus is, like that elsewhere, subject to the formation of boils or furuncles. These owe their origin to the intrusion of micro-organisms into the hair follicles, with resulting inflammation and suppuration.

Certain general bodily conditions, particularly diabetes, seem to favour the development of furuncles, and, according to Gruber, the internal administration of bromide of potassium over a lengthy period has a similar effect. Locally, an irritated condition of the meatal wall is a predisposing cause. Scratching the meatus to relieve itching is also a common cause of the trouble. As might naturally be supposed, the

[1] *Loc. cit.*

presence of a suppurative discharge from the middle ear renders an individual more liable to the disease.

Pain is the most prominent symptom, and it may vary from trivial to severe degrees. It may be elicited by chewing, pressure upon the tragus, or manipulation of the auricle. Deafness is usually absent, but may occur from obstruction in the meatus consequent upon the swelling. On examination. the furuncle will most frequently be found in the cartilaginous meatus, but it may be in the osseous portion. The skin is very red or crimson in the swollen part, which usually is seen on the anterior inferior wall. The tissues also about the tragus are not uncommonly swollen, while if the furuncle is situated on the posterior wall, those over the mastoid process may be affected in the same manner.

The diagnosis of the condition only rarely offers difficulties. It has, however, been mistaken for mastoid periostitis, and the converse has also occurred; but the history of the case and a careful examination of the parts will prevent the confusion. A parotid abscess may point through an incisura Santorini and burst into the meatus, and thus may lead to an error of diagnosis; but the passage of a probe along the sinus will decide such rare cases.

The prognosis is uniformly favourable, but it should be pointed out to the patient that, unless preventive measures are taken, the affection is liable to recur.

Treatment.—On general surgical principles incision should be practised as soon as pus has formed. Common-sense, however, will frequently indicate other treatment. Thus, if the pain is insignificant, the cure by incision is worse than the disease; for incision is very painful, and it is open to doubt whether the course is materially shortened.

Many methods of treating furuncle have been suggested, but most authorities are agreed that syringing with watery solutions should, in general, be avoided. Jacobson recommends the application of leeches upon the mastoid surface if the furuncle is on the posterior meatal wall, and immediately in front of the tragus if on the anterior wall. Antiseptic ointments of various kinds are recommended by some writers for the treatment of furuncle, but, for reasons to be mentioned below, it is advisable to avoid greasy and oily applications to the meatus as far as possible (p. 151).

The treatment suggested by Haug[1] is of very general application and usually gives good results. A strip of gauze saturated in alcohol of 96 to 98 per cent. is inserted into the meatus and covered with perforated waterproof tissue. From time to time the waterproof tissue is removed and alcohol dropped on to the gauze, which should be changed every twenty-four hours.

Gelatin bougies medicated with opium, as introduced by Gruber, are employed by some aurists. The gelatin melts at the temperature of the body, and the meatus becomes bathed in the melted liquid. The writer must confess that he has not obtained very satisfactory results with this method. In all forms of treatment hot applications to the ear and the side of the head help to give relief.

The tendency to recurrence, which is very marked in some cases, may be diminished by the daily instillation of rectified spirit, or by a solution of formalin in water of about ½ or 1 per cent. for about a fortnight after healing. Sometimes, however, these instillations cause pain for a short time after application.

Otitis Externa Circumscripta.—A rare and peculiar form of otitis externa circumscripta has been described by Blau. It is characterized by severe pain lasting for several weeks, swelling, which may extend backwards over the mastoid process, and occasionally by fever, which, according to Hessler, may be considerable. The latter writer adds another feature to the clinical picture—swelling of the neighbouring lymphatic glands. Suppuration never occurs, thus differentiating the condition from furuncle. Haug[2] describes two very severe cases of the disease, the bone of the mastoid process actually becoming involved, with a resulting rarefying ostitis, which required the removal of the affected bone before cure resulted. In one of Haug's cases metastatic pneumonia occurred, and recovery was long delayed. The disease has been termed otitis externa ex infectione, in view of the supposed infective nature of the process.

Otitis Externa Diffusa.—By the term otitis externa diffusa there was described an affection the real pathological entity of which is now considered doubtful. Unquestionably, erysipelas, erythema, or eczema may in a sense be termed

[1] *Verhandl. d. Deutsch. Otolog. Gesellsch.*, 1898, S. 143.

[2] *Deutsch. Med. Wochenschr.*, 1897, S. 29.

inflammations of the outer ear, as the name above indicates; but, both for clinical and pathological reasons, it is not commendable to include these under one common name. The term otitis externa diffusa may therefore be confined to a general inflammation of the external ear, the result of injury either mechanical or chemical.

Otitis Externa Parasitica, or Otomycosis.—There is, however, a condition which may with better reason be designated by the term diffuse inflammation of the outer ear. The chief feature in these cases is the presence of a fungus, and on this account the term otitis externa parasitica, or otomycosis, is employed.

Clinically, the condition consists in the shedding of portions of the epidermis lining the external meatus, in the form of flakes. Even the whole of the cuticle lining the meatus may come away as a soft paper-like cast, frequently stained with wax. This membrane, on close examination, is found to be studded over with minute black or yellow specks or tiny nodules. When the specks are black, the parasite is *Aspergillus niger* or *fumigatus;* when yellow, they indicate the presence of *Aspergillus flavus.* In a case seen by the author, the last-named gave to the whole meatus a brilliant emerald-green colour.

Siebenmann[1] has made a careful study of parasitic otitis, and his contributions should be read in the original. According to his investigations, the affection manifests itself upon an inflamed surface on which serous exudation is present. In the early stage it presents the appearance of a thin layer of flour scattered over the surface, rapidly passing on to a stage in which a whitish membrane is produced. This membrane is shed in the course of about a week, but is rapidly re-formed. In some cases the fungus shows itself rather in the form of a whitish foam, in appearance like cotton wool, or, if growth is very rapid and the fungus fills up the meatus, the pressure produces a substance like macerated blotting-paper.

If a piece of this substance be subjected to the action of weak liquor potassæ and examined under the microscope, the characteristic mycelium and the capitulum, with its

[1] *Zeitsch. f. Ohrenh.*, Bd. xix., S. 7; 'Die Schimmelmycosen d. Menschl. Ohr.,' 1889.

placenta, sterigmata and spores, may be seen (Fig. 59). The colour of the capitulum enables the observer to distinguish the species of the fungus apart from macroscopic appearances. Thus, in *Aspergillus flavus* the capitulum is yellow or green; in *A. fumigatus* the colour varies from a pale yellow to pea green or dark grey; in *A. niger* it is black or of a dirty brown colour (Fig. 60). *Penicillium glaucum* has also been found in the meatus.

The relationship of the fungus to the tissues is interesting. It appears to be in close contact with the latter, but does

FIG. 59.—ASPERGILLUS NIGER. × 100.
(From a case of the Author's. Photomicrographed by Dr. Leslie Buchanan.)

s, capitulum or sporangium. *h*, hyphæ. *m*, mycelium.

not actually penetrate them; further, the fungus is found, not over intact cuticle, but over the exposed corium. In a few cases the mycelium may insinuate itself between the cells of the rete Malpighi.

Cases have been recorded by Burnett[1] where the fungus has been found in the tympanic cavity in which a previous perforation of the membrane was present. Haug[2] even records a case in which the fungus was found in the mastoid process.

[1] *Arch. f. Ohrenh.*, Bd. xii., S. 311; Bd. xv., S. 52.
[2] *Beiträg. z. Path. Anatom. Ziegler*, Bd. xvi., S. 490.

Pathogenesis.—The conditions necessary for the growth of aspergillus in the ear are very interesting, and as previously stated, have been carefully studied by Siebenmann. Healthy dry epidermis and cerumen do not permit of its growth, neither does the presence of pus or mucus; nor does the parasite grow upon a healthy mucous surface. On the other hand, fresh serum forms a suitable pabulum, but the serum must not be allowed to become dry or to undergo putrefaction or disorganization. We find, therefore, that otomycosis occurs in cases of dermatitis of the meatus or in serous secretion in

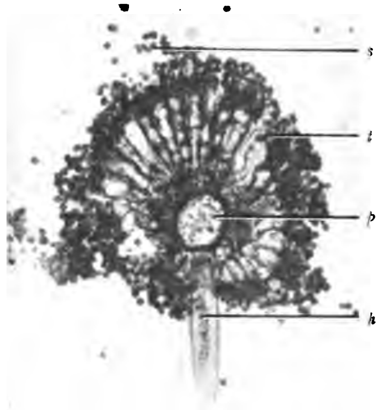

FIG. 60.—SPORANGIUM OF ASPERGILLUS NIGER. × 300.
(From a case of the Author's. Photomicrographed by Dr. Leslie Buchanan.)

h, hypha. *p*, placenta or receptaculum.
t, sterigmata from which the spores are discharged. *s*, spores.

the middle ear, such as may occur when a purulent otitis is in process of healing.

In opposition to the views expressed by Siebenmann, von Roosa holds the opinion that the fungus is the cause of the eczematous condition of the meatus. He has found several varieties of fungus in addition to those enumerated above.

Among the natives of India,[1] Hatch and Row find otomycosis to be very common. They divide the cases into two classes—the moist and the dry. In the former there is a

[1] *Lancet*, December 1, 1900.

sense of heaviness in the ear, slight pain occasionally, and deafness, accompanied by a thin serous discharge. The fungus in these cases is usually *Aspergillus niger*, and the epithelium may be coated very darkly. In the dry variety the symptoms are similar to those described above, while the meatus, on examination, appears to be covered with dry crusts, sometimes accompanied by white patches over the membrana tympani. On removal of the crusts, the walls of the meatus appear red and dry; the fungus in these cases may be *A. flavus*, *niger*, or *fumigatus*. The presence of *Penicillium glaucum* gives a foamy or fluffy appearance.

As regards treatment, Hatch and Row are of the opinion that the particular drug used is not of so much importance as thorough removal by syringing. They recommend, however, subsequent insufflation of boracic acid and iodoform, or swabbing with camphorated salol.

It may well be understood that otomycosis is more apt to occur in localities where the fungus grows abundantly in ordinary circumstances. Thus, it is undoubtedly more common in the tropics than in this country. A warm, moist atmosphere seems specially favourable to its growth.

Among the direct causes of otomycosis, Bezold[1] lays great stress upon the instillations of oils and ointments. But, considering the frequency with which the lay public employs this method of treatment, it may be doubted if there is any real relationship of cause and effect.

When suspicion is aroused the diagnosis of parasitic otitis is easy. Cases frequently remain unrecognized because the existence of the disease is unknown to many medical men. When a papery membrane is syringed or expelled from the meatus, and is found to be covered with many black or yellow specks, the case is in all probability one of parasitic otitis. Microscopic examination will enable the observer to confirm the diagnosis. All cases of parasitic otitis do not exhibit the characteristic specks upon the membrane, and it is therefore wise to examine any such pieces of tissue with the microscope. The tissue should be subjected to the action of weak caustic potash solution before mounting.

The affection cannot be recognized from its symptoms, these not being essentially different from those presented by

[1] *Aerztl. Vereinbl. f. Deutschland*, 1900, No. 422.

slight non-parasitic inflammation of the parts, such as heat, itchiness, and occasionally pain.

Treatment.—The treatment of this disease is frequently tedious. Theobald[1] recommends syringing out the meatus and careful drying, followed by the insufflation of a powder composed of equal parts of oxide of zinc and boracic acid. A 2 per cent. solution of salicylic acid in alcohol (90 per cent.) is recommended by Siebenmann.[2] Perchloride of mercury dissolved in rectified spirit to the strength of 1 in 2,000 is prescribed by many authorities as a good instillation, and its effect is rapid. Whatever line of treatment be adopted, it is important that it should be kept up for a long period after the last disappearance of the parasite, though naturally not with the same degree of energy. Thus, the drops should be employed daily until the pathological changes have disappeared, after which they should be instilled once or twice a week for some months.

Ringworm.—Ringworm of the meatus is an extremely rare affection, to judge from recorded cases, but it must be remembered that the condition may pass unrecognized. Bar[3] of Nice records two examples, and in his monograph divides cases into acute, subacute and chronic. The affection is characterized by a dermatitis, sometimes very severe, and even accompanied by the formation of vesicles and pustules; on the other hand, the dermatitis may be simply scaly. The disease is so variable in its intensity, and simulates other conditions of the meatus so closely, that its diagnosis can only be made by means of the microscope. The treatment is conducted on the general lines followed in ordinary ringworm. Thus, the instillation of perchloride of mercury dissolved in water to the strength of 1 part in 1,000 is valuable. Bar recommends an ointment composed of naphthalene and vaseline (1 to 10 parts respectively) to be smeared over the surface.

Larvæ.—The larvæ of flies may in rare cases be found in the meatus. They may be killed by the instillation of some insecticide, such as alcohol, and then syringed out with warm water or picked out with forceps.

[1] Transactions of the American Otological Society, vol. xxxiii., p. 80.
[2] *Zeitschr. f. Ohrenh.*, Bd. xii., S. 124.
[3] *Annal. d. Malad. de l'Oreille*, May, 1901.

Actinomycosis.—The ray fungus is but rarely found in the tissues of the outer ear. Cases have been recorded in which the disease extended from the lower or upper jaw into the middle ear, and at least one case is recorded by Körner[1] in which the disease spread from the jaw into the external meatus.

The nature of the affection is recognized by the gritty particles that occur in the discharge, which, when subjected to microscopical examination, reveal the unmistakable radiate arrangement of the organisms.

Treatment.—The treatment is conducted on general lines. It may, however, be remarked in passing that ten Siethoff[2] cured a case of actinomycosis of the middle ear by the administration of iodide of potassium in doses of 30 grains per day. The treatment lasted a few weeks.

Pseudo-Actinomycosis.—A disease simulating actinomycosis in almost every respect has been described very minutely by Cozzolino.[3] The discharge from the outer ear was identical in appearance with that of actinomycosis, but on microscopic examination it was found that the parasite was not the ray fungus, but belonged to the order of schizomycetes. A few cases of the disease occurring in other parts of the body have been recorded, and, owing to its likeness to actinomycosis the affection has been termed pseudo-actinomycosis. Cozzolino's case proved ultimately fatal, but there were long intervals of amelioration as the disease ran its course over a period of several years. The treatment consisted of excision of the affected parts, together with the internal administration of iodide of potassium.

Foreign Bodies.—Foreign bodies may gain entrance to the meatus accidentally or by deliberate intention. Pieces of straw or hay may get in during work in the fields among farm servants. Children and people of weak intellect occasionally put peas, slate-pencils, beads, etc., into their ears without reason, and not uncommonly pieces of cotton-wool have slipped in and been forgotten. Insects also gain admission sometimes, and it used to be a common superstition that earwigs had a special predilection for the external meatus. It

[1] 'D. eiterig. Erkrank. d. Schläfenbein,' 1899, S. 145.
[2] *Zeitschr. f. Ohrenh.*, Bd. xxix., S. 240.
[3] *Arch. f. Ohrenh.*, Bd. xlvi., S. 37, and Bd. l., S. 199.

would be impossible to enumerate all the objects which have been found in the meatus, nor is that matter of much importance. It is, however, of value to know the physical and chemical properties of the foreign body before attempting to see or remove it, and the medical attendant would be well advised to give the utmost thought to these considerations. Serious damage has repeatedly been inflicted by attempts to remove a foreign body which would have occasioned no injury had it been left. The meatus may tolerate for an indefinite time smooth bodies such as beads, pebbles, etc. Thus, the author has removed a small white pebble which had lain in a patient's ear for thirty years, without even causing deafness until a few weeks before removal, and even then the deafness was merely due to the accumulation of wax round the stone.

Bodies with edges or points, on the other hand, will very quickly cause inflammation, with ulceration and possibly subsequent stricture of the meatus. Some substances swell by the imbibition of water, such as peas and beans; and others, such as paper and cotton-wool, will soften or macerate. In rare cases a foreign body has been known to cause perforation of the tympanic membrane, pass through the perforation, and gain access to the mastoid antrum. In a remarkable case recorded by Haug,[1] the foreign body, a piece of cotton-wool, passed down the tissues along the Eustachian tube, brought about the formation of an abscess in the neighbourhood of the tonsil, and was recovered when the abscess was opened. In this case, however, a previous radical mastoid operation had been performed, the cotton-wool being inserted into the meatus to keep the parts warm on going out of doors. The tympanic membrane, therefore, would be absent, and according to Haug the cotton-wool would pass through the fissure of Glaser, and so downwards and inwards to the peritonsillar tissue.

Symptoms.—The symptoms resulting from the presence of a foreign body in the meatus vary according to the nature of the substance. In general it may be stated that foreign bodies do not produce symptoms, but exceptions to the rule are many. Thus, if the object completely closes the meatus there will be deafness; if it be chemically active the walls of

[1] *Arch. f. Ohrenh.*, Bd. lvii., S. 45.

the meatus will become irritated; and if it has sharp edges or points the same result will be brought about. Substances which easily undergo decomposition may putrefy in the meatus and give rise to inflammation of the soft parts.

In some individuals a foreign body in the meatus may give rise to neuralgia, reflex cough, vomiting, and even epileptiform attacks and other reflex symptoms.

Living and moving objects in the meatus may give rise to the sensation of loud sounds and cause great pain, and if not killed may even cause suppuration.

Treatment.—It should be remembered that, with the exception of chemically active substances, the removal of a foreign body from the ear is not immediately imperative. Unfortunately, the patient or his friends, not knowing this, may have already made amateur attempts at removal before the case comes before the medical adviser, and sometimes harm is already done.

Having ascertained, if possible, from the patient or his friends the nature of the foreign body, the ear should be carefully examined with a good light, forehead mirror and speculum. The object will then in all probability be seen; but if inflammation of the walls of the meatus has occurred, either as a result of the irritation of the foreign substance or of ineffectual attempts at removal, granulations, blood or wax may obstruct the view.

If the object is clearly visible, the surgeon must rely upon his judgment as to whether an attempt should be made to remove it by properly-shaped forceps or hooks. Paper, cotton-wool and similar objects, may usually be removed in this way. On the other hand, hard objects, and particularly hard rounded objects such as peas, beads, etc., should not be touched with forceps, since they will almost certainly elude the grasp of the instrument and the case will be made worse than before. For these cases the syringe should be employed in the following way. The position of the object in the meatus is noted, and account taken of any little chink that may exist between the object and the meatal wall. The stream of warm water is then directed towards this chink, and the head of the patient inclined to the side of the affected ear. The syringing should be repeated several times, and it will frequently be found that the foreign body will fall out into the basin. Peas, beans or other objects which contain a considerable proportion of water, may be made to contract by the repeated instillation of absolute alcohol for some hours before syringing, the diminution in bulk facilitating the removal. If the syringing fails to remove them, of course they soon regain their original bulk by the imbibition of water.

Should syringing fail to remove the foreign body, recourse may be had to direct instrumental interference, but this must be done carefully. A blunt hook should, if possible, be passed between the object and the meatal wall, then rotated and dragged gently outwards. This manœuvre is frequently successful; and if the object is not too hard, such as a pea or bean, a sharp hook may be used instead of a blunt one.

An ingenious method has been devised by Lermoyez. A camel's-hair brush of suitable size is dipped in melted glue, then laid gently against the foreign body, allowed to set for half an hour, and then withdrawn, probably carrying the object with it. Some foreign bodies may be destroyed by the application of the galvano-caustic point, but care must be taken that the wall of the meatus is not burnt.

If, in spite of these methods, the offending body remains in the meatus, recourse must be had to the operative procedure described later (p. 281).

If on examination it be found that the walls of the meatus are inflamed or damaged in any way, no attempt should be made to extract a foreign body by any of the means described, except syringing. The inflammation should, if possible, be subdued by rest and the application of the ice-bag and instillation of warm boracic acid solution. If these succeed in their object, attempts may then be made at removal; but, unfortunately, they usually fail, because the foreign substance keeps up the inflammatory action. In these cases operation is demanded, and the procedure adopted is as follows. A curved incision is made in the line of attachment of the auricle. The incision should be carried down to the periosteum, but not through it, and care should be taken that the cartilage of the auricle or meatus is not injured. The soft parts are then detached from the posterior and upper walls of the meatus as far inwards as the junction of the cartilaginous and bony portions of the channel. At this point an incision is made through the meatus, and it may be found possible to extract the foreign body through the wound. Should it still remain impacted there, it becomes necessary to remove a portion of the posterior wall of the bony meatus either by chisel or burr until a blunt hook can be inserted behind the object, which may then be extracted. In a few cases the foreign body has been forced into the mastoid antrum, this of course necessitating opening of that cavity by the mastoid operation.

Figures 61-78 illustrate the appearances of the tympanic membrane in normal and pathological conditions.

FIG. 61.—THE RIGHT TYMPANIC MEMBRANE: NORMAL (p. 75).

FIG. 62.—EXOSTOSES AT THE INNER EXTREMITY OF THE EXTERNAL MEATUS.

Long-continued suppuration has completely destroyed the tympanic membrane, and the malleus and incus have been discharged, so that the promontory is visible over a large portion of the field.

FIG. 63.—RIGHT TYMPANIC MEMBRANE FROM A CASE OF ACUTE SUPPURATIVE OTITIS MEDIA.

The swollen and bulging tissues of the membrane have obliterated all appearance of the handle of the malleus. The short process of the malleus is faintly visible above and in front of the small elliptical perforation.

FIG. 64.—LEFT TYMPANIC MEMBRANE FROM A CASE OF ACUTE SUPPURATIVE OTITIS MEDIA.

The discharge was rapidly diminishing when the drawing was made, and the rest of the membrane had returned almost to its normal appearance.

FIG. 65.—KIDNEY-SHAPED PERFORATION IN THE LOWER PORTION OF THE RIGHT MEMBRANE.

(From a case of chronic otorrhœa.)

FIG. 66.—PERFORATION IN THE POSTERIOR PORTION OF THE RIGHT MEMBRANE.

(From a case of chronic otorrhœa. *Cf.* Fig. 72.)

The mucous lining of the tympanum is swollen, and the incudo-stapedial articulation is hardly visible.

FIG. 61.

FIG. 62.

FIG. 63.

FIG. 64.

FIG. 65.

FIG. 66.

A. K. Maxwell delt.]

To face p. 158.

FIG. 67.

FIG. 68.

FIG. 69.

FIG. 70.

FIG. 71.

FIG. 72.

A. K. Maxwell delt.]

[*To face p.* 159.

FIG. 67.—PERFORATION IN FRONT OF THE HANDLE OF THE MALLEUS.

(From a case of chronic otorrhœa.)

The membrane is indrawn owing to the contraction caused by adhesions.

FIG. 68.—PERFORATION IN SHRAPNELL'S MEMBRANE.

After the cure of the suppurative process the hearing was for all practical purposes normal.

FIG. 69.—SESSILE GRANULATION SPRINGING FROM THE POSTERIOR MARGIN OF THE TYMPANIC RING.

(From a case of chronic otorrhœa.)

A small area of necrosed bone was found at the base of the granulation. The perforation is seen reaching to the edge of the tympanic ring.

FIG. 70.—POLYPUS EXTENDING OUTWARDS TO THE OPENING OF THE EXTERNAL MEATUS.

(From a case of chronic otorrhœa.)

FIG. 71.—PERFORATION IN THE INFERIOR PORTION OF THE MEMBRANE.

(From a case in which the suppurative process had ceased several years previously.)

A whitish, crescentic deposit of calcareous salts is seen near the posterior margin. The membrane is somewhat indrawn as the result of the contraction of adhesions.

FIG. 72.—LARGE PERFORATION IN THE POSTERIOR PORTION OF THE MEMBRANE.

The chronic suppurative process had ceased many years previously. The mucous membrane is thin and glazed, and the long process of the incus, the incudo-stapedial articulation and the posterior crus of the stapes, are visible in the upper portion of the perforation. The round window is seen obliquely in the posterior lower portion of the perforation.

Fig. 73.—Tympanic Membrane from a Case in which Two Perforations had been Present, but had become Closed by Cicatricial Tissue.

The larger perforation is in front of the handle of the hammer, and the smaller behind. The tip of the handle of the hammer is bound down to the promontory by adhesions. The drawing was taken before inflation of the middle ear by the air-bag. *Cf.* with Fig. 74, which shows the appearances after inflation.

Fig. 74.—Tympanic Membrane from the Same Case as Fig. 73, but showing the Appearances immediately after Inflation.

The scar tissue closing the perforations is blown outwards, and the adhesion binding down the tip of the malleus has been stretched, and shows a striated appearance.

Fig. 75.—Perforation in Shrapnell's Membrane from a Case in which the Discharge had ceased Some Years previously.

Besides the destruction of Shrapnell's membrane itself, a small area of the bony outer wall of the attic had been destroyed by caries, and a portion of the neck of the hammer is thus visible.

Fig. 76.—Tympanic Membrane in a Case of Serous Catarrh of the Middle Ear.

The upper level of the fluid is indicated by the curved line passing from the anterior to the posterior margin of the membrane. The membrane is but slightly indrawn.

Fig. 77.—Tympanic Membrane from a Case of Non-Exudative Catarrh of the Middle Ear.

The membrane is markedly indrawn, and the inner wall of the tympanic cavity in the region of the promontory is indicated by the lighter, inferior portion of the image.

Fig. 78.—The Tympanic Membrane from a Case of Non-Exudative Middle-Ear Catarrh.

The membrane is indrawn and somewhat thickened. There is a whitish, crescentic deposit of calcareous salts in the lower portion of the membrane.

FIG. 73.

FIG. 74.

FIG. 75.

FIG. 76.

FIG. 77.

FIG. 78.

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[*To face p.* 150.

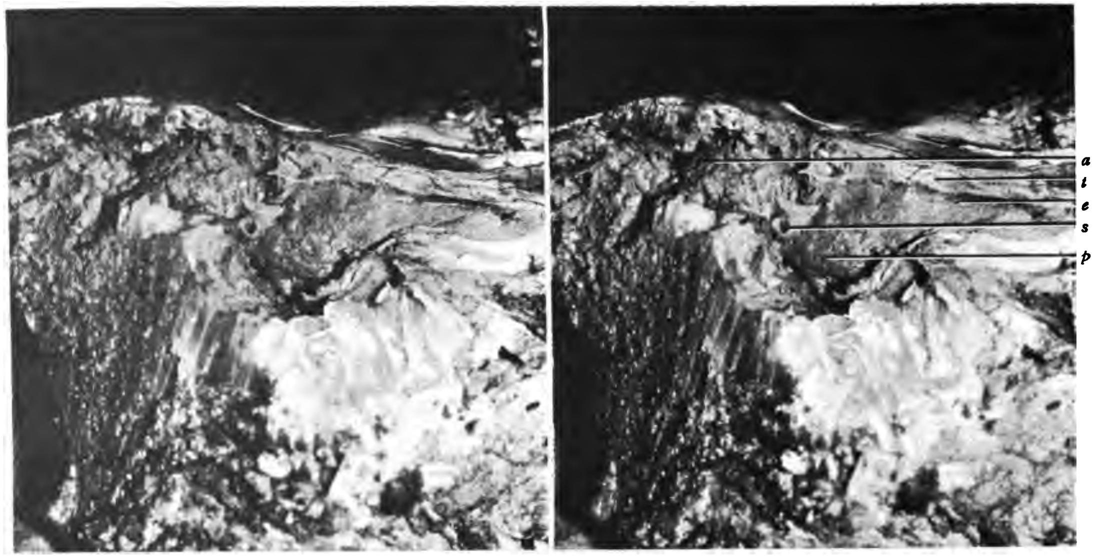


FIG. 79.—MIDDLE EAR AND ANTRUM IN ACUTE OTITIS MEDIA. $\times \frac{2}{3}$ *circa*.

(Prepared and photographed by the Author.)

The patient died of acute pneumonia about five days after the onset of the acute middle-ear affection. The purulent secretion has been removed in order to show the swollen mucous membrane of the tympanic cavity and antrum. The crura of the stapes are hidden by the swollen mucous membrane.

a, aditus ad antrum. *t*, tensor tympani. *e*, Eustachian tube. *s*, incudo-stapedial articulation. *p*, promontory.

[*To face p.* 161

CHAPTER VIII

DISEASES OF THE MIDDLE EAR

Acute Inflammation of the Tympanic Membrane, or *Acute Myringitis.*—The tympanic membrane suffers from acute inflammation in the same way as other structures of the body. It is seldom an independent affection, being usually associated with disease of the meatus or of the middle ear. It may, however, occur as a result of exposure to cold, particularly that form of cold which comes with the east wind. Injury also may result in acute inflammation of the membrane.

Pathology.—The early stages are characterized by hyperæmia, but in a very short period of time, even in a few hours, exudation occurs, and this may be so considerable that it raises the dermic layer from the deeper structures in the form of bullæ. The exudation is not infrequently tinged with blood, and in certain cases may be transformed into pus.

Symptoms.—In uncomplicated cases the hearing is little affected, but the pain is severe. There is no sense of fulness such as is usually complained of in acute inflammation of the middle ear, and this serves to distinguish it from the latter disease. As remarked above, however, it is frequently a manifestation of acute inflammation of the middle ear, and in such cases the symptoms of the more severe disease will mask those in which only the membrane is affected. On inspection, the membrane presents different appearances according to the stage at which the case is seen and the portion affected. There is usually injection of the blood-vessels along the handle of the hammer in the early stage, but this is frequently lost sight of in the course of a few hours, when a general diffuse redness appears. In severe cases small hæmorrhages occur, giving a crimson, spotted appearance, and it is in such cases that the characteristic blisters on the surface of the membrane may be seen. These blisters may be the size of a hemp-seed, and they contain a fluid varying from a clear straw colour to that of pure blood. The blisters have an existence of but short duration, the surface rupturing soon after their formation and allowing the escape of the fluid. As was pointed out by Bezold, these hæmorrhages are peculiarly characteristic of the otitis consequent upon influenza. In rare cases the contents of the blisters may become purulent, and a small abscess in the deeper layers of the membrane result. The part of the drumhead most usually affected is the posterior portion, and indeed, the rest of the structure may be comparatively free of pathological changes.

The differentiation of acute inflammation of the membrane alone from the similar condition of the tympanum is not possible in the early stage. When the membrane only is affected, the sense of hearing is not diminished to any very great extent, a feature which places the disease in marked contradistinction to acute inflammation of the middle ear, save in its earliest stage. Pain does not afford much help in the diagnosis, since it varies very considerably in both affections. Furthermore, it must be remembered that even anatomically there is usually no sharp line of demarcation between the two diseases.

The disease runs a comparatively rapid course, seldom lasting more than three or four days. The ultimate result is almost invariably favourable, and the hearing is very seldom impaired. In a few rare cases, however, the condition may become chronic.

Treatment.—The indication for treatment is to relieve the pain. For this purpose various local applications have been recommended, the best of these being instillations of glycerin of carbolic acid, aniline or laudanum. Blood may be abstracted from the front of the tragus or from the tissues immediately behind the auricle by means of leeches or wet-cupping. In obstinate cases the application of the ice bladder to the surface of the ear has been recommended by many of the German writers.

Chronic Myringitis.—Chronic inflammation of the tympanic membrane is not a very common disease. Most frequently it takes its origin from the acute affection just described, but in some cases it appears to arise spontaneously. It occurs most commonly in anæmic or cachectic conditions. In the majority of cases the whole membrane is affected, but when circumscribed the areas most often diseased are the posterior superior quadrant and Shrapnell's membrane.

The disease manifests itself in two different ways: (1) a moist form; (2) a dry, desquamating form. The moist form is characterized by a scanty purulent secretion having a foul odour. On examination the surface of the membrane presents a moist appearance and a dirty yellowish colour; the blood-vessels, however, are engorged, and thus form a red network on a greyish or yellowish ground. In this type the handle of the hammer is clearly visible, and allows the fact to be noted that the membrane is not indrawn.

In this form of the disease small excrescences may appear on the surface of the drum membrane, and these may even develop into granulations.

The dry form manifests itself as a desquamation of the cuticle of the membrane. In this case there is no secretion, but the outer layer of the membrane is very much thickened, whitish or yellowish in colour, and opaque. The handle of the hammer is not visible, and even the short process itself may be hidden by the thick, opaque, desquamating epidermis. The false membrane can only with difficulty be removed by syringing, and when this has been done it will be seen that the drumhead is congested, velvety in appearance, and has various light reflexes on its surface.

Symptoms.—The most prominent features of chronic myringitis are continuous itching in the ear, and, in the secreting form, a fœtid odour. Only rarely are fleeting pains and tinnitus present. The hearing remains perfect, or is only affected to a very insignificant extent.

The recognition of the disease is easy. The possibility of mistaking it for chronic suppurative middle-ear affections may be eliminated by the use of the catheter, when, in the latter condition, the evidence of a perforation of the membrane is unmistakable.

If left to itself, the disease pursues its course indefinitely, and leaves the tympanic membrane thickened in some cases and atrophic in others; calcareous deposits, moreover, may appear. True ulceration is rare, but has been noticed by

Politzer. Hearing is completely restored when the disease is cured, except in those cases in which marked thickening of the tympanic membrane remains, and even in these the deafness is slight.

Treatment.—The disease, fortunately, is amenable to treatment. If secretion is present, the ear should be syringed out with a weak antiseptic solution, such as carbolic acid or lysol, the meatus dried and boracic acid powder insufflated. This should be repeated every second day, and at the end of a week it will be found that in the majority of cases the secretion has ceased. If, however, the case resists this form of treatment, then the instillation of a 5 per cent. solution of boracic acid in rectified spirit should be tried, the drops being applied daily. Should the spirit cause too much smarting, it may be diluted with an equal amount of water. After instillation the head should be held to the side so that the drops will not run out for at least fifteen minutes. In rare cases even this treatment is of no avail, and it will be found that these are usually characterized by granulations on the membrane. These granulations should either be removed by the snare or destroyed by the application of chromic acid fused on to the end of a probe. It is inadvisable to use the electric cautery in the ear on account of the heat which is radiated from the glowing wire. Having brought the secretion to an end, the treatment is to be directed to the prevention of the desquamation. For this purpose the instillation of a 5 to 10 per cent. solution of nitrate of silver is perhaps the most valuable. The drops should be warm and instilled in the usual way, but should only be allowed to remain in the ear for one minute, after which they should be syringed out with a lukewarm solution of salt and water. Weak watery solutions of other astringents, such as sulphate and chloride of zinc, are also useful in this stage.

Otitis Externa Membranosa.—The dermic layer of the tympanic membrane and of the external meatus is sometimes affected by inflammation associated with the formation of a new membrane which is shed at intervals. There are two different diseases of this type, both being rare.

Pseudo-Membranous Otitis.—This disease was observed first by Wilde, who likened it to the disease of the larynx then known as croup in children.

The disease consists of the exudation of fibrin on the outer surface of the tympanic membrane and of the adjacent portions of the osseous meatus; it is never found on the cartilaginous meatus. Most commonly it is associated with an acute middle-ear catarrh or with furunculosis. The fibrinous membrane is but feebly attached to the underlying surface, and can usually be syringed out without difficulty and without bleeding. It, however, rapidly reappears after an interval of from one to two or three days, and this reproduction is repeated again and again for a period of three weeks, at the end of which the disease appears to have reached its natural termination.

The fibrinous exudate consists of a fine network which is filled with epithelium and round cells, but the most peculiar pathological relationship of the disease is the fact that the *Bacillus pyocyaneus* is frequently found to be present, and to give a characteristic greenish or bluish tint to the discharge.

This affection usually develops with slight pain which ends, as a rule, when the membrane is shed. There is no diminution of the hearing-power, except in so far as the membrane obstructs the passage of sound-waves, and when it is removed the hearing is perfect. The prognosis is always favourable.

Treatment.—Active treatment is not necessary. The membrane should be removed by syringing with a mild antiseptic solution, such as boracic or carbolic acid, but the actual course of the disease is not shortened thereby.

Diphtheritic Otitis Externa.—In rare cases of true diphtheria the membrane is first formed in the external auditory canal. Much more commonly the diphtheritic membrane in the external meatus is caused by extension from the throat to the middle ear, and through the drumhead to the meatus.

Whether primary or as a result of the extension from the throat and middle ear, the false membrane is seen as a greyish-white exudation firmly adherent to the structures underneath, and its removal is followed by bleeding. The meatus is painful to the touch, and so contracted that the deeper parts cannot be seen. Occasionally even the auricle is covered by the false membrane. The tissues in the neighbourhood of the ear are swollen, red and tender, and the lymphatic glands in the neck, as well as those behind the ear are inflamed.

As regards pain, it is a remarkable fact that, according to Wreden and Blau, in the primary form the pain is excessive, while in those arising from extension from the middle ear it is insignificant or absent. It would appear, therefore, that in the latter case there is an anæsthetic condition of the parts.

Course.—Diphtheria manifesting itself in the external ear runs its usual course unless treated by antitoxin.

Treatment.—The constitutional treatment of diphtheria by antitoxin is well known, and the methods need not be enlarged upon here. Locally, weak carbolic acid injections may be administered in order to prevent the growth of other bacteria than those of the specific affection.

Calcareous Deposits.—The tympanic membrane not unfrequently becomes the seat of calcareous deposits. These appear as milk-white, sharply defined areas covered by the ordinary epidermis lining the outer aspect of the membrane (Fig. 78). They may occur in any part of the drumhead except in Shrapnell's membrane, and sometimes almost the whole structure is converted into a calcareous plate. In many cases they form in the remnants of a membrane which has been partially destroyed by a previous long-continued otorrhœa; but they are also frequent in cases where no such condition has existed. They are more common in the last than in the first half of life, but I have seen them in children of twelve years of age.

I have never known them, *per se*, to cause appreciable deafness, though naturally in those cases associated with a previous otorrhœa there is deafness from the latter cause.

No treatment is necessary unless there is coincident deafness from other causes. Even in this case the surgeon must exercise care in the use of the air-douche or catheter, for fear of rupturing the membrane.

Rupture of the Tympanic Membrane.—Rupture of the tympanic membrane and its treatment have already been described (p. 90).

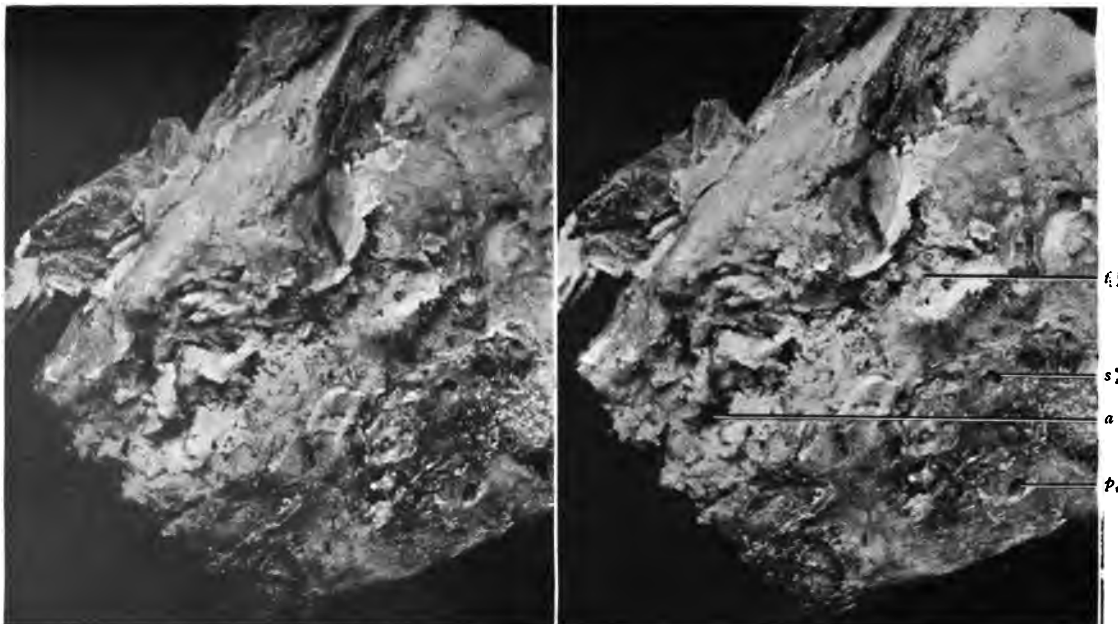
Acute Inflammation of the Middle Ear.

Pathology.—Acute inflammation in the middle ear manifests itself in the same way as acute inflammation in other organs. In the early stages there is hyperæmia of the mucous mem-

FIG. 80.—TEMPORAL BONE FROM A CASE OF ACUTE OTITIS MEDIA. × 2 *circa*. (Prepared and photographed by the Author.)

The preparation was fixed in formalin in order to coagulate the secretion, and thus keep it in its natural position. The tegmen tympani et antri has been removed. (Viewed from above.)

t, attic filled with pus which hides the head of the hammer and the anvil.
s, anterior limb of superior semicircular canal.
a, antrum filled with pus.
p, common limb of superior and posterior canals.



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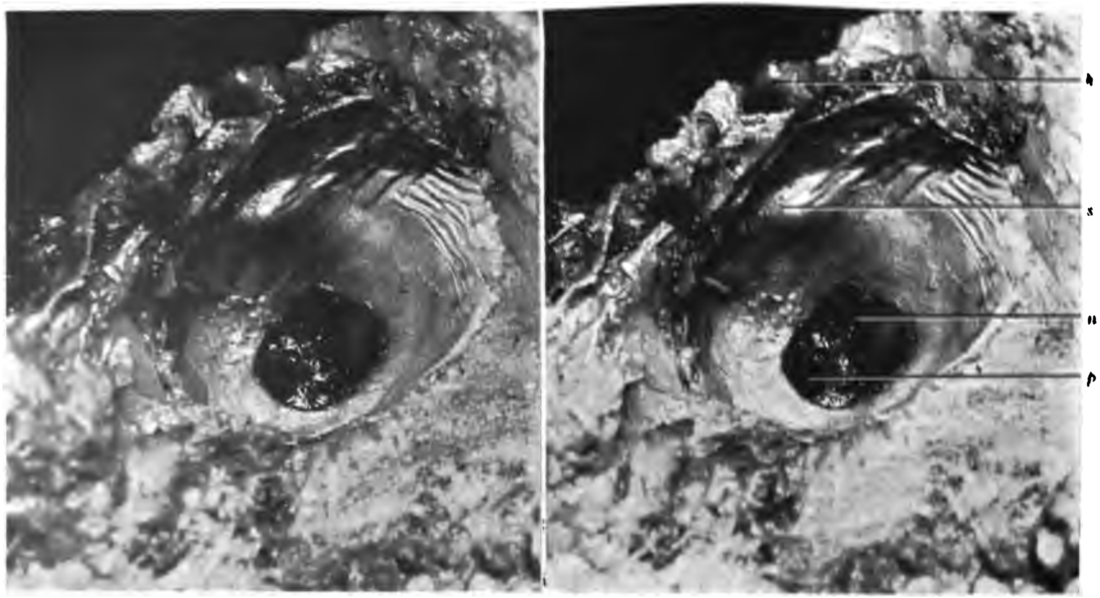


FIG. 81.—PERFORATION OF THE LEFT TYMPANIC MEMBRANE IN THE COURSE OF HEALING, FIVE WEEKS AFTER THE ONSET OF ACUTE MIDDLE-EAR SUPPURATION. ×4. (Prepared and photographed by the Author.)

The original perforation is almost closed by the new membrane, but a small opening still remains in the inferior anterior portion. The tissues are swollen so that the handle of the malleus is not seen.

h, head of malleus. *s*, short process of malleus. *n*, new membrane closing perforation. *p*, perforation still present.

[To face p. 167.

brane, which may extend to the periosteum, and this is followed rapidly by a serous exudation into the tissues, with emigration of red blood-corpuscles and leucocytes. In a further stage there is an exudation into the cavity of the drum, and this exudation may be mucous, muco-purulent or purulent ; in some cases, particularly those consequent upon influenza, the effusion may be bloody. The exudation varies in consistency from that of water to that of jelly, but the latter is rare. The actual cavity of the tympanum becomes diminished considerably on account of the swelling of the mucous lining (Fig. 79).

In the majority of cases the inflammation extends over the whole tympanum and mastoid antrum (Fig. 80), but occasionally it is limited to the tympanum proper. It may be so severe that the periosteum is stripped from the bone, with subsequent necrosis or caries. In certain cases the intracranial structures may be affected by extension of the process, but this is comparatively rare.

Various micro-organisms have been found in the middle ear in cases of acute inflammation. It would appear that the active agent is not invariably the same, but may be the *Pneumococcus*, *Streptococcus pyogenes*, or the *Staphylococcus pyogenes aureus* or *albus*, or one of several. In recent times certain writers have pointed out interesting facts in regard to the course of the disease according to the organism found (see p. 184).

Etiology.—Acute otitis media owes its occurrence to various causes. An acute exanthem, particularly scarlet fever, diphtheria, measles, whooping-cough, influenza, is a frequent cause. Adenoid vegetations, naso-pharyngeal catarrh, and even ordinary nasal catarrh are also predisposing agents. Injuries and operations on the tympanic membrane or in the naso-pharynx are occasional causes, and in the latter case there is little doubt that the use of the nasal douche after these operations tends on the whole to produce the ear affection. According to Wolf,[1] otitis media may be the first symptom of acute rheumatism, and the author has seen a case which seemed to justify Wolf's statement. In infants the presence of the embryonal gelatinous substance in the middle ear, as also the wide Eustachian tube in these subjects,

[1] Wolf, *Arch. f. Ohrenh.*, Bd. xli., S. 213, 1896.

may favour the development of the disease, for it is common in newly-born children.

The disease is more common in children than in adults, no doubt for the obvious reason that the acute fevers and adenoid vegetations are more common in the young. Certain general diseases, and in particular diabetes, seem to favour the occurrence of the ear affection and, unfortunately, to render probable a tedious convalescence.

Course and Symptoms.—Pain is by far the most prominent manifestation of the disease, and is sometimes intense. It may be of a boring, shooting, or throbbing character, and is usually continuous, but frequent remissions may occur lasting often for hours. It is in general worst at night, and any sudden movement of the head, such as shaking, nodding, sneezing, or coughing aggravates the pain noticeably. It is not, however, usually confined to the ear itself, but radiates over the corresponding side of the head and down into the region of the neck; cases have even been recorded in which the pain was felt only in the head, not in the ear. There is usually tenderness to pressure below the auricle and frequently also over the mastoid region. Pain along the gums and in the teeth is sometimes complained of, and for this reason the disease has been mistaken for dental neuralgia. In some cases, it should be observed, the pain is not great, the comparative absence of this symptom being most common in the acute otitis media of scarlet fever and diphtheria.

Deafness at the very commencement is not marked, but within a few hours it usually is very considerable. Tinnitus is sometimes present but is not of a distressing character; it is of the pulsating type.

In children there is generally a considerable degree of fever, but in adults the temperature seldom rises more than one or two degrees, and may even remain normal.

Paralysis or spasms occur in rare cases in the muscles supplied by the facial nerve, these signs probably being due to the existence of dehiscences in the Fallopian canal, which allow the inflammatory products to affect the nerve.

In children vomiting and giddiness may occur, and even in adults these symptoms are sometimes present, and increase very much the gravity of the case, both in relation to life and, if recovery ensue, to hearing. They do not necessarily indicate an extension of the infection into the cranial cavity, or even into the labyrinth, but they are very suggestive of these complications.

On examination, the auricle in some cases may stand out from the side of the head more than in normal conditions, a result of infiltration of the soft tissues over the mastoid process. The membrane is seen to bulge outwards, and its surface appears to be uniform throughout ; the handle of the hammer, and even the short process of that bone, may be concealed (Fig. 63). The general colour of the membrane is red, as is also that of the adjacent parts of the meatus, which are nearly always more or less involved in the inflammation. In influenza irregular-shaped hæmorrhages may appear in the membrane, and in some cases this sign may help in the diagnosis of the general affection. Occasionally the membrane itself does not seem to be so much infiltrated as in the cases just described, and appears then as a network of congested bloodvessels upon a yellowish-white ground ; in these circumstances the handle of the hammer is usually visible. In the later stages a yellowish point may appear, indicating the presence of pus behind the membrane. This spot is more commonly seen in the posterior quadrants, but may occur anywhere. In some rare cases the inflammation is limited to the attic, and in these the only visible change may be in Shrapnell's membrane.

When suppuration has occurred, rupture of the tympanic membrane takes place sooner or later at the little yellow spot described above, and pus suddenly appears in the meatus. This is followed in the majority of cases by instant relief of the pain and abatement of all the symptoms. It has, however, perhaps been assumed too readily that pain invariably disappears on rupture, and the medical attendant is occasionally disappointed that the patient appears to be no better. This is true even in cases in which there is no serious complication in the mastoid antrum or within the cranium, and there is little doubt that many operations upon the mastoid have been performed under the impression that the continuance of pain after the rupture of the drum membrane indicated serious trouble in these parts.

In young infants the clinical picture of this disease is different from that described above. In general it may be said that acute inflammation of the middle ear in these subjects has no localizing symptoms in many cases, and is therefore sometimes unrecognized during life, to be discovered post-mortem. The cause of the symptoms may first be revealed while making a methodical examination of all the organs in order to discover an explanation for the occurrence of such general symptoms as diarrhœa, fever, loss of weight, vomiting, loss of appetite, sleeplessness or general peevishness. Convulsions and strabismus may occur in very young subjects, and the disease is not infrequently mistaken for meningitis.

Diagnosis.—The recognition of the disease is easy in all except young infants, and nothing need be added to what has already been said. It is of the utmost importance, therefore, that the condition should not be overlooked in the recently-born infant or young child, and the practitioner should invariably examine the ear in all cases in which any of the symptoms narrated above make their appearance. Gomperz[1] has pointed out these signs as aids to the diagnosis of the condition in young children: salivation, œdema in front of the ear and enlarged glands in the neck. It is a remarkable fact that in young infants the discharge frequently obtains exit by other means than that of a perforation in the membrane. It may escape from the tympanum and appear immediately behind the auricle, simulating a subperiosteal abscess in that region, or pass along between the soft tissues of the meatus and the bony wall and rupture at some point into the meatus. It is possible that the secretion may find its way down the comparatively wide Eustachian tube into the throat. On inspection the membrane does not always appear so red as in adults, but bulging, opaque and white, with vessels radiating over its surface.

Treatment.—Before local treatment is attended to, it is important that the general condition of the patient should be considered. In all cases of acute inflammation of the middle ear the sufferer must be kept in one room, and indeed it is better that he should be put to bed. A gentle laxative should be given and the diet should be bland.

The indications in regard to local treatment are, the relief of pain and the prevention of suppuration, if this has not already occurred. No regard need be paid to the deafness

[1] Gomperz, *Monatschr. f. Ohrenh.*, 1897, S. 307.

at this stage of the disease, since the hearing almost invariably returns when the inflammation has subsided under early and appropriate treatment. The pain must in the first place be attended to, and the methods of bringing relief are various. The German aurists have laid great stress upon the local application of cold, both for the purpose of relieving pain and diminishing the inflammatory reaction. Perhaps the best method of applying cold locally is the ice-bag, which should be laid upon the affected ear for several hours; after this a considerable diminution in the amount of pain is frequently experienced. But if cold does not give relief in the course of a few hours, or if it appears to add to the discomfort of the patient, it should be given up, as its continuance may do harm rather than good. The old-fashioned treatment, which consists in the application of leeches, still remains a valuable adjunct to the present methods, and it is probable that we neglect too much this means of relief. It will naturally be understood that the artificial leech is quite as valuable as the living animal. Two to four of the animals may be applied, some in front of the tragus, some over the mastoid process. The abstraction of blood by this means usually brings about a rapid and considerable diminution in the pain.

Instillations of carbolic acid dissolved in glycerin, to the strength of 1 part of the former to 5 or 10 parts of the latter, have been recommended by Bendelak-Hewetson, and there is no doubt that in many cases the pain is very much diminished by this means. Carbolic acid may also be applied in the form of Gruber's gelatin aural bougies. Opium in the form of laudanum is sometimes useful.

Of local applications, the writer has found that the instillation of 5 minims of a solution of iodoform in anilin offers the surest means of relief. The instillation should be carried out in the way described on p. 108, and, after the head has been held with the affected ear uppermost for five or ten minutes, it will be found that the pain has disappeared, and will not return for a period of many hours, or even for a day or two. Occasionally, indeed, it does not return at all, and the patient gradually recovers from the disease. If the pain returns, the instillation may be repeated after twenty-four hours have elapsed. The usual precautions in the use of anilin must be strictly attended to. They have been described on p. 112.

Paracentesis.—In acute inflammation of the middle ear, whether the case has progressed to the stage of suppuration or whether the exudation is still clear, the question of making an incision in the drum membrane may arise. In the writer's experience, this operation has rarely been found necessary. In general, it may be stated that paracentesis should not be performed unless pus is present in the tympanum or pain is unrelieved by other measures. In other words, the disease is to be treated on the same surgical principles as acute inflammation in other organs. Some few years ago it was the fashion to recommend paracentesis in all cases of acute inflammation of the middle ear. Like other surgical procedures that ignore the study of the natural history of disease, this fashion was soon dropped.

It may therefore be held that paracentesis should be delayed as long as possible, and the surgeon should proceed to do it with regret. The suppuration which follows incision in the great majority of cases is frequently difficult to cure, and the duration of the disease is not shortened by the operation. Furthermore, paracentesis in cases of acute inflammation is intensely painful unless a general anæsthetic be administered, and this entails a further burden upon an already suffering patient.

In some cases, however, indications for incising the membrane do really arise, and these are a continuance of the pain in spite of all local applications, the occurrence of facial paralysis or severe tinnitus, and the appearance of a yellow spot on the membrane, indicating the formation of pus within the drum.

Symptoms indicating severe constitutional disturbance, such as delirium, convulsions, intolerable headache, and loss of appetite, naturally demand the opening of the drum cavity, and usually also of the mastoid antrum (*vide* p. 281).

In the case of young infants, fortunately, the disease seems on the whole to run a favourable course without surgical interference. Hartmann lays it down as a rule not to undertake any surgical procedure in these cases unless the infant is obviously suffering from loss of weight, rise of temperature, or general loss of health. In the case of infants, the meatus should be carefully cleared of masses of epithelial cells before performing paracentesis. The removal of these epithelial masses requires patience.

The performance of the operation is simple, and it is hardly possible to inflict any serious injury. At the same time, however, the patient should be placed under the influence of a general anæsthetic, since the operation, though of momentary duration, is intensely painful. Local anæsthesia by means of the instillation of cocaine, eucaine or any other substance, is not completely satisfactory in the case of an acutely inflamed membrane. Nitrous oxide gives an anæsthesia of sufficiently long duration.

If the patient elects to stand the pain without an anæsthetic, he may be encouraged to do so ; but it is an error of judgment to tell him that it will not be severe, for he will assuredly find out that the statement is not true, and will be apt to regard the surgeon either as being ignorant of his work or else possessed of an indifferent regard for the truth. It is important to emphasize this matter, since it is sometimes stated that the operation is not very painful. The mistake has probably

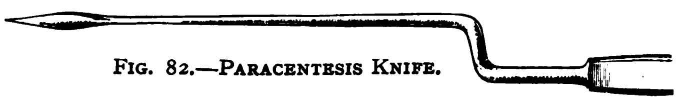


FIG. 82.—PARACENTESIS KNIFE.

arisen from the fact that incision of the membrane is not very painful when there is no acute inflammation.

Various instruments have been devised for the purpose of puncturing the drumhead, and in this matter the surgeon need not be too precise in his selection. Either the lancet-shaped knife or the paracentesis knife (Fig. 82) recommended by Gruber may be used with equal satisfaction. The incision should be made with its centre at a yellow spot in the membrane, if such is present, as this spot indicates the position at which Nature intends to make the perforation. If, however, there is no indication of this kind to guide the surgeon, he should commence his incision in the posterior superior quadrant, and continue it downwards for a distance of two or three millimetres. The incision should be too large rather than too small, and care should be taken to see that the membrane is completely perforated and the wound gaping. This matter is of great importance, since the commonest error of the beginner is merely to scratch the surface of the membrane, with, of course, no relief to the symptoms, and without influencing the course of the disease. Such a mistake is less likely to occur if the patient is under the influence of a general anæsthetic. Certain surgeons recommend an incision in front of the hammer, but it is difficult to see on what reasons they base their advice, since this region is more distant than the posterior portions of the membrane, and not so directly in the line of vision. The possibility of injuring the stapes by making the incision in the posterior quadrant is remote, and need hardly be taken into practical consideration. It should be noted that, if one particular part of the membrane seems to bulge outward more than the rest, the incision should be made at that part. Again, if the flaccid membrane be reddened and bulging, it is well to make an incision in it in addition to that made in the membrane proper. The omission of this additional incision is sometimes the cause of the continuance of pain after opening the drum cavity in the ordinary way. One possible risk in performing paracentesis is injury to the bulb of the jugular vein in those cases in which there is a dehiscence in the floor of the tympanum. This accident has been known to occur in performing the operation for other troubles than acute inflammation, but one would be inclined to think that the pressure of the fluid in the drum in acute cases would guard against this calamity by driving the wall of the vein downwards and the membrane outwards.

After the incision has been made, the exudation may rush out from the tympanum with considerable force, or it may refuse to flow at all, the differences in this matter depending upon the consistency and amount of the fluid and the pressure to which it is subjected.

Although, as just stated, the fluid may refuse to flow when the incision has been made, it will gradually ooze out in the course of a few hours, with relief to the symptoms. There is therefore no necessity for any attempts to draw the exudate through the incision by means of rarefaction of the air in the meatus or by giving the air-douche through the nose. The meatus may be syringed out gently after the operation with a solution of sanitas of the strength of 1 part of the fluid to 4 parts of water. The meatus should be gently packed with iodoform gauze, and a little pad of cotton-wool placed over the outer part of the ear and held in position by a bandage. The ear should be dressed every day, and if suppuration occurs or has already occurred, the case must be treated on ordinary surgical principles.

In the majority of cases the operation of paracentesis gives immediate relief to the pain, but it must be admitted that the exceptions to this rule are not uncommon. The continuance of this symptom is probably due to the fact that the cavities in the upper part of the middle ear and the mastoid antrum are cut off from communication with the tympanum proper, and therefore, although the tension is relieved in the latter cavity, it continues in the former. In these cases, relief may be obtained from the instillation of glycerin of carbolic acid or the solution of iodoform in anilin mentioned above. But if the pain still continues in spite of these measures, it becomes necessary to perform the simple mastoid operation (see p. 281).

After-Treatment.—After the membrane has been perforated either by the knife or in the process of nature, the disease usually pursues a course towards complete recovery. During this period, however, certain measures may be taken to assist nature in her efforts, and to prevent the recurrence of undesirable symptoms. Various authorities employ different measures for the purpose of achieving this end. Haug advised what might be called the expectant method, in that he avoided interference with the affected region in almost every possible way. Thus, he forbade syringing, instillation of any fluids, the insufflation of powders, the air-douche, or any attempt to interfere with inflammatory conditions in the throat or nose. He termed his method of treatment the "dry indifferent." The method consists in the drying-out of the meatus with sterilized cotton-wool plugs, after which dry gauze impregnated with chinolin-naphthol is packed gently into the meatus, this antiseptic having no irritating properties. This procedure is carried out twice a day, and there is no question that in many respects it could not be improved upon. It permits, as Haug said, the disease to run its natural course, and the aurist who pursues it will always feel satisfied at least that he has done nothing to injure the patient's prospects of complete recovery. Haug dispensed with the use of the air-douche in all cases except those in which the hearing does not improve of itself, and even then he only employed it after the fourteenth day of the disease. The patient is advised during the acute phases not to blow the nose, or at least to do so in the gentlest possible way. By following this line of treatment, Haug maintained, and probably with justice, that complications are rarer than under more vigorous treatment, and that in the majority of cases the duration of acute suppurating middle-ear inflammation is diminished by one half.

Stacke advises a line of treatment very similar to that of Haug, but he forbids even the drying-out of the meatus with the cotton-wool plugs. He merely packs the external meatus with absorbent gauze which he allows the patient to change himself.

Jacobson, although commending Haug's method of treatment in the majority of cases, maintains that it is not a course to be pursued if the secretion is thick and contains tough, stringy muco-pus. He states that the danger of producing complications by syringing has been much exaggerated, and seems to lay particular stress upon the value of syringing if it be done with a sterilized syringe and sterilized water, or 1 per cent. boracic acid solution raised to the temperature of the blood. The present writer is extremely doubtful as to the value of these precautions with regard to sterilizing the fluids and instruments used. The danger of producing complications by means of syringing does not arise from the possibility of introducing germs in the fluid employed, but in driving those micro-organisms which are already in the tympanum into the other cavities of the ear. An additional danger is the mechanical irritation produced by the act of syringing. In general, however, Jacobson's proposition that, if the discharge does not show signs of diminishing after two or three weeks' treatment by the dry method, then syringing may be employed, is an appeal to common-sense.

Bezold recommended the insufflation of boracic acid powder in such a way as to cover the membrane and fill a small part of the inner end of the meatus. The majority of aurists, however, condemn this method of treatment, on account of the danger of causing blocking at the perforation, which in these acute cases is usually very small. The objection certainly seems natural, and, although the writer has not seen such mischief occurring, he has heard of several such cases.

The same objections do not arise in the case of instillations. There are, however, other objections to some of these fluid applications. Thus, solutions of substances in water are not desirable, since the mucous lining of the tympanum seems to bear the presence of water badly.

The writer has certainly seen benefit from the instillation of drops consisting of rectified spirit diluted with an equal amount of water. The alcohol seems to prevent the deleterious effects of the water.

Speaking in general terms, it may be said that the treatment of an acute middle-ear inflammation after perforation has occurred should become more active as time passes. Thus, in the early stages nothing more should be done than simple cleansing or the instillation of dilute rectified spirit. After about a week, should the pain remain away entirely, the air-douche may be used very gently, in order to drive the secretion from the tympanum into the meatus, and to prevent adhesions forming. After another week has elapsed, the air-douche may be used more freely, but still not too forcibly. In the third week, should the discharge

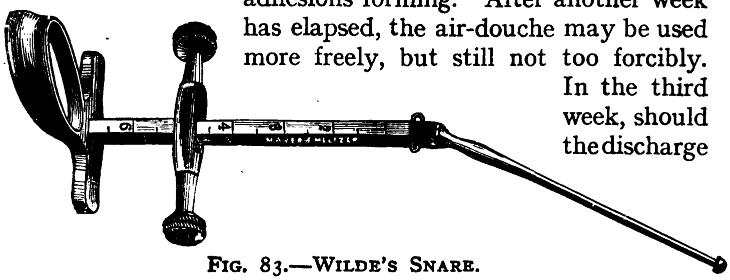


FIG. 83.—WILDE'S SNARE.

continue free in spite of treatment, it is justifiable to undertake small surgical procedures on the membrane. If the perforation appears too small, it may be enlarged from above downwards. There is no need to give a general anæsthetic in this case, since the membrane may be rendered insensitive by the instillation of a few drops of cocaine and anilin solution (p. 112). If the perforation is too highly placed to permit of free drainage from the cavity, it may be enlarged by an incision from above downwards. Should the outflow of pus be hindered by the presence of granulations on the margin of the perforation, they may be removed by the snare (Fig. 83), or destroyed by touching with a crystal of chromic acid fused on to the end of a bent probe. For the same purpose nitrate of silver may be used, but in the writer's experience it is by no means so satisfactory, since its action is much more superficial. Whether chromic acid or nitrate of silver be used for the purpose, it is important to dry the surface of the granulation as thoroughly as possible before and after applying these escharotics. The galvano-cautery point has been recommended by some writers for the purpose of destroying granulations. It must be remembered, however, that this instrument radiates heat to a considerable extent into the surrounding structures, and it is quite possible that harm might result. For this reason the author does not employ the instrument in the ear.

In the majority of cases the discharge will be brought to a termination in the course of a few weeks by one or other of the methods described. In rare cases, however, the secretion continues to be poured forth in spite of treatment, and the surgeon should then make a careful examination for any constitutional weakness which may possibly be present. Thus, scrofulous individuals are more liable to be troubled with a long continuance of the discharge than those who are robust. Diabetes and arterio-sclerosis are also factors which tend to delay the cure. In the poorer classes insufficient and improper feeding is a disturbing factor in the treatment, and care should be taken to see that these conditions are, so far as possible, rectified by attention to the general health.

A local cause of the continuance of the discharge is, undoubtedly, caries or necrosis in the temporal bone. This is, perhaps, more common in the otitis of scarlet fever and diphtheria than in others. It is by no means always possible, however, to ascertain if the bone is affected, and, unless there are serious symptoms, no attempt should be made in the early stages to find out the existence of necrosis or caries by means of the probe.

In very rare cases, the discharge persists in spite of the utmost endeavours of the surgeon, and the disease becomes chronic. The treatment of these cases will be discussed later.

Having brought the secretion to a termination, the surgeon must use every means to restore the hearing to its previous normal condition. Fortunately, in most cases the hearing improves without any treatment, and reaches the normal shortly after the cessation of the discharge. The perforation almost invariably heals over, and in the author's experience the healing process always proceeds from above downwards.

The upper part of the perforation closes first, probably because the discharge accumulates in the lower part of the tympanum, and prevents healing at the lower margin of the exit into the meatus (Fig. 81). There are some cases, however, in which the hearing remains more or less impaired, and for these treatment must be carried out energetically. The air-douche is usually the simplest and most effective means of restoring the hearing. It should not be used too often at the beginning—not more, that is, than two or three times weekly —and at first the air should be blown in rather gently. If the air-douche fails, it may be that the catheter will succeed, and the latter instrument has this advantage—that the surgeon can hear by means of the auscultation-tube whether or not air has entered the tympanic cavity. Should even the catheter fail us, recourse must be had to massage either by means of Lucae's spring pressure probe (Fig. 95) or a pneumo-massage machine.

Some authorities recommend the use of the air-douche from the beginning, but it is difficult to understand what is gained thereby, and it is quite possible that the treatment might do harm.

In recent times, Bier's method of treatment by passive congestion has been tried in acute middle-ear inflammation ; but it is not free from risk, and it may be regarded as doubtful whether the course of the disease is favourably influenced in any case.

The treatment by vaccines introduced by Sir Almroth Wright has been applied to acute inflammation of the middle ear. It appears to be free from danger, but there is not yet sufficient evidence to show whether the disease is shortened in its course by this method.

The treatment of this disease by the ordinary methods described above is almost invariably so satisfactory that neither the treatment by passive congestion nor by vaccines has gained many adherents among aurists.

Endocranial Complications.—Although the cranial cavity is comparatively rarely infected from the middle ear in acute inflammation, there are occasional exceptions to this general rule. The surgeon, therefore, must be careful, when attending a case of acute otitis media, to watch for symptoms which may point to such serious conditions as abscess of the cerebrum or cerebellum, sinus thrombosis, extradural abscess, or meningitis (see p. 244).

Mastoid Periostitis. — In some cases acute middle-ear periostitis occurs over the mastoid process. This is more common in children than in adults, but is occasionally found in the latter. The condition is obvious on inspection, the tissues in the region being swollen and tender, and the auricle displaced outwards.

The treatment is surgical, and should be carried out without delay. An incision must be made down to the bone, a drainage-tube inserted and the wound treated on ordinary surgical principles. Sometimes, though not always, a fistula will be found leading through the bone to the antrum, and in these cases it is wise to enlarge the fistula and allow free drainage from the latter cavity.

Empyema of Antrum.—In nearly all cases of acute middle-ear inflammation the mastoid antrum is coincidently involved (Fig. 79), but, fortunately, in the majority this subsides along with the improvement in the middle ear. Occasionally it happens that the discharge remains pent up in the antrum, as evidenced by the continuance of the pain in spite of free drainage from the middle ear, and marked tenderness on pressure over the tip of the mastoid process. It is to be noted that frequently there is no periostitis or swelling in this region in these cases.

The only available treatment is to open the mastoid antrum by the simple, not the radical operation (see p. 281).

CHAPTER IX

DISEASES OF THE MIDDLE EAR (*Continued*)

Chronic Suppurating Inflammation of the Middle Ear (Otitis Media Purulenta Chronica).

CHRONIC suppurative inflammation of the middle ear is one of the most common diseases of temperate climates, and perhaps it is this familiarity with the disease which led the public in past times, both medical and lay, to treat it with the proverbial contempt. It was a contempt, however, for which the tribute that had to be paid was excessive. The seriousness of the disease is now recognized by all medical men, and it is the duty of these to point out to their patients the dangers of the condition. All suppurating ears are dangerous—some more, some less—and he is living in a fool's paradise who thinks that, since no evil effects have followed in the course of many years, he is safe from further trouble. The writer has seen death occur from meningitis, the result of a middle-ear suppuration which had lasted for fifty years. The passage of time does not to any degree guarantee the patient from serious consequences.

But there are other reasons beside the possibility of a fatal issue which call loudly for active treatment of all suppurating conditions in the middle ear. The continued inflammatory action which goes on in the mucous membrane of the tympanum always causes more or less deafness, which, if the suppuration is brought to a close, will in the majority of cases diminish to a very great extent. Again, the condition is a dirty one, and on that ground alone should be treated most carefully. The discharge, moreover, frequently has a more or less unpleasant odour, and for social reasons should be treated. It is possible that the mere existence of a suppurating ear may bring about a lowered condition of health. The writer has seen patients in which this apparently was the case, but they are rare. The converse is more likely to be true—that a condition of ill-health will keep up a suppuration from the middle ear which would cease under more favourable bodily conditions.

Etiology.—The majority of cases of chronic suppuration follow the acute disease when the latter has been left untreated. There are a few, however, which seem to come on insidiously—or, at least, appear without any of the usual symptoms of acute inflammation. It is possible that some of these, at least, are tubercular in their nature, for we know that an acute tubercular inflammation in the middle ear may occur without any pain whatsoever (see p. 240). Schwartze states that in very exceptional cases the disease may arise from extension inwards of a chronic inflammation of the drum membrane, or even of the meatus; and he cites, as an example of the latter, a case in which the middle ear became affected from a neglected chronic eczema of the meatus.

Pathology.—The anatomical changes in the middle ear vary within wide limits as regards their extent, but in their nature are similar to those which accompany purulent formation in other parts of the body. Hyperæmia is, of course, always present, as also is infiltration with leucocytes. There is always a certain amount of swelling of the mucous lining, and this may sometimes reach excessive dimensions. Occasionally the swollen mucous membrane fills up all the cavities of the middle ear. The mucous lining in some parts is eroded, and the ciliary epithelium is destroyed in those parts in which it normally exists. Connective-tissue formation results, and in some cases granulations are formed (Fig. 85), and these in their turn may become so large as to merit the name of polypus. Adhesions may form between various parts of the mucous membrane, with resulting anatomical changes in the relative position of the ossicles.

As a result of caries of the ossicles, these bones are frequently extruded (Fig. 86). The anvil is most commonly lost, next the hammer, while the stapes is rarely discharged.

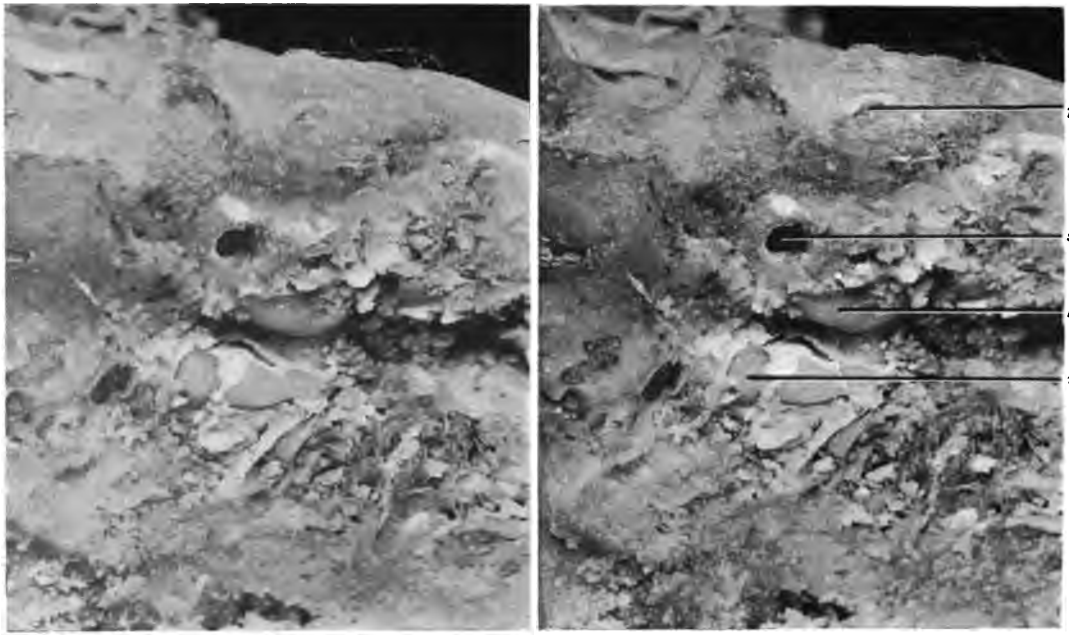
Frequently the anatomical changes are limited to certain portions of the middle ear, such as the tympanum proper or

Fig. 84.—Attic, Aditus, and Portion of Antrum from a Case of Chronic Suppurative Middle-ear Disease. The Tegmen Tympani et Antri has been Removed. $\times \frac{11}{9}$. Viewed from Above.

(Prepared and photographed by the Author.)

The cavities were filled with purulent secretion, which has been, to a large extent, removed. Numerous small masses of the coagulated secretion are still present, especially in the region of the hammer and anvil.

p, posterior limb of superior semicircular canal.
s, anterior limb of superior semicircular canal.
h, horizontal canal.
m, head of malleus; the pointer crosses the incus, the aditus, and the antrum.



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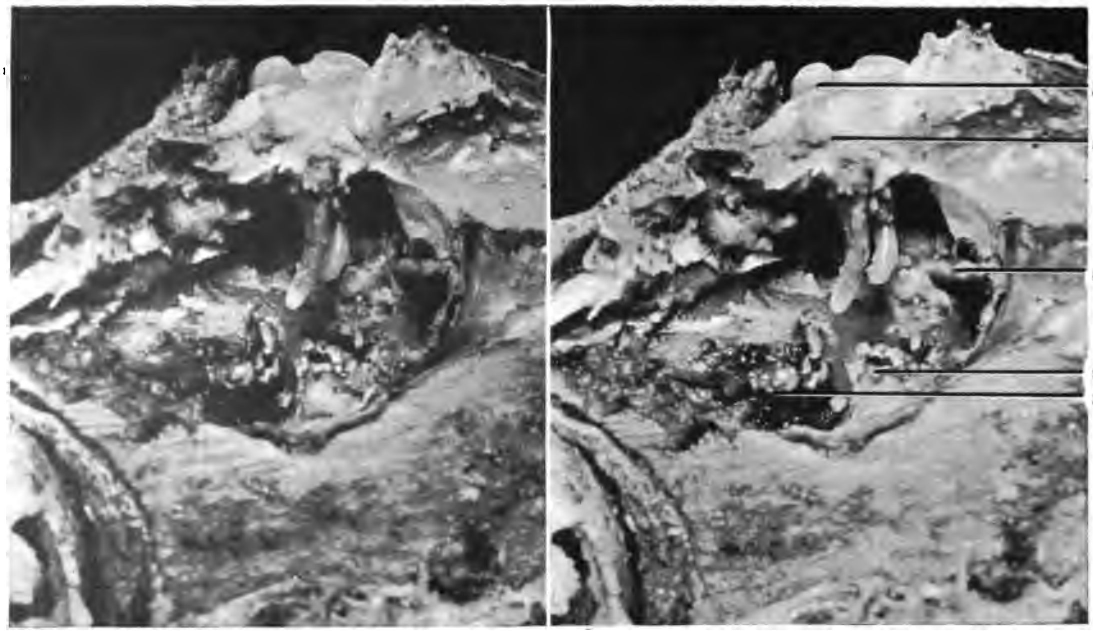

Fig. 85.—Left Middle Ear and Ossicles from a Case of Chronic Suppurative Middle-ear Disease. × 3½.

(Prepared and photographed by the Author.)

The outer and upper walls of the attic have been removed to show the secretion surrounding the neck of the malleus and body of the incus. The secretion has, for the most part, been removed from the tympanic cavity.

h, head of malleus.
s, purulent secretion in attic.
g, granulation springing from tympanic ring.
r, secretion lying in the niche of the round window.
p, granulation springing from promontory.

[To face p. 183.

the attic. The mastoid antrum, on the other hand, is never involved alone. In many cases all the cavities in connection with the middle ear are affected (Fig. 84), and in a small percentage the inner ear becomes diseased, while in others serious results may ensue from extension into the cranial cavity. But these will be described later.

When examined post mortem, the secretion may be seen filling all the cavities of the middle ear (Figs. 84, 85). Caries and necrosis of various parts of the walls of the middle ear may be present, and sometimes the whole petrous portion of the temporal bone is involved. Such was the case from which the specimens illustrated in Figs. 97 and 98 were taken. The whole pyramid of the temporal bone was carious, but the endosteum of the cochlea retained its shape, though the cavity of the organ was a mass of granulation tissue and pus. The vestibule and portions of the canals were completely destroyed, while other portions of the latter preserved their outlines. It is a curious fact that in this case deafness was the only symptom of ear disease apart from the discharge, and the patient did not die of any intracranial complication, but of malignant disease elsewhere.

The tympanic membrane is always affected to a greater or less extent in chronic suppuration of the middle ear, and the most obvious change in this structure is the existence of one or more perforations. These perforations have rounded edges, and are usually circular, elliptical or kidney-shaped. Frequently there is only one perforation, but it is not uncommon for two, or even three, to exist together. The margins of the perforation may be adherent in places to the promontory or other parts of the tympanum, and granulations not infrequently grow from the margins of the perforation or from the middle ear itself (Fig. 85). In some cases the whole membrane is completely destroyed, and under these circumstances the hammer is found to be absent. In addition to the perforation, the tympanic membrane, or what is left of it, is thickened, and is frequently the seat of calcareous deposit.

On microscopic examination of the mucous lining of the middle ear, the usual changes characteristic of chronic inflammation are to be found. The connective tissue is infiltrated with round cells and the bloodvessels are dilated. The periosteum is almost invariably affected to a greater or less extent, and this is not difficult to understand when it is remembered that the two layers—the mucous membrane and the periosteum—are in such direct union. This involvement of the periosteum may bring about hyperostosis or caries of the underlying bone.

The secretion which is poured forth from the inflamed surface is always more or less purulent, and its odour may be that of ordinary pus, sweetish and rather sickly. On the other hand, it frequently has a most disgusting smell, which may seriously affect the social life of the sufferer. A foul odour frequently indicates caries, but it is certainly not always a proof of this condition. The cause of the smell is merely the decomposition of the pus by putrefactive bacteria, and this decomposition may take place in any neglected case, or even in those which are well cared for.

The *bacteriology* of chronic suppurative otitis has been investigated by Milligan, Wyatt Wingrave, Zaufal, and others. It is similar to that of the acute form of the disease, but the infection is uniformly mixed and saprophytic organisms are abundant.

In regard to the other microscopic features of the discharge, Milligan found that the epithelial cells were flattened and squamous rather than columnar, as in the acute form of the disease. Lymphocytes are relatively more numerous in the chronic, and polymorphonuclear leucocytes in the acute affection.

Cholesteatoma.—In some cases of chronic otorrhœa the epithelium tends to grow inwards from the meatus or from the edge of the perforation, and cover the mucous lining of the tympanum and neighbouring cavities. When this occurs, the epithelial cells shed from the surface tend to gather into masses of more or less firm consistency, which are termed cholesteatomata. These masses by their pressure may cause erosion of the surrounding bony walls, and thus lead to intracranial or labyrinthine complications. Cholesteatomatous formations are particularly liable to arise in cases in which the perforation in the membrane reaches in some portion of its margin to the tympanic ring. It may be added that middle-ear suppuration associated with the formation of cholesteatomata is particularly difficult to treat.

Symptoms and Signs.—The feature of chronic middle-ear suppuration which is of most importance is the *discharge.* In saying this it is important to remember that the patient and the surgeon look upon the disease from different standpoints. To the patient, therefore, the discharge, if it be very slight in amount, is not of much significance, and the symptoms of which he complains are the deafness or the odour from the ear. But to the surgeon these symptoms are secondary in their significance. The reason of this difference in the point of view lies, of course, in the fact that the surgeon knows that there is a certain danger to life in all suppuration occurring in the middle ear, however slight the amount. The patient does not usually realize this.

The amount of discharge may vary within very wide limits. It may be so slight as to become dry before it reaches the outer parts of the meatus, and the patient may thus be quite unaware of the fact that he has a suppurating ear at all. On the other hand, it may be so profuse as to run down on to the neck within an hour of complete cleansing of the meatus. The secretion produces in some cases an eczema of the meatus associated with a certain amount of infiltration of the tissue. The eczema may extend into the concha, or even down over the lobule. This eczema is, of course, the result of the irritation caused by the discharge, and may appear either on account of a skin which is easily irritated, or because the discharge is of a particularly irritating nature. The glands in the neck are sometimes enlarged, but this does not occur so frequently as might be expected. It is seen more often in children than in adults, and in the latter, indeed, is uncommon unless complications have occurred. The enlargement of the glands may indicate a tubercular element in the disease, but does not do so by any means in all cases.

On examination with the speculum, the meatus is seen to be partially filled with pus, and on removal of this various appearances may be seen. The membrane may appear but little altered in colour, and the perforation may be recognized without any difficulty. Examination presents in most cases only slight difficulty to the experienced observer, but the beginner should always pursue his inspection in a methodical manner. The author, in giving instruction, advises the student to look carefully for the short process of the hammer. It is not always easily found, but of all the normal anatomical landmarks it is the one which is generally most easy to find. Having obtained this landmark, is is usually possible to trace the handle of the hammer downwards and backwards, but in some cases the distortion of the parts is so great that the handle is almost horizontal in position. If the short process of the hammer is not visible, an edge of a perforation may be discovered; and having once found even a small portion of the edge, the greater part may usually be made out by tracing the margin from that already observed. In some cases the hammer and the whole of the tympanic membrane have disappeared. In such the head of the stapes may sometimes be seen close to the posterior and upper margin of the tympanic ring, but, unfortunately, this is a landmark which the observer may not be able to discover. Occasionally the field usually occupied by the membrane appears as a uniform, red, velvety surface of mucous membrane, in which no anatomical characteristic structure is to be found. When the discharge is very scanty, it sometimes dries and forms scabs over parts of the membrane, and these must be removed before the changes in the appearance of the membrane can be observed.

Granulations and polypi sometimes fill the whole diameter of the meatus, and prevent a view of the membrane altogether. Granulations are recognized by their pulpy consistency and their colour, which varies from pink to crimson (Fig. 69). Polypi are recognized by their pearly or faint pink colour, rounded outline, and proximity to the speculum (Fig. 70). Granulations and polypi must be removed before a satisfactory view of the deeper parts can be obtained.

Sometimes the meatus is occluded by epithelial and cholesteatomatous débris, which must be removed to allow of thorough inspection. As remarked before, the whole membrane may have disappeared, and nothing but the inner wall of the tympanum will then be seen. The *perforation* (or perforations) present every variety of outline and position (Figs. 64, 65, etc.). They have one feature in common, however—that is, a curved outline. The recognition of a perforation is usually very easy, but there are two possible fallacies. An atrophic patch in the membrane sometimes, though rarely, has a sharply defined outline and appears dark, thus simulating a perforation very closely. The other fallacy lies in the possibility of mistaking a cicatrix, which has filled up an old perforation, for an existing perforation. Both these fallacies can be eliminated by the use of the air-douche. If air be driven into the tympanum, it will rush out through the perforation, causing at the same time a whistling sound. If, however, only a cicatrix or an atrophied patch be present, the air will not escape from the drum, and there will be no whistling sound. The effect of inflation upon a cicatrix or a patch of atrophied membrane is to blow out the resilient tissue into the form of a bubble projecting outwards. By observing these precautions, therefore, there is no fear of making an error in diagnosis.

There is usually only one perforation, but two, or even three may be present. When there are more than two, it is usual to find that one of them is in the flaccid membrane. The size of a perforation may vary from that of a pin-point to that of the membrane itself. The cause of the differences in the size of perforations has not yet fully been determined. It certainly does not depend either upon the duration of the discharge or upon its amount. Moreover, the writer has satisfied himself that it is not in proportion to the severity of the acute inflammation from which the chronic condition has arisen.

In tubercular cases the perforation is usually large, but this is probably explained by the fact that in these the healing of any tissue proceeds with difficulty or not at all. According to Jacobson, the perforations which result from scarlet fever, diphtheria and typhus are apt to be large.

The colour of the surface which is seen through the perforation varies. It may be red, in which case the mucous lining has not been covered with epidermis; or it may have a pearly-grey lustre if the epidermis has advanced into the cavity of the tympanum and covered over the mucous lining beyond the aperture. In some cases granulations grow out and occupy the perforation, so that the edges of the latter are not visible. If healing has taken place in parts, the margin of the perforation may be adherent at these portions to the inner wall of the tympanum.

Perforations in the posterior superior quadrant sometimes permit of a remarkably clear view of the long process of the incus, if that bone is still present, and of the head of the stapes together with the posterior crus of the same bone (Fig. 72). The round window is occasionally seen in perforation of the posterior quadrant, but it is to be remembered that, as viewed from the position of the observer, it appears crescentic, on account of the oblique position in which it is seen. It will naturally be understood that these structures last described will only be visible when the mucous membrane of the tympanum is not swollen to any great extent.

Less frequently observed than the perforations just described are those which are found in Shrapnell's membrane (Figs. 68 and 75). They occur when the suppuration takes its origin in Prussak's space, and indicate very frequently the existence of caries of the neck or head of the hammer, or of the outer wall of the attic. Although very frequently possessed of curved edges, these perforations are not uncommonly triangular in shape. Suppurations occurring in the attic and finding exit through Shrapnell's membrane, are apt to run a very chronic course, and are difficult to bring to a termination. There are several reasons for this. Caries of the neck of the hammer, of the anvil, or of the outer wall of the attic, is frequently present as above stated, and keep up the suppurative process. The comparatively small size of the perforation, also, does not permit of that free exit of pus which is afforded in the larger perforations of the membrane proper; and for the same reason it is difficult to bring medicaments into contact with the diseased tissues. The frequent presence of cholesteatomatous masses also tends to keep up the discharge and prevent satisfactory local treatment.

In contradistinction to perforations in the membrane proper, these under discussion do not, as a rule, permit of the passage of air from the Eustachian tube through the middle ear and out into the meatus; hence, in making a diagnosis, we must remember that the absence of the whistling sound on inflation through the nose does not indicate absence of a perforation in Shrapnell's membrane. At first sight it might appear difficult to explain this, but it must be remembered that the natural communication between Prussak's space and the tympanum proper is very narrow, and may easily become completely obliterated from the swelling of the tissues which must occur in suppurative inflammation of the little cavity.

The prolonged suppuration which exists, whether it be

Fig. 86.—Caries of the Incus. × 3. Removed during the Radical Mastoid Operation.

(Prepared and photographed by the Author.)

l, carious surface at base of long process which has been eroded away. *s*, short process.

[*To face p.* 188.

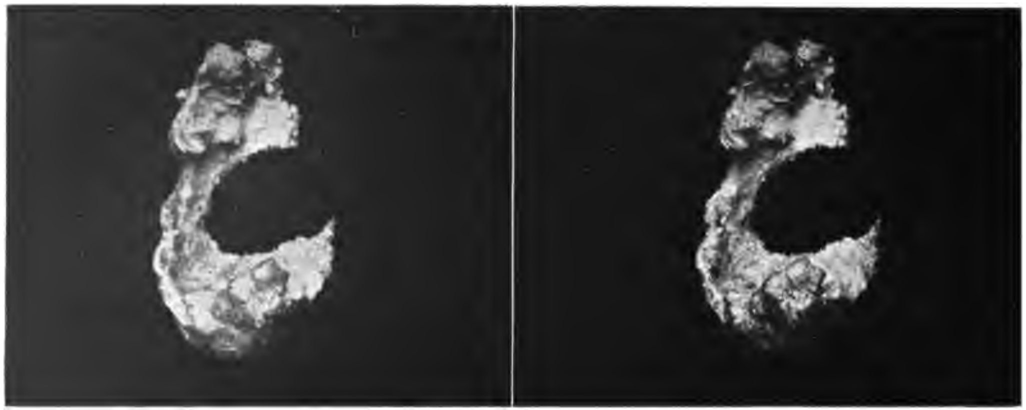

Fig. 87.—Sequestrum removed from the Region of the Carotid Canal during the Radical Mastoid Operation. ×2. From a Case of the Author's.

(Photographed by the Author.)

[*To face p.* 189.

limited to portions of the middle ear only or involve the whole cavity, leads frequently to *caries* (Fig. 87). Thus, the ossicles may become necrosed in whole or in part (Fig. 86). Of these, the incus is most usually affected, next the hammer, and much less frequently the stirrup. The outer wall of the attic is a favourite seat of necrosis. In the case illustrated in Fig. 75 this has occurred, and the subsequent discharge of the carious bone has brought about the cure of the disease. The Fallopian canal is sometimes affected by necrosis of its walls, with consequent extension of the inflammatory action into the nerve and subsequent facial paralysis.

Deafness to a greater or less extent is invariably present in chronic suppuration from the middle ear, but the degree varies within wide limits. It may be so great that the patient can only hear the voice when shouted close to his ear, or it may be so slight that a stranger would not be aware that the patient was deaf at all. It is never absolute unless the inner ear is affected coincidently. This latter point is of value in diagnosis, for when the question arises, in regard to intracranial complications, as to whether the inflammation had extended into the cranial cavity by way of the labyrinth or not, the presence or absence of hearing-power in the affected ear is a crucial test. The subject will be referred to later when intracranial complications are discussed.

The degree of deafness, as stated above, varies within wide limits, but it is by no means always easy to say why this should be. Contrary to what might be expected, the extent to which the membrane has been destroyed has but little influence upon the degree of deafness. This fact was brought home to the writer most forcibly in the case of a boy who consulted him for suppurative catarrh of both middle ears of several years' duration. Both tympanic membranes, with the exception of a small patch in the anterior superior quadrant, had completely disappeared; yet, after the cure of the suppuration, the patient heard so well that neither he nor his friends thought that he was deaf at all. The same case illustrates another point to which attention was originally drawn by Bezold. This aurist pointed out that, though the hearing for most notes might be remarkably good in the entire absence of the membrane, yet for the very low notes its presence was necessary for their transmission to the inner ear. When the boy left school, he desired to enter the medical profession, and passed successfully through his first year at college. When he came to do clinical work, however, he found that he was unable to hear the sounds of the heart or of respiration by means of the stethoscope, in spite of the utmost patience and concentration. He again came to me in his difficulty, and a careful examination of his hearing-power was made. I found that, though the hearing was perfect for the notes of high and medium pitch, it was seriously affected for the very deep notes. This, therefore, explained his difficulty in the use of the stethoscope, for the tones which go to compose the sounds made by the heart and lungs respectively are composed for the most part of low notes. Unfortunately, there is no means of relief for such cases, and the young man had to relinquish the prospect of entering the medical profession, in spite of the fact that he was otherwise a first-class student.

Although it is not always possible to ascertain in every case the cause which affects the hearing in suppurative catarrh, this is probably only due to the fact that we are not able by inspection to have a complete view of the structures involved, particularly of those in the region of the oval and round windows. In all probability, the chief factor which determines the extent of the deafness is the mobility of the stapes and of the membrane of the round window, excluding, of course, such obvious obstructions to the entrance of sound-waves as polypi, granulations and swollen mucous membrane.

In connection with this subject, it is interesting to note that when the perforation is confined to the flaccid membrane the hearing-power is usually remarkably good, and indeed, the patient is frequently not aware of his deafness at all. The explanation of this probably lies in the fact that the ossicles, and particularly the stapes, are not affected as regards their mobility, and that the mucous membrane in the region of the two windows is not swollen by inflammation. This absence of deafness to any noticeable extent in cases of perforation on Shrapnell's membrane should be remembered in the matter of treatment. Every effort should be made to cure such conditions by conservative means, and not to resort to operative procedures so readily as is sometimes done.

Pain is not a characteristic feature of chronic suppuration; but this statement must, of course, be qualified. So long as the outlet for the discharge is free, pain will not be complained of by the majority of patients. But should obstruction occur, with consequent retention of pus, the symptom will make its appearance almost at once, and usually with a considerable degree of severity. Should the outlet become free again, the discharge reappears and the pain passes off. But there are other cases in which pain may occur even when the discharge is free. This may indicate either caries of the walls of the middle ear or an extension of the disease into the cranial cavity.

An occasional, if rather uncommon, symptom of chronic suppuration is *facial paralysis*. It may be transitory or permanent. When it depends merely upon the pressure of the exudation which has found its way into the canal of the facial nerve, the paralysis passes off when the exudation escapes from the canal. It is probable also that a neuritis may occur without destruction of the nerve fibres, and in these cases also recovery will ensue, though it will be slow. On the other hand, the nerve fibres may be completely destroyed in the suppurative process, and from this there is no recovery, the patient remaining for life without expression upon the affected side of the face. Facial paralysis usually indicates the existence of caries, but it may occur without this condition, and must not therefore be looked upon as a certain sign of it.

Diagnosis.—The recognition of suppurative catarrh of the middle ear is, except in the rarest cases, without the slightest difficulty. Sometimes the discharge is so little in amount that it dries almost immediately and forms a scab, and on inspection no pus is seen. If, however, this little scab be removed with a blunt probe, a minute drop of discharge will be seen underneath it, and enable the surgeon to recognize the condition. The cases in which this occurs most frequently are those in which the suppuration is limited to the attic and the perforation is in the flaccid membrane. In rare circumstances a similar condition may be found in other parts of the membrane.

Treatment.—With regard to the treatment of chronic suppuration, one of the most important points is to convince the patient that treatment really is very necessary. The indifference with which patients usually regard this serious condition is remarkable, with the result that many lives are lost annually which might have been saved had the sufferers been alive to the dangerous nature of the disease. When a patient is known to have a suppurating middle ear, the medical attendant fails in his duty to the patient if he does not insist upon having the condition rectified.

The methods of treatment of suppuration in the middle ear are too numerous to be described in detail in all cases. A few of the more important methods will be described, and others which have not appeared to be so satisfactory will merely be mentioned. There are, however, certain general principles which should be attended to in all methods.

Since all local conditions are influenced to a greater or less extent by the *general health*, it is clear that this should receive attention in all cases. Thus, in the very poor, the supply of nourishment is often insufficient, and the surgeon will attempt to combat the suppuration in vain if the tissues are not getting a proper supply of healthy blood. The patient, therefore, must be well fed. In other cases, particularly those which are tubercular, cod-liver-oil, petroleum emulsion, and iron should be administered, and the latter drug should also be given when anæmia is present. If any general bodily condition, such as diabetes, is affecting the patient, it must be treated with the utmost care, for the suppuration in these subjects will almost certainly continue so long as the general disease is allowed to run unchecked. If there be reason to suspect syphilis, iodide of potassium and mercury must be given, although the suppuration is usually independent of the general infection. In very stubborn cases residence in a dry climate has a beneficial effect, but, unfortunately, it is frequently difficult to obtain proper local treatment in suitable climates. If, however, proper medical attention can be given to the patient, and if his circumstances permit, there is no doubt that he has a better chance of recovery under these conditions. In regard to this matter, however, it should be mentioned that the seaside is, on the whole, not so good as inland climates, probably on account of the moisture which is always more or less present by the sea.

It is necessary to emphasize again the importance of rectifying any catarrhal or suppurative condition in the nose and naso-pharynx. The effect of local treatment in the ear will in large part be annulled if infection by way of the Eustachian tube is constantly taking place. In regard to this important subject the reader is referred to Chapter VI.

The most important matter, however, is the local treatment of the disease. In former times astringents were used locally to a great extent. With the advent of antiseptic surgery and the knowledge of the causes of suppuration, these applications came to be used less, and germicides more. More recently still it has been found that even germicides fail very frequently, and aurists now consider that the most important matter in the treatment of the disease is the removal of the secretion. This removal is effected by various methods, some of which will now be described.

The method most commonly employed for the purpose of removing the discharge is that of syringing through the meatus. The method is not very satisfactory in obstinate cases, since the water does not by any means get into all the various cavities in which pus may be present. In simple cases, however, it is usually quite sufficient for the purpose, and the surgeon should not employ the more complicated methods to be described later, if the simple syringing will suffice. There is no need to describe in detail the method of syringing through the meatus; the danger of too forcible syringing should, however, be mentioned, since under certain circumstances harm may result if the jet of water is too powerful. The liquid employed for the purpose should not be water alone, but should contain some ingredient either of an astringent or antiseptic nature. The solutions employed for syringing are numerous, the most important being boracic acid, 10 per cent., carbolic acid, 1 per cent., sulphate of zinc, 1 per cent., chloride of zinc, 1 per cent., and so on with other antiseptics and astringents. Solutions of ordinary sanitas are in general quite as satisfactory as those just mentioned. No doubt there are cases in which the former solutions will be more efficacious than sanitas, but such are few in number. The strength of the solution employed is 25 per cent.; it is not painful or irritating, and the smell is pleasant rather than the reverse. In all probability, sanitas owes its value to the peroxide of hydrogen which it contains.

The writer has found solutions of peroxide of hydrogen equal in value to those of sanitas for the purpose of

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cleansing the ear. The strength used varies from 10 per cent. to 50 per cent., and none of these solutions cause pain save in rare cases. This substance has, as is well known, the peculiar property of forming a foam when it comes into contact with pus, and in all probability the bubbling and foaming which result when the substance enters the tympanum will help to clean that cavity more thoroughly than other solutions used in the same way.

Another efficacious solution is that of chlorine-water, particularly in those cases in which the secretion is foul-smelling. The strength employed is 1 part of chlorine-water to 4 parts of pure water, or, if this should cause pain, it may be diluted to half that strength. The smell of chlorine is disagreeable to some people, and the substance has not such great advantages over others that patients should be inflicted with the smell of it when other solutions may suffice equally well. Its chief value lies in its deodorant properties, and, as will be seen later, there is another and more satisfactory way of removing the odour. If chlorine-water be used for syringing, it must be dried out very carefully immediately afterwards in order to prevent excoriations in the meatus. It must be remembered that chlorine acts chemically upon most metals, and must be used with a glass syringe.

Formalin in weak solution has in recent years been recommended by Lucae for the purpose of syringing out the discharge. This substance is a powerful germicide, but, unfortunately, it is also extremely painful in anything but the weakest solutions. Ten to twenty drops of formalin in a pint of water is quite strong enough, at any rate at the commencement of treatment; and, indeed, it will be found that patients will not stand stronger preparations even after having used it for some time. Should any of the solution pass down into the pharynx, it will produce a burning sensation in the throat, and the patient should then gargle with cold water and swallow some at the same time. The writer has not found the formalin treatment very satisfactory.

According to many authors the instillation of water, with or without chemical substances dissolved in it, is not a satisfactory form of treatment under any conditions. It must not be understood that water is not to be syringed into the ear, but only that it must be carefully dried out afterwards. The author's own experience in this matter is in accordance with the view just expressed, and he now never employs watery solutions except for the immediate purpose of removing discharge.

The first to institute the ***dry method of treatment*** was Bezold (*Arch. f. Ohrenh.*, 1879, S. 1), and the substance he employed to carry out the principle of the method was boracic acid powder. There is no doubt that boracic acid powder owes its success chiefly to the fact that it absorbs the discharge. This method of treatment is, on the whole, perhaps the most generally valuable of all, and it has held the field for almost twenty years. Like all other applications it has disadvantages and is not applicable to all cases. One of its supposed disadvantages is the possibility of blocking up the perforation through caking of the powder, with subsequent pain and other symptoms of retention of the discharge. The possibility of such an occurrence in chronic conditions must in reality be somewhat remote. The author used this method for many years, and during all that time no case occurred in which the boracic acid powder caused symptoms of obstruction. A more real objection is the occasional occurrence of a slight eczematous condition which the powder sometimes calls into existence on the walls of the meatus. In order to obviate this, Jacobson used a mixture of boracic acid and burnt alum in the proportions of 10 parts of the former to from 1 to 3 of the latter. Before insufflating the powder the ear must be thoroughly cleansed and, what is most important of all, it must be dried as carefully as possible. The method of drying out the ear is described on p. 108. After this has been done, sufficient powder is taken up into the insufflator (Fig. 51) to fill the inner third of the meatus. It is blown in by the insufflator and left there for twenty-four hours. If at the end of this time the powder still appears dry, it should be allowed to remain; but if it has been swept away by the discharge, the procedure must be repeated. The treatment should be carried out by the medical attendant daily, three times a week, or twice a week, according to the period of time during which the powder remains dry after it is insufflated.

In recent times the dry treatment has been pursued more actively by other means than boracic acid powder. Thus, some aurists omit syringing or application of water to the ear in any form at all, but merely clean the ear thoroughly with pledgets of cotton-wool, and then introduce a thin strip of gauze as deeply into the meatus as possible, the remaining part of the meatus being packed gently with the gauze. This, strictly speaking, is the dry method of treatment, and, provided it can be carried out sufficiently thoroughly, is one of the very best. The difficulty in the matter of treatment lies in the fact that the gauze is frequently saturated with the discharge in the course of a few hours, and it is not always convenient for the patient to come to the surgeon, to get a fresh piece inserted, so frequently as twice a day. If the amount of discharge is only moderate, the gauze is not saturated within twenty-four hours, and this allows of the treatment being carried out with only one visit a day. The gauze, needless to say, should always be inserted by the medical attendant, as it is important that the deeper part of the strip should be in contact with the tympanum or tympanic membrane. The principle which underlies this method of treatment is the removal of the secretion by means of the capillary attraction of the gauze, and the latter, therefore, ceases to be of any value as soon as it is saturated. Indeed, when saturation has been reached, the gauze is worse than useless, since it now acts as a plug, causing more or less obstruction. It is for this reason that the ear must be dressed so frequently.

Alcohol in various degrees of dilution has been used with great success in the treatment of suppuration in the middle ear. In one sense of the term, alcohol may be looked upon as being among those agents which are used in the dry method, for the beneficial effect is produced by its power of abstracting water from the tissues. It may therefore be looked upon as one of the agents by which we avoid the introduction of water into the meatus. The method of carrying out the treatment by alcohol has certain very distinct advantages. In the first place, it can be applied by the patient himself at home. It is, moreover, simple in its performance, is not open to the objection that there can be any possibility of its causing retention of pus, and, if properly carried out, is usually painless. The method of treatment is as follows. The ear is dried out thoroughly in the usual way, and the head is then laid on the table, with the affected ear uppermost. In commencing treatment the alcohol must be diluted with water down to a strength of about 20 per cent., and of this half a drachm is poured into the meatus and allowed to remain there for about ten minutes. If much pain is experienced, the alcohol should be syringed out at once with warm water, and a weaker solution tried, or another form of treatment should be adopted. In the writer's opinion, the latter course should be followed, since, if the patient cannot stand 20 per cent. of alcohol at the beginning, it is not probable that he will be able to stand the higher strength within anything like a reasonable time. If, however, there is no pain on using the 20 per cent. solution, a 50 per cent. strength should be used on the next occasion; and should this, again, cause no smarting, the strength may be raised to 80 per cent. or 90 per cent. of alcohol. This strength should be employed for a few days or a week, but if there is still no improvement with it, absolute alcohol may be used. The applications should be made twice or three times a day, but, as McBride has pointed out, a syringe ready filled with warm water should always be at hand, in order to wash out the alcohol instantly if severe pain should occur. In some individuals the instillation of alcohol causes symptoms of fulness in the head, giddiness, or headache, and in these subjects it should be avoided. The alcohol treatment is particularly valuable in cases in which the mucous membrane is swollen, or where numerous small granulations are present, the explanation of its value being the fact that it extracts the water from these tissues.

Another method of treatment is that introduced by the writer (*Lancet*, April 18, 1903), in which the local application is a saturated solution of iodoform in anilin. This method has the advantage, like alcohol, of not causing any obstruction to the outflow of pus, and is therefore quite free from danger in that respect. It has, besides, the property of at once removing the objectionable smell of the discharge. The method is painless, and, if properly employed, is free from danger. On the other hand, if the surgeon is careless with regard to the amount used or the method of its introduction, he may have trouble from the absorption of too much anilin. The instructions given on p. 112 are therefore to be carefully followed. The ear is very thoroughly cleaned and dried after preliminary syringing with water, and the head is then turned to the side, with the affected ear uppermost. Ten to twenty drops of the solution are next poured into the meatus, and allowed to run down into the tympanum. The head is kept in this position for a period of from five to ten minutes, and the solution is thoroughly mopped out from the meatus until the cotton-wool pledgets come out dry. The application of the anilin is nearly always painless, but in some cases there is a slight amount of smarting. This is never sufficient to require the immediate removal of the anilin, and it does not indicate any reason for discontinuing this method of treatment. In some cases it is desirable to dilute the anilin solution of iodoform by the addition of olive-oil or parolein, so that there are equal parts of the anilin and the oil. Of the two diluents the writer prefers the olive-oil, though both precipitate a considerable proportion of the iodoform from the anilin. The precipitation of the iodoform does not seem to have much effect in diminishing the efficacy of the preparation, and it makes the measuring of the dose easier. The applications should be made every other day, and on the intervening days other forms of treatment may be employed by the patient at home. In infants and young children the method of application is different. In these cases one or two minims of the solution can be applied on a small piece of cotton-wool at the end of a probe, which is then pushed deeply into the meatus until the saturated cotton-wool reaches the membrane, where is it rotated a few times and the solution pressed out. The excess is then dried out.

This method of treating suppurative catarrh is, with one exception, applicable to all cases. Some individuals are possessed of a skin which is highly sensitive to anilin. In these subjects the mere painting of a minim of anilin on the skin will raise an erythematous blush on the part touched in a few hours, and this is associated with a considerable degree of itchiness. The erythema lasts for two or three days, and if the drug be applied during this period the irritation is increased, and the condition after several applications may reach the stage of eczema. It is obvious, therefore, that we cannot apply anilin in any form to these patients more than once, or at the utmost twice a week. The application, even if made once a week, is sufficient to get rid of the objectionable smell of the discharge, and for this purpose it may be used in susceptible individuals. The use of anilin solutions in the manner described above does not prevent the simultaneous employment of other methods, and in those individuals who are possessed of the idiosyncrasy just mentioned the solution may be applied once a week, other lines of treatment being adopted in the intervals. Patients should never be allowed to use anilin themselves.

By some one of the methods described the surgeon will be able to bring the disease to a termination in the great majority of cases suffering from purulent otorrhœa. Numerous other substances have been used in the treatment of this condition. Of these, emulsion of iodoform in glycerine, chromic acid in 3 per cent. aqueous solution, chinosol in powder, aristol and xeroform in the same condition, and salicylic acid in watery or alcoholic solution, have all been used.

Special Difficulties in Treatment.—In the foregoing pages the treatment of suppurative disease of the middle ear has been described for general purposes. But there are many cases in which these measures will not of themselves suffice. Thus, if *granulations or polypi* be present, the applications will not reach the real seat of the disease, and the discharge will continue. They must therefore be removed or destroyed. Polypi are best removed by means of Wilde's snare (Fig. 83). By means of this instrument a delicate wire is inserted into the meatus between the wall of that channel and the polypus. The loop is manipulated gently until it encircles the base of the growth, and is then tightened. If the wire is sufficiently fine, it sometimes cuts through the pedicle, and the growth can be removed with the syringe without any traction upon its base. In other cases the tissue is too tough, and the polypus must then be wrenched away with the snare. The bleeding which follows is frequently considerable, but never of more than a few minutes' duration. The pain of this little operation is usually insignificant, and it may be diminished, though not quite annulled, by means of a 15 per cent. solution of cocaine. Not infrequently there is more than one polypus, and if the parts are visible after the removal of the first, the others may be extracted in the same way. Usually, however, the bleeding prevents this undertaking until some little time has elapsed. It will naturally be understood that the meatus is, as far as possible, cleansed by an antiseptic solution before the removal of the growth. Granulations, if they are attached by a pedicle, are removed in exactly the same way as the polypi, but it is not always quite so easy to encircle the base of the granulation, on account of its smaller size. The use of the hot wire snare has been recommended by some writers for the removal of polypi and granulations, on account of the absence of hæmorrhage with its use. Most authorities, however, advise the use of the cold snare, since the hot wire usually produces considerable pain, and sometimes a severe reaction.

Granulations which have not a pedicle cannot be removed by means of the snare; they must be destroyed either by chromic acid or by the electro-cautery point. Of these two, chromic acid is to be preferred, for the same reason that the cold wire snare is preferable to the hot. A probe roughened at the bulbous extremity is heated in the flame of the spirit-lamp and immediately dipped into a bottle containing crystals of the acid; a few crystals will be melted by the heat of the probe, and will adhere to the bulb, forming a coating of the acid. The surface of the granulation is dried carefully with pledgets of cotton-wool, and the chromic acid on the probe is then applied to the granulation and pressed against it. The acid should be kept in contact with the granulation for a period of about half a minute. A scab will then have formed upon the growth, which will drop off in the course of a few days. The excess of chromic acid should be mopped off immediately after the application. During the procedure there is usually no pain, nor does any supervene afterwards. In exceptional cases, however, pain may occur, but it may be annulled by syringing with warm water, and then applying a solution of cocaine, after which the re-application will be painless. It is usually necessary to repeat the process several times before the granulation completely disappears. and it will naturally be understood that a second application is not made until the scab of the previous one has separated. Nitrate of silver has been recommended instead of chromic acid, but its action is much more superficial, and it has no compensating advantage. Other substances also have been recommended for the same purpose, but none of them are in any way superior to chromic acid. The electro-cautery point has, however, one advantage—the granulation shrivels up rather more quickly under its influence than under that of chromic acid. It has, however, the disadvantage of causing more pain at the time, and is much more likely to be followed by inflammatory reaction. Except, therefore, in the case of very tough granulations, chromic acid is to be preferred.

One of the difficulties occasionally met with in treatment is the presence of a *perforation too small* to allow of satisfactory drainage from the middle ear. In these cases the perforation should be enlarged downward by an incision extending to the lower margin of the membrane.

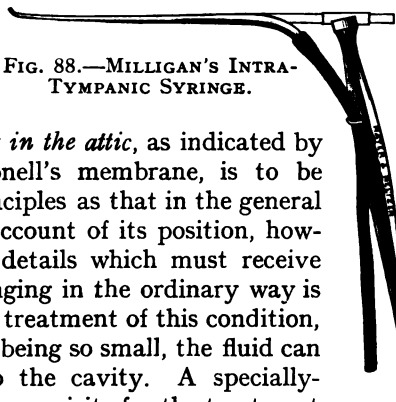


FIG. 88.—MILLIGAN'S INTRA-TYMPANIC SYRINGE.

Suppuration occurring in the attic, as indicated by a perforation in Shrapnell's membrane, is to be treated on the same principles as that in the general tympanic cavity. On account of its position, however, there are certain details which must receive special attention. Syringing in the ordinary way is of but little value in the treatment of this condition, because, the perforation being so small, the fluid can hardly obtain access to the cavity. A specially-shaped tube, therefore, is requisite for the treatment of such cases, and an instrument of this description, designed by Milligan, will be seen in Fig. 88. The stem of the nozzle must be of such a length that it can reach from the outer limit of the speculum to the perforation. It should be so thin that it obstructs the view of the membrane as little as possible, and at its outer extremity it should be bent to an obtuse angle. The fluid to be injected may be contained either in the barrel of a syringe or in an india-rubber ball, and is injected into the thin tube and so into the attic. The fluids which may be used for injection are the same as those which have already been mentioned as useful in the treatment of ordinary suppuration. It is even possible to insufflate boracic powder through one of these intratympanic syringes, as they are termed, and such a method of treatment has been recommended by Bezold. Unfortunately, the powder usually cakes in the tube and prevents the further insufflation. The introduction of the tip of the tube through the perforation requires a little dexterity, which, however, is soon acquired by practice. The procedure should be repeated two or three times a week for several weeks if the method is to have a fair trial.

Suppuration from the attic produces less deafness than that from the general tympanic cavity. Indeed, in quite a considerable number of cases there is no perceptible deafness at all so far as the patient is aware, and even when the hearing is tested in the most delicate manner the loss is found to be insignificant. For this reason, every possible care should be taken to bring the discharge to an end without having recourse to operative procedures on the membrane or ossicles. With patience on the part of the patient and of the surgeon, a considerable proportion of cases can be cured without any destructive operative undertaking. It is taught by some surgeons that in cases of perforation in Shrapnell's membrane the discharge rarely ceases under these mild measures. But this is putting the matter, perhaps, rather too strongly. It is, however, perfectly true that these cases are more difficult to treat than those in which the perforation is in the membrane proper, but the fact that the hearing is usually so good is a strong reason for delaying operative procedures which will diminish it.

The presence of *cholesteatomata* is sometimes an insuperable obstacle to the cure of middle-ear suppuration by means of local applications. Milligan has recommended the use of salicylic acid dissolved in anilin for the purpose of softening and removing the cholesteatomatous mass, and this is a more rational application than watery or glycerin solutions of bicarbonate of soda and other ingredients. These cases frequently require operative treatment for their cure, but milder measures should always be given a fair trial, unless there are symptoms necessitating operation (see p. 203).

Caries of the wall of the tympanum or of the ossicles is another frequent cause of the continuance of suppuration in spite of treatment. Indeed, it is rare to find these cases recovering without recourse to operation, but such a fortunate result does sometimes happen if the diseased part is very small in area.

Empyema of the antrum greatly increases the difficulty of cure by local applications. It is frequently impossible to diagnose the condition, but bulging of the upper posterior wall of the meatus is suggestive.

Tubercular cases rarely, if ever, heal by local applications (see p. 241).

When, in spite of local applications, the discharge continues, the surgeon must consider what operation is most suitable for the particular case. The factors upon which his decision is to rest are described on p. 278 *et seq.*, and the details of the various operations are referred to in the section on Operative Procedures.

Treatment of suppurative ear disease by the measures just described should be persevered with for six months, or even a year, before recourse to operation, unless symptoms supervene which demand interference of a more severe kind, or when there is quite obviously no improvement at all after treatment of various kinds for two or three months.

The great majority of cases of suppurative disease of the middle ear can be brought to a termination without having recourse to the radical mastoid operation. It must not be supposed, however, that treatment by means of local applications may be pursued in all cases for such a long time as that indicated above for the majority. A certain proportion present symptoms that may be termed 'warnings,' and in these the mastoid antrum should be opened with little or no delay. By far the most important symptom in these cases is repeated attacks of pain, often associated with diminution in the amount of discharge. Such cases should be operated on without delay.

The presence of a narrow fistula leading into the mastoid antrum also calls for operation, not so much on account of the immediate danger as because it usually indicates such implication of the walls of the antrum that the local application of drugs is not at all likely to effect a cure.

Such symptoms as giddiness and staggering gait frequently, though not always, indicate involvement of the labyrinth in the suppurative process, and call for operation.

In spite of the utmost care and the most skilful attention that can be bestowed upon cases of otorrhœa, there remains a residuum in which the discharge continues. It is difficult, for obvious reasons, to estimate with any degree of accuracy the percentage of cases which resist treatment. In the first place, much depends upon the class to which the patient belongs. Thus, in the wealthier classes, where there is every opportunity for the surgeon's orders being carried out to the utmost detail, and where the patient may be put under the influence of the most favourable surroundings both in the matter of food and climate, the percentage of incurables is small. On the other hand, a patient living in the dirty slums of our large cities, ill-fed, breathing a foul atmosphere, and existing under insanitary conditions, offers a poor soil for the surgeon's efforts. It may be said in general therefore that, while the number of cases requiring the mastoid operation is comparatively small in private practice, it is large among the poor.

After-Effects.—When the discharge from the middle ear has ceased, either as the result of treatment or without it, there are certain changes left behind which may cause various symptoms or permit of a return of the suppuration. In chronic cases there is a perforation which always remains for a long time, and usually throughout life. This is very different from the result which occurs after acute suppuration. In the latter case, as we have seen, the perforation heals up rapidly, and in the course of a few weeks the membrane has usually returned to its normal appearance, and the hearing is perfect.

It is quite impossible to foretell with certainty what will happen in a case of chronic otorrhœa after the discharge has stopped. The following general considerations should be borne in mind when the surgeon is asked to give his opinion as to the ultimate results. The prospect in regard to the closing of the perforation will depend, in the first place, upon the duration of the discharge which has been brought to a termination. The shorter the period over which the discharge has lasted, the more probably and the more rapidly will the perforation be closed by a cicatrix. Again, perforations are more likely to be closed in the case of young subjects where the tissues are still in a state of active growth than in those who have reached adult life. The general health of the patient is another factor which must be taken into consideration, the healing process naturally occurring more rapidly in those who are strong and well. The size of the perforation certainly affects the result, small perforations being more easily filled up than large ones. To this rule, however, there are many exceptions, and every aurist can call to mind cases in which the whole membrane has apparently been destroyed, only to be filled up with a delicate new one. The new membrane does not, however, possess a *substantia propria* or fulfil the functions of the original drumhead quite perfectly so far as the hearing is concerned. When the perforation is situated in a membrane which is atrophic, there is very little likelihood of any repair, and the same may be said when the edges of the perforation are the seat of calcareous deposit. When the suppuration has been of long duration, there is a tendency for the epidermis to grow in over the granulating edge, and thus prevent any subsequent healing of the perforation. The discharge may cease, but the opportunity for repair of the membrane has gone.

The presence of a perforation in the membrane is, *per se*, a comparatively slight detriment to the hearing. A patient even with a large perforation, or with the whole tympanic membrane destroyed, may sometimes be able to hear so well that his friends are unable to recognize the fact that his hearing is affected at all. If, however, these individuals be tested with the deeper notes of the tuning-fork, it will invariably be found that their hearing-power for these tones is not equal to that of the normal ear. This defect is unimportant in most walks of life, but it may under certain circumstances be a matter of more importance than would be thought possible, as in the case cited on p. 189. It is seldom, however, that chronic suppuration leaves the hearing so slightly damaged as this. In the great majority of cases it is affected to a greater or less extent, fortunately not usually sufficient to prevent the patient from hearing the ordinary conversation voice close at hand, though sometimes this does occur. The impairment of hearing is only in small part due to the perforation in the membrane. The long-continued inflammatory action in the tympanum has produced adhesions and cicatricial contractions which prevent the ossicles, more particularly the stapes, from vibrating in response to the sound-waves. In many cases, also, the membrane of the round window has become thickened and unfitted for the proper performance of its function. It may even be, as recorded cases show, that the stapes has become fixed in the oval window by a process of ossification.

As regards the troubles from which the subject of a perforation in the membrane suffers, fortunately these may usually be included in the one symptom of deafness. Occasionally, however, a certain amount of tinnitus is also present, but it rarely reaches such a point as to be really troublesome, and differs in this respect from the same symptom as frequently manifested in the non-suppurating forms of middle-ear disease. There is little doubt that the tinnitus which occurs as a residuum after chronic middle-ear suppuration is due to a fixation of the stapes, more or less complete, in the oval window.

Paracusis Willisii is present occasionally in those who have recovered from otorrhœa in both ears.

In order to bring about as little impairment of hearing as possible, the aurist should use every endeavour to prevent adhesions forming while the discharge is still going on, and to stretch or rupture these adhesions after it has ceased. The use of the air-douche is most suitable for this purpose, and its constant employment during the healing process may make all the difference in the hearing-power after the cessation of the discharge. Even if adhesions have formed, they may be stretched or ruptured by means of the air-douche, and thus the patient's hearing may be improved to a considerable extent.

Many attempts have been made, and sometimes successfully, to bring about an improvement in the hearing-power by cutting adhesions which have formed during healing. The aurist, however, is well advised to be careful in adopting any of these measures. The tympanic cavity is a peculiarly unsatisfactory field for minor surgical operation if the avoidance of suppuration be a desideratum. It is extraordinary how even a simple incision in the membrane may produce a transient purulent discharge from the tympanum. Now if, after one of these operations upon adhesions, pus should appear in the tympanum, the object of the operation is defeated, for the adhesion will almost certainly re-form.

The surgeon, therefore, should have very good grounds before undertaking any of these operations, particularly as only a comparatively small percentage produce any noteworthy improvement. In the first place, to justify the proceeding both ears must be affected, and the degree of deafness should be considerable. A healthy condition of the auditory nerve is necessary to the success of the operation, and the operator should be sure that this condition is fulfilled.

Before commencing the operation, the surgeon should ascertain as accurately as possible the position and the extent of the adhesions which limit the movements of the ossicles. The condition of affairs in this respect can be recognized by various means. Simple inspection with a sufficiently brilliant light will sometimes show the actual adhesions themselves, particularly if they pass from the tip of the handle of the hammer to the promontory. Other adhesions may sometimes be seen passing from the hammer to the stapes. On the whole, however, inspection alone does not usually help us very much in the matter ; it should be

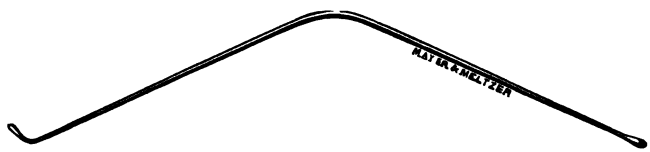


FIG. 89.—INTRATYMPANIC PROBE.

supplemented by the use of Siegle's speculum, described on p. 78. If there are adhesions binding any portion of the membrane down, dimples will appear at the adherent spot, and will be recognized on sufficiently careful inspection. The position of these adhesions should be carefully noted, so that they may be cut subsequently with the least possible manipulation.

Further information may be gained by the use of a very fine probe, with the bulbous extremity bent almost at right angles to the instrument itself. Of course, the bent portion at the end should be very short (Fig. 89). The tip of the probe is introduced through the perforation in the membrane, and swept round the edges until it meets with an obstruction. The position of the obstruction should be noted, and from this it may be inferred whether it is of the nature of an adhesion or is merely a normal anatomical structure, such as the tendon of the tensor tympani.

A subject upon which the writer lays considerable importance is the ascertaining of the degree of mobility of the stapes which still remains. Sometimes this may be ascertained directly in the following way; but for this test the perforation must be in the posterior quadrant and the head of the stapes must be visible; otherwise the method cannot be carried out. The hearing distance of the patient is first of all carefully ascertained. A bright light is then thrown through an ordinary speculum in such a way as to show the head of the stapes as clearly as possible. The spring-pressure probe devised by Lucae is then introduced through the speculum, and carried slowly down until its broadened extremity rests upon the head of the stapes. Extremely gentle pressure is then brought to bear upon the bone, and is maintained for a few seconds. It is then relaxed for a few seconds, and then applied once more for the same time. The alternate pressure and relaxation should be applied three or four times, and the probe then removed. The hearing distance should now again be measured, and any change for the better should be noted. The whole procedure must be carried out with the utmost steadiness and lightness of touch; indeed, it should only be done by an expert if awkward contingencies are to be avoided. Even with the most delicate pressure, slight degrees of pain and giddiness are sometimes produced. This test affords, in the author's opinion, the most valuable indication as to subsequent procedure. Thus, if no improvement in the hearing results after applying the test, it may be justly assumed that no operative treatment will improve the hearing. This in itself is no small gain, for it is the unfortunate uncertainty of most of these operations in the middle ear which has caused them to be looked upon by aurists as unsatisfactory procedures. A negative test, therefore, of this description will save the aurist from many attempts to improve the hearing by means of the catheter, pneumo-massage, or operations on the tympanum. It may be laid down as an axiom that, if the stapes is ankylosed, no procedure will improve the hearing permanently until an opening is made in the wall of the labyrinth, either by the removal of the bonelet or by means of an artificial opening elsewhere. Both these operations have been undertaken, and in neither case have the results been such as to justify the procedures at present. As surgical knowledge advances and methods improve, it may be that some means will be found of rendering these operations safe in their performance and permanent in their results. (The operation of severing adhesions is described on p. 213.)

Before the physiology of the middle ear was properly understood, it was thought that in many cases the defect in the hearing, which remained after suppuration had ceased, was due to the presence of a perforation of greater or less magnitude in the membrane. From this it was naturally inferred that if the perforation could be closed by any means the hearing would improve. Numerous attempts, some of them successful, have been made to bring about a closure of the perforation. Unfortunately, the hearing frequently does not improve at all, and may even be made worse; but a small percentage of the cases do improve when the perforation is closed. There are other reasons, however, for attempting to bring about a closure of the perforation. As long as a direct communication exists between the meatus and the tympanum, there is a considerable possibility of the suppuration returning sooner or later. This, therefore, is the real reason why it is desirable in many cases to bring about a closure of the perforation.

The different means that have been devised to close the perforation may all fail, and frequently do. In order to prevent disappointment, therefore, the surgeon should be careful in the selection of the cases. The facts which should guide him may be briefly mentioned. First, the younger the subject, the more likely will he be to achieve his object. This is what we should expect from our knowledge of the recuperative power of the tissues in young people as distinguished from those in the later registers of life. The presence of calcareous deposits or of atrophic patches in the remaining portions of the membrane are indications against any interference. The size of the perforation is a matter of some importance; the smaller it is, the more readily will it be closed. The presence of the hammer undoubtedly favours the restitution of the membrane; it forms a peninsula from which the new cells may be reproduced. Adhesions binding the hammer or the remains of the tympanic membrane to the promontory do not, as a rule, offer a satisfactory field for attempts at restoration of the membrane. Finally, there are not a few individuals in whom the mucous membrane of the tympanum is so sensitive that any interference whatsoever causes suppuration. These cases should be left alone. It will naturally be understood that, if the hearing-power is good, no attempt should be made to close the perforation.

One method of bringing about closure of the perforation is that devised by Berthold. The free edges of the perforation are freshened by means of a small knife, and on to the raw surface thus produced there is laid a thin, small piece of epidermis which has been taken from the forearm of the patient. In successful cases the graft holds and the perforation remains closed. Unfortunately, in spite of the utmost precautions, suppuration sometimes ensues and the operation fails. Instead of human epidermis, the membrane lining the inside of the shell of an egg is sometimes employed. That surface of the membrane which lies contiguous with the shell is placed in contact with the raw surface of the tympanic membrane. This operation is only suitable for small perforations.

A method more frequently employed than that just described consists in constantly freshening and irritating the edges of the perforation with some suitable chemical agent, of which the best is trichloracetic acid. The details of this procedure are as follows. A fine probe is tipped at its extremity with a minute pledget of cotton-wool, and is then dipped into a 50 per cent. aqueous solution of the acid. This is passed very carefully along the meatus until it is in contact with the edge of the perforation, and the tip is then carried round the margin, great care being taken not to allow the instrument to touch the mucous lining of the tympanum. The procedure is repeated about every fifth or sixth day, the requisite condition being that the scab of the previous application should have been shed before the next application is made. The ear should not be syringed after the application of the acid, and the use of solutions of cocaine for anæsthesia is undesirable, since the fluid is apt to produce suppuration in the middle ear. The results of the closure of a perforation vary in different cases. In a fair proportion the improvement is quite perceptible, and subjective noises may sometimes disappear ; but, on the other hand, the hearing is sometimes made worse, and tinnitus, which before was absent, may now occur. The cause of these unfavourable symptoms is said to lie in the existence of adhesions binding down the tympanic membrane or the ossicles to the inner wall of the cavity.

A number of authorities are strongly of opinion that perforations in the membrane should be left alone.

A less questionable means of bringing about improvement in the hearing, after suppuration has ceased, is the employment of *pneumo-massage* in order to stretch the adhesions. In the present connection, it need only be remarked that this form of treatment should not be carried out until a week or two have elapsed from the last appearance of the discharge. The applications should be made two or three times a week and over a considerable period of time.

For the purpose of stretching adhesions, some aurists employ Lucae's spring-pressure probe applied to the short process of the hammer. It may be added that, if the position of the perforation will permit, the probe may be applied direct to the stapes, as described on p. 208, and in these the results are better than when the instrument is applied to the hammer.

FIG. 90.—YEARSLEY'S ARTIFICIAL DRUM.

Yet another means of improving the hearing is the *artificial tympanic membrane*. There are various forms of the artificial membrane, but none of them seem to be improvements on the original little artifice which Yearsley first employed more than sixty years ago. It consists merely of a little ball of cotton-wool about the size of a match-head or a pea (Fig. 90). The means of applying it is simple, the little pellet being carried down the meatus at the end of a pair of bent forceps and put into the perforation. With a little practice the patient may be taught to do this himself, and, indeed, he must learn to do so for the following reason. The tympanic membrane is so extremely sensitive to the presence of a foreign body that at first the pellet can only be allowed to remain in for a few hours at a time, and must not be left in during sleep. It is obvious, therefore, that the patient must learn to do this himself, as he cannot expect to be able to go to the aurist every day. As a matter of fact, patients of ordinary intelligence learn to place the pellet in the right position with remarkable accuracy merely by the sense of touch. In order to make removal more easy, a thread may be attached to the wool, and the end of it left in the outer part of the meatus.

The improvement which is sometimes afforded by this means is astonishing. For example, a patient who might not be able to hear ordinary conversation at a distance of a yard may follow it without any difficulty at a distance of five yards after the application of the artificial membrane. Unfortunately, however, the number of these cases is not very great. The majority obtain a certain amount of improvement with the artificial drum, and in some cases even a small improvement is of the utmost importance, as, for example, where an individual might have to give up his calling owing to dulness of hearing. It is clear that in such cases a very little improvement in the hearing might enable him to undertake his work.

Unfortunately, some patients in whom the improvement is quite pronounced cannot stand the presence of the foreign body for more than a few minutes. The cotton-wool causes inflammation in the mucous lining of the tympanum, and, if its use is persisted in, suppuration will ensue. These patients must forego the use of the artificial drum. In order to render the cotton-wool less irritating, it is advisable to soak it in sterile liquid vaseline or a very thin solution of glycerin in water. Of these two agents, the writer has found that the vaseline is much more satisfactory.

The period of time during which it is possible to leave the drum in position varies very much with individuals. As remarked above, some cannot stand it at all; others may endure it for half an hour or several hours, and in rare cases it may be left in for several days. It is, however, always advisable to remove the pellet at night.

In order to gain the full benefit of the artificial drum, various trials must be made in order to find out the exact position in which the greatest improvement in hearing is brought about. It is, therefore, important that the patient himself should learn to introduce and remove the object.

It is a rather remarkable thing that the principle on which the artificial drum benefits the hearing is not certainly known. There seems to be no doubt that the improvement does not depend, as would have been supposed, upon its rendering the membrane more complete. If this were so, then cotton-wool would be one of the worst substances to employ.

Numerous different modifications of the artificial drum have been proposed, but it is doubtful if any of them are superior to the simple pellet of cotton-wool. It is unnecessary to describe these various instruments, since they may all be found in the surgical instrument-makers' catalogues. It need only be remarked that Gomperz recommends the insufflation of a minute quantity of boracic acid powder into the region of the round and oval windows. This is said to act quite as well as any artificial drum, is not irritating, and may remain in the ear for weeks and months. It is only applicable, of course, to those cases in which the mucous lining of the tympanum is transformed by the ingrowth of the epidermis so that there is no moisture present.

Should all these methods fail to relieve the patient of his symptoms, the question of operation presents itself. In this matter great care must be exercised, since the results of these operations are always uncertain, and they must be considered in a sense to be merely justifiable experiments. In the first place, therefore, let no operation be done on these patients unless a considerable degree of deafness be present in both ears, or in those rare cases in which tinnitus of a severe type is present.

Severing of Adhesions.—It is not necessary to describe in detail every possible variation of the procedure which is requisite when it is decided to operate on adhesions. It must be emphasized, however, that the position and extent of the adhesion should be carefully made out as described on p. 207. With this knowledge, the operator should select a suitable knife, and under the influence of cocaine the adhesion should be severed. In cases in which the handle of the hammer has become adherent to the promontory, Grunert recommended a special operation, which consists in severing the adhesion, and then performing the same operation upon the tendon of the tensor tympani. He next makes two incisions, each of them parallel with the handle of the hammer, one in front and the other behind; the incisions are carried upwards to the bony margin of the tympanic ring. A fine probe, bent at the end to a right angle, is then introduced through the anterior incision and hooked round the handle of the hammer. The latter structure is then dragged outwards into the meatus until it is vertical in direction. This produces a subluxation of the head of the hammer in relation to the anvil. The handle of the hammer consequently remains in the position described, and there is little or no chance of adhesions re-forming between that structure and the promontory.

More serious defects in hearing are produced when the adhesions affect the movements of the stapes. In order to relieve these, Politzer recommends the following method. An incision is made immediately below the head of the stapes, and is carried for a short distance in front of and behind that ossicle. If the hearing is not improved by this means, he recommends a similar horizontal incision above the stapes, but in this case, of course, the operation is only possible if the long process of the anvil is absent.

In cases in which the tendon of the stapedius is involved in the cicatricial tissue, Kessel and some others recommend a vertical incision in such a position that the tendon of the muscle shall be severed along with the cicatricial tissue. In some cases the deafness has been improved by this means, and, what is more remarkable, both ears have been known to improve in hearing-power even where the operation was only performed on one side. Tinnitus has also been affected favourably by this operation. It is unfortunate, however, that the procedure sometimes makes the hearing worse, produces giddiness and a peculiar sensitiveness towards noises which was not previously present. On account of the uncertainty of the result, the operation is one which cannot be recommended.

Kessel recommends in certain cases in which the handle of the hammer is isolated, that the tendon of the tensor tympani should be cut. It is open to question if anything is to be gained by this procedure.

When there is complete calcification of the membrane, a condition which not uncommonly ensues upon long-continued suppuration, Schwartze and Stacke recommend excision of the whole membrane along with the hammer. Of course, it will be understood that this should only be undertaken when there is very marked deafness in both ears, or when the subjective noises are very troublesome. Excision of the membrane in these cases, however, is almost invariably followed by reaction and subsequent suppuration, which may take a long time to cure. The operation therefore should not be undertaken lightly. Its effect upon the tinnitus is usually more satisfactory than upon the hearing.

Removal of the incus or of the long process of that bone has been recommended by Burnett in cases in which pressure is brought to bear upon the stapes by an indrawn hammer acting through the anvil. The advantage of this operation is that the reaction is not so severe as in the operation just described.

Mobilization of the stapes has been recommended by Miot and others in certain conditions in which bone-conduction is particularly good, the deafness not of long standing, and in which bony ankylosis of the stapes can be excluded.

The method of operating, according to Miot, is as follows. An incision is made along the posterior border of the membrane, if this still remains, the incision being kept close to the bone, and the upper part of it reaching above the region of the long process of the anvil. The flap thus formed is turned down, and the tip of a specially-constructed probe introduced through this perforation and carried immediately below the incudo-stapedial articulation. The probe is then tilted gently upwards and downwards alternately, in order to find out if the ossicle is movable. Should this not succeed, the tip of the instrument is carried to the front of the joint between the ossicles, and pressure backwards is now tried in order to see if the stapes can be raised a little out of the oval window. Improvement in the hearing, if it is going to occur at all, is usually apparent immediately after the operation, but in rare cases it may appear after a few days, or even weeks. A gradual diminution frequently takes place some time after the operation, but the procedure can be repeated two or three times. If it be desired that the operation should be carried out again, either the perforation made by the first operation should still be present in its whole extent, or should be completely closed. It is not wise to attempt it when healing is nearly finished.

Excision of the stapes has been practised in these cases with a certain amount of success. It is certainly more valuable in the conditions under discussion than in those which occur as the result of non-suppurative processes in the middle ear, or of changes in the bony capsule of the labyrinth. The conditions which may be said to justify the attempt have been laid down by Panse[1] and are as follows: (1) a healthy condition of the auditory nerve as shown by the existence of good hearing-power by bone-conduction; (2) bilateral deafness to such an extent that it is a considerable burden to the patient; (3) absence of any considerable improvement by other methods. The operation should always be performed on the worse ear, since the results are uncertain.

In all cases the operation should be carried out under deep chloroform anæsthesia, local anæsthetics being quite undesirable for the purpose, while ether produces too much hæmorrhage, obscuring the field of operation. The field must then be well illuminated, either by bright direct daylight or by means of an electric light attached to the forehead of the operator. In order to control hæmorrhage, small pledgets of cotton-wool rolled round the tips of numerous probes should be ready beforehand. Before applying these, they may be dipped in a solution of adrenalin chloride, 1 in 5,000. A curved incision is made behind the auricle and in the line of its attachment, and this, along with the membranous meatus, is raised from the bone right down to the tympanum, on the posterior and superior walls. The drumhead and two outer ossicles are then removed, and finally the outer wall of the attic is chiselled away. The edges of the bone are then smoothed down by means of a burr, and all bleeding is carefully stopped. An attempt is next made to extract the stapes by gently pulling the head of the bone outwards without attempting lateral movements. If this does not succeed, a very fine burr of ½ millimetre diameter is then placed carefully between the stapes and the anterior inferior angle of the oval window, and a small hole is bored downwards. A fine hook with the bent portion only ½ millimetre in breadth is next passed down the little perforation, and hooked round the inner surface of the footplate of the stapes, which is then removed, either entire or in fragments, by drawing the hook outwards. The region of the oval window is then covered over with a mixture of iodoform and boracic acid. The walls of the tympanum at the mouth of the Eustachian

[1] 'Die Schwerhörigk. durch Starrheit der Paukenfenster,' 1897, S. 257.

tube are scraped, in order to try to bring about a complete closure of the tube. Bleeding is again stopped, and the whole region strewn with a thick layer of iodoform and boracic acid. The wound behind the auricle is stitched up, and the meatus packed firmly with gauze. By this means, in the course of time, the tympanum will be covered over with a layer of epidermis instead of mucous membrane. When this has occurred, pneumo-massage should be carried out for a considerable time, in order to prevent the new membrane, which closes the oval window, from becoming too rigid.

Upon very much the same principle as that of removing the stapes, attempts have been made to bring about improvement of hearing and diminution of the tinnitus by means of making an artificial opening in the wall of the labyrinth in front of and below the oval window. The results have been even less satisfactory than those in which the stapes was removed.

The description just given of the various operations for the relief of the cases under consideration is intentionally brief. The reason for this brevity is the author's lack of faith in their practical value. It may be added further, that comparatively few aurists put them into practice. It is, however, desirable that the student should know that they have been done, and that the results are very uncertain and usually unsatisfactory.

In recent times *fibrolysin* has been used in the form of subcutaneous injections, with the purpose of softening the adhesions which may occur on the cessation of suppuration.[1] To be of any avail, the treatment must be carried out for several weeks at least, an injection being given every second day. The results of this method of treatment are occasionally satisfactory, and it has the advantage over operative procedures in respect to the fact that it does no harm in so far as the ear is concerned. The treatment is of more value in the cases under discussion than in those in which deafness results independently of previous otorrhœa. The drug may be considered quite safe in healthy individuals, but it should be avoided in old people, and in those in whom there is any reason to suspect renal or arterial changes. Pritchard has recorded a fatal result, due apparently to the use of fibrolysin.

[1] French, *Lancet*, July 24, 1909.

In my own cases I have had no trouble with the drug, beyond the pain of the injection and a certain amount of infiltration of the tissues in the neighbourhood which, however, always passed slowly away.

Bezold's Mastoiditis.—Before leaving the subject of suppurative disease of the middle ear, reference must be made to the rare condition in which pus escapes from the inner surface of the tip of the mastoid process and forms an abscess which may point on the surface of the neck or in the pharynx. This is named *Bezold's mastoiditis,* after its discoverer, and, as stated above, it is very rare.

Treatment.—The only treatment is surgical, and it must be carried out without delay. The abscess must be opened in the neck, or wherever it may be pointing. But this is not sufficient to cure the condition. The mastoid antrum must also be opened, and the cells of the process removed down to the tip. Granulations and carious bone must be removed; the abscess cavity should be drained both through the wound behind the ear and through that by which it has been opened in the neck.

CHAPTER X

NON-SUPPURATIVE DISEASES OF THE MIDDLE EAR

In the preceding chapter suppurative disease of the middle ear, both in the acute and chronic form, was considered. These are clinical and pathological entities, and lend themselves, therefore, to definitions which are fairly satisfactory, in so far as medical nomenclature can be.

But the non-suppurative diseases of this region are not of this class, owing doubtless to the fact that the pathology of the different conditions is not sufficiently known. It is, therefore, most satisfactory to follow at present a nomenclature which depends rather upon clinical observation than upon direct pathological investigation. But it must be borne in mind that such a nomenclature is only of temporary value, and will gradually disappear as our knowledge of the pathological changes increases.

Non-suppurative diseases of the middle ear, then, may be divided into three groups : acute catarrh, chronic catarrh with exudation, and chronic interstitial conditions without exudation. It must be noted, however, that we do not know to what extent these different groups are merely various stages of one condition, and it is certain that in many they are such.

ACUTE CATARRH OF THE MIDDLE EAR.

It is doubtful if, from the pathologist's point of view, there is any good reason to separate acute non-suppurative catarrh from acute inflammation of the middle ear. The difference is, so far as is known, chiefly one of degree. But clinically the presence or absence of suppuration is so important that it is advisable to separate the two conditions. In both affections the etiology is the same.

Symptoms.—In acute catarrh the patient complains of *deafness* of comparatively rapid onset, associated with a feeling of fulness in the ear.

Tinnitus of a mild type is frequently present, but it is usually intermittent, and disappears for a time after the use of the air-douche. Crackling noises in the ear are occasionally mentioned by the patient, and are probably due to the opening of the Eustachian tube after it has been closed for a considerable time. This symptom is sometimes also due to the bursting of air-bubbles on the surface of the fluid which is always present to a greater or less extent in the middle ear.

Autophony, or the sensation of hearing one's own voice unpleasantly loud, is a common and rather distressing symptom.

Pain varies considerably in degree, but is not of the same intensity as that which occurs in acute inflammatory affections; sometimes it is absent altogether. Constitutional symptoms are either entirely absent or nearly so, and intracranial complications are of the rarest occurrence, although some writers have recorded cases which appear to indicate that the possibility of such a catastrophe cannot be absolutely excluded.

Inspection shows *changes in the membrane* which vary in different cases. Usually it is reddened to a certain extent, especially in the region of the handle of the hammer; but only rarely does the colour reach the diffuse, angry, crimson tint which is almost uniformly present over the whole membrane in the more severe inflammation previously described. The membrane itself also is not infiltrated to the same extent, and consequently the handle of the hammer is not hidden as in the more severe affection. Bulging of the membrane, if present, is not usually very marked, and more often the drumhead is actually indrawn to a certain extent. If the membrane is not infiltrated, it is sometimes possible to see a fine horizontal line traversing it and indicating the upper surface of the exudation within.

Treatment.—The treatment is similar to that employed in mild cases of acute inflammation. For the relief of pain the solution of iodoform or cocaine dissolved in anilin may be instilled under the usual precautions (p. 112). Glycerin of carbolic acid may be employed in the same way, but is not quite so efficacious. A blister behind the ear is of use both in relieving the pain and bringing about absorption of the exudate. In the early stages the air-douche should not be used, but after a few days, when the pain has subsided, it may be employed daily. Similarly, the treatment of the nasal or naso-pharyngeal catarrh, which is usually the cause of the mischief in the ear, may be begun after the acute symptoms have passed off. The measures for relieving the nasal catarrh should be mild at first, consisting of antiseptic and alkaline sprays, such as the following:

℞ Listerin.	℥ss.
Sod. bibor. } Glycerin. }	āā ʒii.
Aq.	ad ℥iv.

The progress towards absorption of the exudate is indicated by the improvement in hearing, which is usually rapid. But the case must not be lost sight of until the deafness is completely gone.

In a few cases the exudate in the tympanum is not absorbed so rapidly as is desirable. In these a succession of blisters over the mastoid region should be ordered at intervals of a few days or a week. Every effort should be made to bring about absorption of the fluid without having recourse to incision of the membrane, because, if this operation is carried out, suppuration will almost certainly ensue and will be tedious to cure. The reader need not believe statements to the effect that suppuration after incision can be avoided by sufficiently careful antiseptic precautions. Sometimes, however, it is necessary to perform paracentesis in order to prevent the condition becoming chronic. On general principles, every antiseptic precaution should be taken before operating, but the surgeon need not blame himself if suppuration should occur.

While the treatment of acute middle-ear catarrh is highly satisfactory, it is important to remember that in many cases there is a chronic catarrhal condition in the nose or naso-pharynx. When this is the case, it is necessary to rectify these conditions, in order to prevent a return of the middle-ear trouble or the risk of the affection becoming chronic. The treatment of the nasal and naso-pharyngeal conditions has already been described.

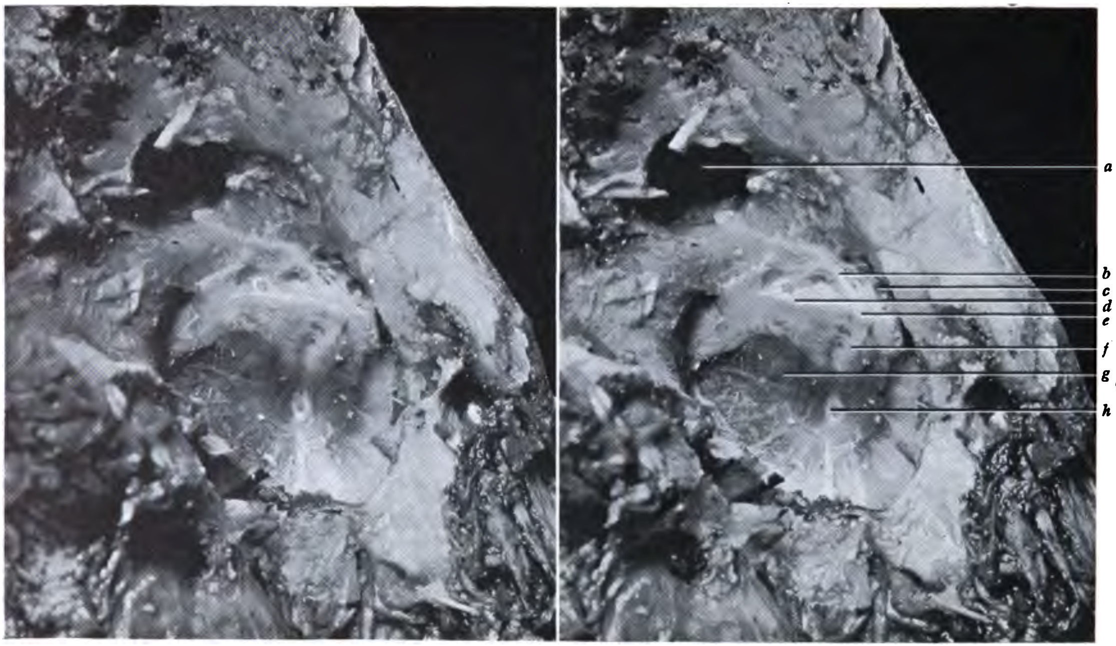
CHRONIC SECRETING CATARRH OF THE MIDDLE EAR.

The acute middle-ear catarrh just described not unfrequently becomes chronic, and the differentiation between the two must, therefore, be to a certain extent arbitrary. It is impossible to fix a definite period at which the acute condition passes into the chronic stage, but it is obvious that, if the changes described in the last few pages are allowed to continue over a lengthened period of time, the conditions become more and more settled in their pathological and anatomical relationships. As evidence of this may be mentioned the fact that in the chronic condition the tympanic membrane is invariably indrawn, and frequently either atrophied or thickened. Atrophy of the membrane is apt to occur through the continued excessive stretching to which it is subject, and on inspection it will be found that the atrophied part may be so thin that the inner wall of the tympanum appears distinctly in the field, and the observer may be under the impression that the corresponding portion of the tympanic membrane has altogether disappeared. This error is easily corrected, for, on giving the air-douche, the atrophied membrane is blown away from the surface of the promontory on which it rests, and appears to bulge forward into the meatus, thus altering the picture more completely than would be possible in any other condition. This condition of atrophy of the membrane, it must be pointed out, does not by any means supervene in all cases, and the objective signs may be very similar to those already described in the acute form of the catarrh. Some of the changes which occur in chronic exudative catarrh of the middle ear are shown in Figs. 91 and 92. The case was that of a patient who had suffered from the symptoms of exudative middle-ear disease for a period of six months. He died of malignant disease of the stomach, and, on examination of the temporal bone, the conditions seen in the figure were revealed. The exudation, which at the time of examination was coagulated by the

FIG. 91.—RIGHT TYMPANIC MEMBRANE, ETC., REMOVED POST-MORTEM FROM A CASE OF SEROUS CATARRH OF THE MIDDLE EAR: VIEWED FROM THE OUTER ASPECT. × 2½. (Prepared and photographed by the Author.)

The membrane is very much indrawn.

a, opening into antrum to allow of the entrance of the fixing fluid.
b, posterior fold of the membrane.
c, Shrapnell's membrane depressed.
d, fold caused by indrawing of the membrane.
e, short process of hammer.
f, manubrium of hammer,
g, tympanic membrane behind hammer.
h, umbo.



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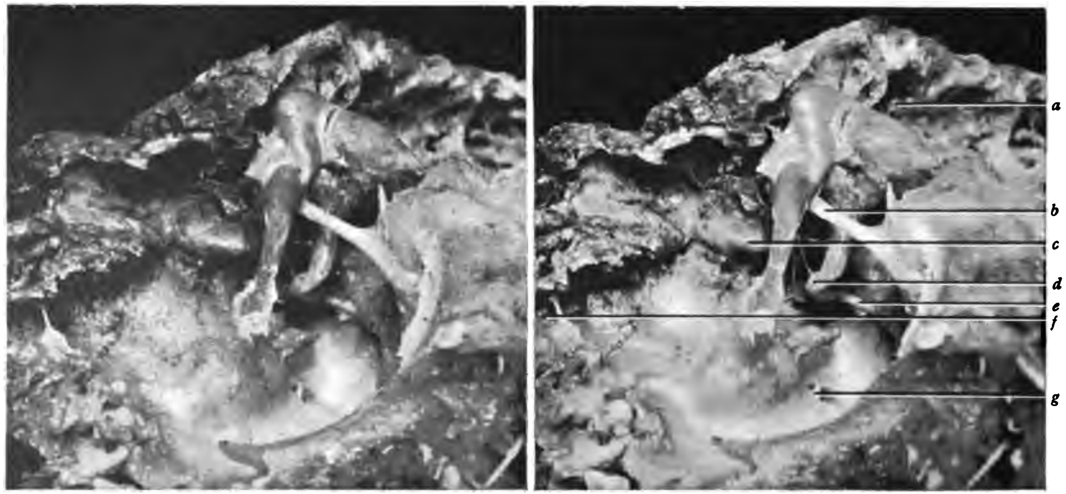


FIG. 92.—LEFT TYMPANUM FROM A CASE OF SEROUS MIDDLE-EAR CATARRH. × 3½.

The membrane and anterior and superior walls have been removed. The preparation has been rotated clockwise to the extent of about 30°, and is viewed from the outer aspect.

(Prepared and photographed by the Author.)

a, aditus ad antrum.
b, posterior portion of chorda tympani.
c, tendon of tensor tympani covered by mucous membrane.
d, tip of the long process of the incus.
e, tendon of stapedius.
f, opening of Eustachian tube.
g, coagulated serous exudation lying over the round window. The exudation may be seen over other portions of the tympanum, especially in the lower part.

[*To face p.* 223.

spirit in which the preparation was put, covered the floor of the tympanum and extended up over the walls of the cavity, so that the round window was overspread. The mucous membrane itself was thickened, reddened, infiltrated and succulent.

The membrane in chronic exudative catarrh is not reddened at all, and this distinguishes the picture from that in the more acute conditions. In some cases a fine horizontal line may be seen running across the membrane (Fig. 76), which indicates the upper margin of the fluid within, and on changing the position of the head for a few minutes this line may be made to alter its position. In many cases, however, no such line is present, owing either to the fact that the exudate is too small in amount to reach the level of the membrane, or is so great that it reaches above the upper margin of the membrane.

If the air-douche be given, small bubbles may be formed within the drum, and these can be seen as little circles on inspection of the membrane. This sign is of great positive value in the diagnosis, but, unfortunately, it is very frequently absent.

Pain is absent in chronic exudative catarrh, but it must be remembered that an acute exacerbation may call it into existence. *Tinnitus* is not unfrequently mentioned by the patient, but it is trivial in degree when compared with the distressing subjective noises of otosclerosis. Autophony is sometimes complained of. *Paracusis Willisii* is not present so long as there is exudation, but in some cases, when the fluid disappears and adhesions form, this symptom may be present, as will be described later (p. 234).

The degree of *deafness* varies within fairly wide limits, but the loss is never so great that the ordinary conversational voice, in close proximity to the ear, cannot be heard. The dulness of hearing is not constant in degree, but varies greatly under different circumstances. Thus, a cold in the head makes it worse, as also does damp weather. On the other hand, a bright, dry atmosphere improves the hearing, and residence at a high altitude has an even more beneficial effect. In this connection, therefore, it is interesting to observe that a low barometric pressure, *per se*, is not detrimental, as is sometimes stated.

Along with the deafness, patients usually complain of a sense of fulness or heaviness in the ear. Occasionally a loud crack is heard by the patient, and simultaneously the sensation of fulness as well as the deafness are much relieved, the relief lasting for some little time. These changes are due to a sudden opening of the Eustachian tube.

It should be noted that the deafness in the chronic condition does not usually permit of such complete temporary removal by means of the air-douche as it does in the acute form. This is, no doubt, due to the fact that the mucous membrane and ligaments are more permanently affected

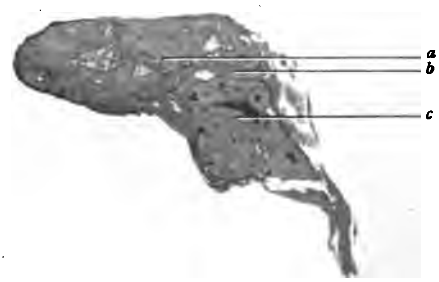


FIG. 93.—SECTION THROUGH THE HEAD OF THE MALLEUS AND BODY OF THE INCUS IN WHICH THE OSSICLES WERE FIXED BY ADHESIONS. × 8 *circa.*

(Prepared and photographed by the Author.)

a, body of the incus. *b*, adhesions in the malleo-incudal joint. *c*, head of malleus.

when the disease has lasted for some time ; but in some cases it is to be explained by an even more serious change in the middle ear. This consists in the formation of adhesions between the ossicles themselves and the adjacent structures. Thus, the handle of the hammer may become adherent to the promontory, or a band of connective tissue may bind the crura of the stapes to the wall of the oval window. The joints of the ossicles may also be affected, with resulting adhesions between the head of the hammer and the body of the anvil (Fig. 93), or between the long process of the anvil and the head of the stirrup. Furthermore, it must be remembered that, since the hammer is placed for a long period abnormally near the promontory, the tendon of the tensor tympani may gradually shorten to accommodate itself to this changed position. When, therefore, air is forced into the tympanum, the structures do not by any means return to their true anatomical position at once, and we find consequently that the degree of improvement in hearing is not invariably very pronounced.

Calcareous deposits sometimes appear in the membrane itself, but these do not seem, *per se*, to affect the hearing to any noticeable extent; at any rate, they are frequently seen in individuals whose hearing, so far as can be ascertained, is normal.

Treatment.—The treatment of the chronic form of the disease is in most respects similar to that of the acute. Unfortunately, the results of the treatment are not quite so satisfactory, and the time required to produce the desired effect is much longer.

Since the causes, both of the acute and chronic form of the disease, are to be found for the most part in catarrhal conditions in the naso-pharynx or the nose, it is imperative that these should be rectified. This matter cannot be emphasized too much. No treatment, however skilfully carried out, will give the best result unless the cause of the affection be in the first place removed. And it must be remembered, moreover, that for some reason the effect upon the ear of changes in the nose and naso-pharynx is not always in proportion to the extent of the visible anatomical changes in those regions. In his own experience, this fact has been borne in upon the writer in a most remarkable manner, and others have made similar observations. Perhaps the results of the presence of adenoid vegetations illustrate the matter more clearly than anything else. Thus, one may find the naso-pharynx almost completely filled up with these growths, associated with marked mouth-breathing, with excessive secretion and very loud snoring, while the ears remain unaffected throughout. On the other hand, it is by no means uncommon to find deafness brought about by an insignificant adenoid hypertrophy—a condition which, excepting for the deafness, may show no evidence of its existence. The reason for these striking differences is to be found, in part at least, in the position at which the adenoids are situated. Thus, a small degree of adenoid hypertrophy, if it be near the mouth of the Eustachian tube, may cause deafness, while a large centrally-situated mass may not. It must also be remembered that the degree of the catarrh is not always in proportion to the size of the growths, and the former is probably quite as important a factor as the mechanical obstruction caused by the latter. Whatever the explanation may be, the clinical fact must be always borne in mind that the effect upon the hearing is not in direct proportion to the extent of the anatomical changes.

The nose and naso-pharynx having been brought into a healthy condition, if they are not so already, it remains to carry out the direct treatment upon the ear. The most important means that we have at our command for this purpose is, undoubtedly, inflation of the middle ear. This may be accomplished either by Politzer's method or by means of the catheter. It will naturally be understood, however, that the latter must be employed if improvement does not result after the air-douche in the ordinary way. The inflation should be carried out daily for a period of one week, then three times a week, until there is no further improvement. It is quite possible to carry out treatment by the air-douche to excess, as will be made evident by the fact that the hearing-power, instead of increasing, as it did at first, will be found to be diminishing. It is advisable, therefore, not to continue the use of the air-douche for longer than six or eight weeks; and, naturally, it must be discontinued if it ceases to produce improvement before that period has elapsed. It is not desirable to advise patients to perform Valsalva's experiment upon themselves, for they are liable to use it too frequently, and bring about a condition of atrophy of the membrane and further loss of hearing.

There are certain adjuncts to the use of the air-douche which have been recommended by various writers. Schwartze advises that, if the secretion in the tympanum has not disappeared within fourteen days from commencing treatment by inflation, the surgeon should try the effect of injection through the catheter of watery solutions of chloride of ammonium, ½ to 3 per cent., or sulphate of zinc, ¼ to ½ per cent. At the most, 8 to 10 minims of the solution should be injected, not more than twice in the week, for fear of causing inflammation of the mucous membrane.

Nascent chloride of ammonium in the form of vapour has also been recommended as an injection through the catheter, and the vapours of turpentine, of iodine, and of steam have been employed for the same purpose. It is open to question how far these substances have any direct effect upon the tissues of the middle ear, though no doubt they are beneficial to the mucous lining of a part, at least, of the Eustachian tube.

The passage of bougies up the Eustachian tube to the distance of 1 inch have in some cases undoubtedly a beneficial effect. There are different methods of employing these instruments. Most aurists simply pass the bougie through the catheter and up the Eustachian tube to the distance of about 1 inch, and leave it there for a few minutes. Others employ bougies medicated in special ways. Thin pieces of gut of suitable length are left to saturate in a 10 per cent. solution of nitrate of silver in water; they are then dried for twenty-four hours, and immediately before use are smeared with vaseline or paraffin, and introduced through the catheter into the tube, where they remain for five minutes. The procedure is repeated every second or third day.

A simpler method of achieving the same end, and probably quite as effectual, is the mere smearing of an ordinary celluloid or whalebone bougie with a ½ per cent. ointment of nitrate of silver, the vehicle being lanoline. In this case the bougie is left in for a period of from twenty minutes to half an hour; it is only repeated, however, twice a week. In exactly the same way, other medicaments, such as solutions of iodine in iodide of potassium and glycerin, may be employed. The treatment by the medicated bougies should not be continued for more than a fortnight, in order to avoid the risk of inflammation in the middle ear.

The repeated application of blisters behind the ear sometimes is of great service in procuring absorption of the exudate.

The effect of climate upon patients suffering from middle-ear catarrh is well known, and a sojourn in a suitable locality may be of benefit. Unfortunately, to derive the full benefit from climatic changes, the patient must have time and means at his disposal. For those living in Europe, Egypt affords a satisfactory climate during the winter months, and the same may be said of the Riviera and Algiers. But the most pronounced benefit is derived from residence at a high altitude, and for this purpose Zermatt, Pontresina, or Davos are suitable.

In cases of serous catarrh of the middle ear, there may remain, after the fluid has completely disappeared, a certain degree of dulness of hearing and of tinnitus. These symptoms should be treated for some time, in the hope that they may be made to disappear; but it must be admitted that the aurist will not always be able to accomplish his object. The employment of the air-douche is the simplest means of treating those symptoms, but unless they show signs of disappearing within a fortnight or three weeks it should be abandoned. Kessel recommends tenotomy of the tensor tympani in those cases in which there is tinnitus of a continuous character, provided that the stapes is still movable and the auditory nerve is not seriously affected, as revealed by the tests for hearing. According to Kessel, this little operation improves the hearing and relieves the tinnitus, giddiness and headache, which are sometimes present. A less heroic method of treating these symptoms is that of pneumo-massage; the fluid should have disappeared for some time, however, before employing this treatment.

In those cases in which the active middle-ear catarrh has passed away, but has left the membrane atrophied and relaxed, the collodion treatment, described by McKeown, Lannois and Keller may be of use. It is carried out as follows. A thin solution of collodion is prepared and held ready for immediate use. The air-douche is then given to the patient, and the aurist must ascertain by inspection that the membrane has really been driven outwards by the air. The patient's head is then tilted well to the side, so that the axis of the meatus is vertical. The collodion is now poured into the meatus through the speculum, and allowed to run down on to the membrane. The excess of collodion is then removed immediately by means of pledgets of absorbent cotton-wool wrapped round the end of a probe. The head of the patient is still kept in the same position—

that is, with the meatus vertical—for several minutes, until the collodion has set. When the fluid is first poured in, the patient experiences a sense of cold, owing to the evaporation of the ether and alcohol; this is followed by a sensation of warmth, which may be pleasant, but more frequently is the reverse, as it amounts sometimes to considerable smarting. The coating of collodion thus formed upon the drumhead lends a stiffness to that membrane, thus making it, in its physical character, more like the healthy structure. In successful cases the improvement is noticeable almost at once. After a period of from four to six or eight weeks the coating of collodion separates off and leaves the membrane in a condition of tension more approaching the normal. The coating of collodion should be picked out with forceps, and the procedure should be repeated two or three times.

On *a priori* grounds it is difficult to see how this method of treatment can really be permanently beneficial. It must be remembered that the natural tension of the membrane is maintained by the circular and radiating fibres which exist in the normal condition. Now, in the atrophied membrane these fibres no longer exist, or, if so, they have lost their original character. When, therefore, the support of the collodion is removed, it is but natural to suppose that relaxation of the structure will again appear, since the causes that produce it are still in existence. As stated above, however, this is merely *a priori* reasoning, and the writer would advise a trial of this method in all suitable cases, for it can do no harm. It is just possible that there may be some power of repair still left in the tissues of the membrane, by which a permanent increase in tension may be brought about.

Attempts have been made to increase the rigidity of an atrophied membrane by means of multiple punctures. The principle underlying this method of treatment lies, of course, in the recognized pathological fact that cicatricial tissue tends to contract constantly. The method, therefore, has a theoretical basis; but, like so many other methods based upon such considerations, it fails in its object when put to the touchstone of practical experience. The truth is that, in the designing of this method, the various factors, anatomical as well as physical, which come into play were not sufficiently considered. It is, of course, perfectly true that cicatricial tissue tends invariably to contract; but its contraction can be influenced, or indeed kept in entire abeyance, by mechanical means, if these forces are sufficiently strong and sufficiently constant. This factor is present in the case under discussion. For it is to be noted that a cicatrix of the membrane is extremely thin, and the power of contraction is therefore exercised by a comparatively small number of contracting fibres. The changes of pressure within the tympanum, on the other hand, whether they be in the negative or the positive direction, are quite sufficient to prevent this contracting power in the cicatrix from bringing about any appreciable increase in the tension of the membrane.

EUSTACHIAN CATARRH.

Under the name Eustachian catarrh are included certain cases in which the mucous membrane of the Eustachian tube is affected rather than that of the tympanic cavity. Pathologically there is probably little difference between the two conditions, and there can be little doubt that in all cases the mucous membranes of both the middle ear and Eustachian tube are affected, though to a varying extent in each. Clinically, however, there is some justification in the term, and this is especially the case in respect to the results of treatment.

Symptoms.—Deafness is not so marked in Eustachian catarrh as in exudative catarrh of the middle ear, but it varies greatly from time to time. Similarly, climatic conditions affect the deafness to a very great degree, and frequently, indeed, there may be intervals of almost perfect hearing during a spell of warm, dry summer weather or during a sojourn at a high altitude. There is the same sense of *fulness in the ears* as in cases of exudative catarrh, but this symptom is not usually so pronounced, and also varies greatly from time to time. *Tinnitus* of a mild type may be present, and sudden loud cracks may be heard occasionally when the Eustachian tube opens and allows air to rush into the tympanum.

The membrane is indrawn, but there is no line to be seen running across it and indicating the presence of fluid unless, of course, middle-ear catarrh is superadded to the Eustachian affection, which is not infrequent. On inflation of air into the tympanum the improvement is very marked and, moreover, lasts much longer than is the case in the middle-ear affection.

Treatment.—Eustachian catarrh is always the result of an extension from the nasal and naso-pharyngeal passages. In children adenoid growths are by far the commonest cause of the trouble, while in adults hypertrophy of the posterior end of the inferior turbinated body is the usual source of the mischief, but polypi and other nasal affections are sometimes found. It is necessary to rectify these conditions before attending to the local trouble in the Eustachian tube, and in many cases it will be found that, on restoring the nasal passages to a healthy condition, the deafness disappears without further treatment. If, however, the dulness of hearing still remains, the tympanum should be inflated three times weekly for a period of a few weeks, while the soft parts below the lobule of the auricle and between the angle of the jaw and the mastoid process should be firmly massaged night and morning. If there is any obstruction in the Eustachian tube owing to the swelling of the mucous membrane, as evidenced by difficulty of inflation per catheter, a bougie should be passed, but inflation should not be performed *immediately after* the use of this instrument.

NON-SUPPURATIVE DISEASE OF THE MIDDLE EAR WITHOUT EXUDATION.

Of the non-suppurative forms of middle-ear disease, there remains to be described a certain type which probably includes several different pathological entities. Clinically, however, the cases present sufficient similarity to justify their inclusion under one definition until further advances in pathological anatomy and pathogenesis enable us to apply a more scientific nomenclature. The terms *chronic adhesive processes in the middle ear* and *otofibrosis* may be considered for practical purposes synonymous with the term employed above for these cases. The older term ' dry catarrh of the middle ear ' cannot be properly employed in the same way, since there is no doubt that a large number of the conditions included under this name by the older generation of aurists were in reality cases of otosclerosis.

Pathology.—There is little doubt that many cases merely represent a later stage of the affection which was described in the preceding pages as exudative catarrh. Hence we find that there is considerable round-cell infiltrate into the mucous lining of the tympanum associated with the formation of fibrous adhesions and contractions. In the early stage secretion may be present, but later this disappears, and clinical examination reveals the fact. The new-formed connective tissue by its contraction tends to prevent the movements of the ossicles; and the mucous membrane, though still thickened, becomes smooth and pale, and is usually more firmly united to the bone beneath than in the healthy condition. The extent of these changes varies greatly in individual cases, but, according to Politzer, it is apt to be most pronounced at those places where the ossicles are in contact with the walls of the tympanum. Strictures of the Eustachian tube may occur as a result of the swelling of the mucous membrane. In rare circumstances the mucous membrane may become the seat of calcareous deposits, and even new-formed bony tissue may develop. Only very rarely is there bony union between the stapes and the walls of the fenestra ovalis, and this feature, among others, differentiates the condition from that of otosclerosis. According to Moos, the intratympanic muscles may undergo atrophy and fatty degeneration; but in a great number of cases, as Politzer has shown, this does not occur, and in the few examined by myself no sign of any change was present in the tensor tympani. Politzer has also shown that changes in the bony capsule of the labyrinth may take place, similar to those found in otosclerosis.

But it must not be assumed that all cases coming under the clinical term employed in this section present the pathological changes just described. The majority may belong to this category, but it is quite possible that many are different in their pathogenesis and may present atrophic changes from the beginning. The subject requires much further investigation before definite conclusions can be reached.

Etiology.—In the majority of cases the causes are the same as those which bring about the exudative form of middle-ear catarrh. Hence we usually find evidence of present or past disease in the nose or naso-pharynx. Other but less definitely determined causes are given by some writers—such conditions as anæmia, Bright's disease, tuberculosis, general ill-health, and, of course, the inevitable rheumatism and syphilis. Heredity plays but little, if any, part in the affection, beyond that which it does in all diseases. In this respect, therefore, the condition contrasts with that of otosclerosis. In perhaps the majority of cases the disease is bilateral, but there is a large number of exceptions to the rule, this being another feature in which it differs markedly from otosclerosis.

Diagnosis.—The diagnosis is not usually difficult. On *inspection*, the membrane is seen to be somewhat more opaque than normal, and is indrawn. In many cases some portions are opaque, while others are particularly transparent owing to atrophy. Deposits of calcareous salts are frequently present in the membrane, and are easily recognized by their milk-white colour and sharp outline (Fig. 78). The light-reflex is usually narrow and elongated, but great variations occur in this respect. In rare cases the inner surface of the membrane may be adherent to the promontory, and this condition may sometimes be recognized by the use of Siegle's pneumatic speculum, when it will be observed that the adherent portion does not move with the rest of the membrane.

On using the catheter, the air is heard to enter the tympanum without any of the bubbling sounds which accompany its entrance when fluid is present, but beyond this the character of the sound is of little value in diagnosis. After inflation there is usually some degree of improvement in the hearing, but it is by no means so striking as that which occurs under the same circumstances in the exudative form of the disease.

On testing the hearing, the results are characteristic of middle-ear disease. Thus bone-conduction is prolonged relatively to air-conduction. The hearing for the low notes is much more seriously affected than that for the high ones, and, indeed, for the latter the hearing may be perfect. If one ear is affected the sound of a tuning-fork held against the skull or on the teeth, in the middle line, is heard best in the affected ear.

The degree of *deafness* varies within wide limits, but never reaches the very severe defect found in labyrinthine disease and sometimes in otosclerosis. Variations in the degree of deafness may occur, but they are not such a marked symptom as in the exudative form of middle-ear disease.

Tinnitus is more frequently present than in exudative catarrh, but less frequently than in otosclerosis. It is not so continuous as in the last-named affection, is rarely as severe, and does not, therefore, usually produce such a distressing effect upon the patient. But in this respect the temperament of the sufferer affects very considerably the importance he attaches to the symptom. A sense of fulness in the head or ears is frequently present, but attacks of giddiness are very rare.

Paracusis Willisii is sometimes noted by the patient, but not quite so frequently, perhaps, as in otosclerosis. It indicates the presence of comparatively firm adhesions, or of delicate bony trabeculæ passing from the stapes to the walls of the oval window (see p. 99).

Prognosis.—There is no possibility of complete recovery of the hearing. On the other hand, the deafness never reaches the high degree which is frequently characteristic of otosclerosis and labyrinthine disease. The prognosis depends, for the most part, upon the extent and duration of the improvement in hearing after inflation by the catheter. The greater the improvement and the longer it lasts the less serious is the outlook. Another important factor in prognosis is the rapidity of the progress of the disease. Thus, a case in which the deafness has become fairly marked in the course of a few months will ultimately become much worse than one in which the symptom has reached a similar point after many years.

Some writers consider paracusis Willisii to be a bad omen; but while this may be justified in many cases, it is not so in all, and Yearsley[1] considers that the symptom is an indication for treatment.

Treatment.—The treatment of the affection must be varied according to the case. If it be found that there is considerable improvement after the inflation of air by the catheter, the procedure should be repeated two or three times a week until no further improvement can be obtained. The injection

[1] Yearsley, 'Textbook of Diseases of the Ear,' p. 269, 1908.

of various substances, such as chloride of ammonium, up the Eustachian tube may be employed in combination with the catheter, as described in the section on therapeutics (p. 109). Urbantschitsch strongly recommends the occasional passage of the Eustachian bougie, and there is no doubt it sometimes has a beneficial effect even when there is no stricture. Lake has pointed out the importance of not inflating the middle ear immediately after passing the bougie. The inflation of superheated air through the catheter has been recommended by Hopkins.[1] The results obtained by this method of treatment are on the whole, however, rather disappointing. Pneumo-massage is sometimes of distinct value, but, like the catheter, it must be judged according to its effects on the first or second occasion. Thus, if no improvement is produced on the first or second application, there is nothing to be gained by continuing the treatment. Various instruments have been designed for the purpose of applying pneumo-massage, and one of these is shown in Fig. 94. Delstanche was the first to apply the principle of vibratory massage by means of alternate rarefactions and condensations of air, and the improvements on his method have only been in the direction of increasing the rapidity of the vibrations. Sometimes pneumo-massage diminishes the tinnitus without improving the hearing, but the converse rarely occurs. Opinions vary greatly as to what should be the duration of each application. Some maintain that no benefit accrues from a sitting of more than two minutes, while others consider that twenty minutes' application is necessary at each sitting. Personally, I never allow the instrument to be applied for more than five minutes.

In recent times hypodermic injections of fibrolysin have been recommended, and, according to the experience of Gay French, they frequently bring about some improvement. I have seen distinct increase in the hearing-power in one case, and it was not open to the fallacy that the improvement could be attributed to other treatment carried out simultaneously. This case had previously undergone no improvement from the use of inflation and pneumo-massage, and neither these nor any other form of treatment were employed during the administration of fibrolysin when improvement occurred.

[1] Hopkins, *New York Medical Record*, June and September, 1902.

Unfortunately, however, in the few other cases in which I used the drug there was no appreciable improvement. We may say, therefore, that this treatment may occasionally prove helpful, but generally it will fail. To be of any value, one ampoule of the drug should be injected twice or three times a week for three or four weeks, or even longer. There appears to be no danger in this treatment in the case of

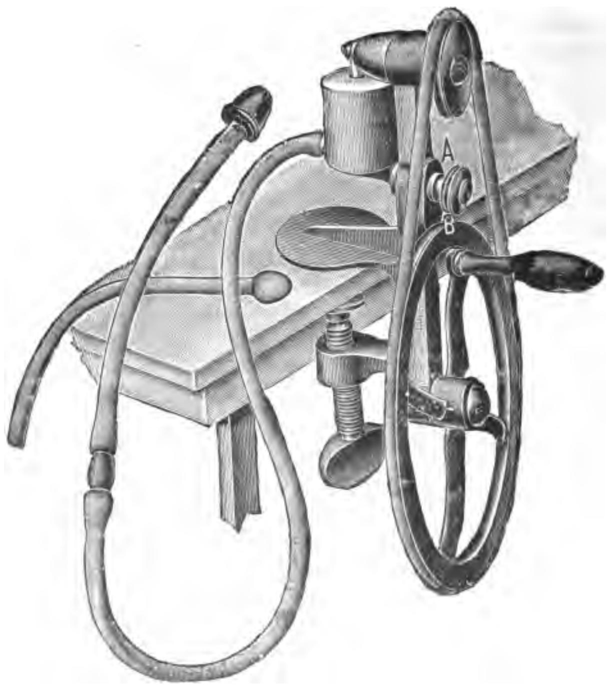


FIG. 94.—PNEUMO-MASSAGE APPARATUS.

individuals in ordinary health, but it should not be employed in those who suffer from arterio-sclerosis or kidney affections, or in old people. Pritchard has recorded a case in which serious results followed its use under these circumstances. The results of the treatment are on the whole disappointing, and the patient, before being subjected to it, should be made to understand clearly that it is of the nature of an experiment.

If a stricture of the Eustachian tube is present, this should be dilated by the passage of bougies once or twice a week; and, associated with this, applications may be made to the walls of the tube in the way described in the section on therapeutics. An ointment consisting of hydrarg. oxid. rub. gr. 14, vaseline ℥i, may be applied by the bougie, and better still is the solution introduced by Lake :[1]

℞ Hydrarg. oxid. rub.	gr. 4.
Lanolin.	gr. 100.
Parolein.	ad ℥i.

In the same way, iodine may be applied in the form of the following solution :

℞ Iodine	gr. 6.
Pot. iodid.	gr. 12.
Aq.	ʒii.
Ol. menth. pip.	♏ 2.
Glycerin.	ad ℥i.

In this, as in all forms of catarrhal disease of the middle ear, the condition of the nasal and naso-pharyngeal passages must first be carefully treated. The presence of adenoid growths, of catarrhal conditions of the mucous membrane, of atrophic rhinitis, or of suppurative disease of the nasal sinuses, will nullify all attempts at improving the hearing.

Operative Procedures.—Many little operations have been designed with the object of improving the hearing or diminishing the tinnitus. The following is a list of the various operations which have been devised and carried out, and then rapidly dropped out of practice—at any rate, by most aurists. Incision of the posterior fold, tenotomy of the tensor tympani muscle, extraction of the incus, mobilization of the stapes, extraction of the stapes, cutting of adhesions in the tympanic cavity, removal of the tympanic membrane, the making of an artificial perforation in the membrane, and section of the anterior ligament of the malleus. There is no necessity for wearying the reader with a description of these operations, since they are almost invariably failures from the beginning, and in the few in which there is any improvement in the symptoms, it is but temporary.

[1] Lake, Trans. Otolog. Soc., vol. vii., p. 70.

Lucae has attempted to loosen the ossicles by applying the cup-shaped end of his spring-pressure probe (Fig. 95) to the short process of the malleus, and pressing gently inwards several times for the space of a few seconds. Improvement certainly does sometimes result from this procedure, but

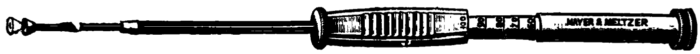


FIG. 95.—LUCAE'S SPRING-PRESSURE PROBE.

usually it is only temporary. A general anæsthetic is necessary in order to give a fair trial to what is a distinctly painful procedure. The pain is due, not only to the pressure on the short process, but also to the strain which is put upon the whole chain of ossicles — hence the insufficiency of local anæsthesia.

CHAPTER XI

DISEASES OF THE MIDDLE EAR (*Continued*)

NEW GROWTHS IN THE MIDDLE EAR.

NEW growths in the tympanum are rare, assuming that cholesteatomata and ordinary polypi are excluded from the category.

Epithelioma is by far the commonest type of new growth in the middle ear, and, indeed, any other may be looked upon as distinctly rare. It is in the great majority of cases a sequence of middle-ear suppuration more or less chronic. Doubtless the disease may arise in an ear previously unaffected in this way, but such cases are very exceptional, and often equivocal, because it is almost impossible to prove that the growth did not originate in the deeper parts of the meatus or on the outer surface of the tympanic membrane.

Symptoms.—The diagnosis is not difficult when once suspicion has been aroused; but, as a matter of fact, the first time the case comes under observation it is often mistaken for one of ordinary middle-ear suppuration. The mistake is natural, since middle-ear suppuration is nearly always a precedent condition. In the author's experience, the most valuable diagnostic symptom is pain on chewing. Although, so far as he knows, attention has not hitherto been directed to this symptom, it is one which should always arrest attention, for it is characteristically absent from an uncomplicated case of middle-ear suppuration. Another suggestive sign is frequent and profuse bleeding, and this is particularly significant if it is associated with the presence of granulations in the deeper parts of the meatus, which return very quickly after removal. When once suspicion has been aroused, the granulation tissue should be examined by the microscope, and the diagnosis can be made without difficulty. Pain and facial paralysis are also important diagnostic signs.

Prognosis and Treatment.—The prognosis is grave in the extreme. The anatomical relationships of the part almost certainly prevent complete removal of the growth, and by the time the disease has manifested itself the patient is already the victim of a fate which cannot be avoided. Opinions are not agreed as to the best method of treatment. Many surgeons look upon the condition as one to be left untouched, while others remove as much of the growth as possible.[1] When the mastoid antrum becomes affected, some surgeons recommend opening the cavity in order to relieve the pain caused by pressure. But the relief obtained in this way is at most only partial, and the free administration of morphia is necessary in all cases. Death usually occurs from meningitis, cerebral abscess or septic thrombosis.

Other new growths, such as various types of sarcoma, endothelioma, chloroma, etc., have been found in the tympanum, and it will naturally be understood that any tumour in the neighbourhood may extend into the cavity. It is highly probable that most cases described as sarcoma of the middle ear do not really originate in that cavity, but have extended into it from the meatus or from the tissues in the neighbourhood.

TUBERCULAR DISEASE OF THE MIDDLE EAR.

Tubercular disease rarely occurs in the middle ear as a primary condition, but is not unfrequent as a secondary manifestation of the disease already established in other organs, particularly the lungs. In some cases, however, the ear is the first organ to be affected by the tubercle bacillus, and the primary focus in these cases is usually in the mastoid process.

Symptoms and Signs.—The disease usually begins without any very noticeable pain, and the absence of this symptom is of value in diagnosis, since it is very characteristic of ordinary acute inflammation. In other respects the disease presents, in the earliest stage, features similar to the latter condition. Before long, however, differences manifest themselves. Thus, while there may have been but one perforation at the begin-

[1] West and Scott, 'The Operations of Aural Surgery,' Lewis, 1909.

ning, others now appear, and this, too, in spite of treatment. The membrane itself undergoes comparatively rapid destruction, and granulations form; but throughout the process pain is noticeably absent. The discharge is frequently not very profuse, and is usually thin and often fœtid. Caries and necrosis of the bony walls of the cavity are very common, and consequently facial paralysis is more frequent in tubercular than in ordinary suppurative disease of the middle ear. For the same reason the labyrinth is apt to become affected, and the deafness, therefore, to be very marked. Headache and other severe symptoms are not usually present unless intracranial complications occur.

It is a common mistake to assume that suppurative disease occurring in the middle ear of patients who are suffering from tubercular disease elsewhere, is to be looked upon as itself tubercular. As a matter of fact, this assumption is not justifiable, and the diagnosis must be made by considering the local signs and symptoms as described above, and by bacteriological examination. Even the examination of the discharge by means of the microscope sometimes leads to error, for it so happens that, in the discharge of non-tubercular cases, acid-fast bacilli are frequently found, which present appearances very similar to those of the tubercle bacillus. Milligan recommends inoculation of guinea-pigs with the discharge, and this is certainly the surest way of determining the nature of the disease.

Prognosis.—The prognosis of tubercular disease of the middle ear is grave. This is particularly true of those cases, and they are the large majority, which are secondary to tubercular disease elsewhere. When, however, the disease is primary and circumscribed in the mastoid process, the outlook is much more favourable, provided operation be undertaken without delay.

Treatment.—The treatment to be followed depends upon the nature of the case. It would obviously be unjustifiable to operate for tubercular middle-ear disease in a patient who was in the last stages of pulmonary phthisis. But if the primary lesion in the lung or elsewhere is in the earliest stage, it is desirable to operate upon the ear as soon as the case is recognized as one of tubercular origin. And the reason is obvious, for the patient may recover from both the lung and the ear affections, if operation be performed early. But if it be delayed, he will not recover from the ear affection even if the lesion in the lung should heal. Furthermore, the disease in the ear forms a focus which it is desirable to remove in all cases except in those in which the fate of the patient is already sealed.

The use of tuberculin by the method introduced by Wright might be tried in cases in which operation is inadvisable. I have had no experience of this method myself, nor am I aware of any expression of opinion as to its value in these cases by those experienced in the treatment of ear affections, and therefore competent to judge. It is probable, however, that in the course of a short time opinion will have crystallized in respect to this line of treatment.

When the lesion in the temporal bone is primary, or when other tubercular foci are present, but are either in a very early stage or of such a nature as not in themselves to endanger life—*e.g.*, tubercular lymphatic glands, etc.—then the radical mastoid operation should be performed without delay (see p. 287). The operation should be done with particular care, and every trace of disease must be removed, else it is sure to return.

It need hardly be said that local applications are not likely to succeed in curing tubercular disease of the middle ear. Their employment is limited to ameliorating the symptoms, such as fœtor, etc. Of these, the most useful, in the experience of the writer, is the solution of iodoform in anilin. The method of preparation of this solution and its use are described on p. 197, and need not be repeated here; but it is necessary to emphasize the importance of carefully drying out the solution a few minutes after its instillation, in order to prevent toxic symptoms.

OTHER CHRONIC INFECTIVE CONDITIONS ASSOCIATED WITH MIDDLE-EAR SUPPURATION.

Syphilis.—Besides tuberculosis, other chronic infective diseases sometimes manifest themselves as suppurative disease of the middle ear. Of these, syphilis and actinomycosis may be mentioned.

Suppurative disease due to syphilis is rare, or perhaps it would be more correct to say that it is rarely possible to demonstrate a relationship between the two. By means of the tests recently devised by Wassermann and others, however, it may be found that more cases come under this category than has been suspected.

Diagnosis.—The diagnosis is difficult unless there be some definite lesion in the nose or pharynx that may cause infection, and even in this case the diagnosis only amounts to a probability. It must not be supposed that otorrhœa occurring in a syphilitic subject is necessarily a syphilitic lesion. The appearances found on inspection do not differ from those of ordinary suppurative disease, beyond the fact that destruction of the soft parts and caries or necrosis of the bone occur rather more rapidly.

Prognosis.—The prognosis is certainly better than is the case in tuberculosis, but it is not very favourable. Intracranial complications are rarer than in tubercular disease, but the effect upon the hearing is usually very unfavourable, since the labyrinth is apt to be infected at a comparatively early stage.

Treatment.—By far the most important feature of the treatment is the administration of mercury and iodide of potassium. Large doses of these drugs should be given in order to prevent further advance of the disease. Local treatment consists in the use of the same measures as those employed in ordinary chronic suppuration, but it should be carried out with the utmost rigour. Should symptoms of intracranial trouble arise operation must be performed without delay.

Actinomycosis.—Actinomycosis is a very rare cause of otorrhœa, but cases have been recorded by Cozzolino, Zaufal and others. The local manifestation in the ear is almost invariably secondary to a lesion elsewhere in the body. The diagnosis is arrived at by the discovery of the ray fungus in the discharge from the ear. The prognosis is unfavourable, and in Zaufal's case, in which the disease was circumscribed in the temporal bone, free removal did not prevent its advance to a fatal termination. Brain abscess or other intracranial complication is usually the direct cause of death, but in a case recorded by ten Siethoff cure resulted, apparently from the administration of large doses of iodide of potassium.

CHAPTER XII

INTRACRANIAL AND LABYRINTHINE COMPLICATIONS OF MIDDLE-EAR DISEASE

THE most serious result of suppurative processes in the middle ear is the extension of the disease from that cavity into the interior of the skull. Further, suppurative disease of the middle ear is by far the commonest cause of similar disease within the cranial cavity. In recent years this has been emphasized by surgeons and aurists, and, fortunately, the medical man nowadays is usually well aware of such complications and is able to prevent them by timely treatment. The importance of this subject has already been referred to and need not detain us longer now. In the following pages there will come under consideration the pathways by which infection may proceed from the ear to the interior of the cavity of the skull. The causes and results of this infection will then be mentioned along with the pathological conditions, and finally the diagnosis and treatment of the various affections will be described.

Pathways of Infection.—One of the commonest pathways of infection is through the posterior wall of the antrum. The intracranial condition is almost always preceded by caries of the bone, though it is conceivable that the organisms might be conveyed by the veins or lymphatics. When infection follows this path, the endocranial affection which results may either be extradural abscess, thrombosis of the superior petrosal or lateral sinuses, meningitis, cerebellar abscess or a combination of any of these.

A second pathway of infection is through the roof of the tympanum or the roof of the antrum (Fig. 96). In this case, also, caries usually precedes the intracranial disease, though it may be very limited in extent. In such cases the result may be extradural abscess, cerebral abscess, thrombosis of the cavernous sinus and meningitis. Meningitis is, perhaps, relatively rather less common when the pathway of infection is through the tegmen tympani than when it is by other channels. These pathological conditions may also be present together.

The labyrinth frequently forms a pathway for infection, the organ having first become affected through the oval window, the round window, or through the promontory or horizontal canal after caries of the bony walls. From the labyrinth the infection may spread along the auditory nerve, the aqueduct of the vestibule, or the aqueduct of the cochlea; or it may be carried by the veins of the organ to the interior of the skull. When infection passes by way of the labyrinth the posterior fossa of the skull is almost always the one infected. There appears to be comparatively little tendency for infection to pass through the arch of the superior canal to the middle fossa, in spite of the fact that the bony partition here is very thin. In addition to the other forms of intracranial infection mentioned above, labyrinthine suppuration may give rise to abscess of the saccus endolymphaticus on the posterior surface of the temporal bone. In this case the condition may, from a practical point of view, be considered one of extradural abscess.

Infection of the cranial cavity may be brought about by spread of the organisms along a little vein which runs from the inner wall of the antrum, under the arch of the superior canal, into the interior of the skull.

Other but less common pathways of infection are the carotid canal and the cellular spaces surrounding the pyramid of the temporal bone.

Whatever be the pathway of the infection, the results may in any case be similar, except as regards their position. That is to say, no matter by what path the organisms gain entrance, they may produce extradural abscess, serous meningitis, purulent meningitis, septic thrombosis, etc. The reason why one of these conditions should occur in one case and not in another is not easy to determine. It probably depends to a considerable extent on the rapidity with which infection has proceeded from the middle ear to the cranial cavity. Thus, if the process be slow, there is time for granulations and adhesions to form between the dura mater and bone, or between the dura mater and arachnoid membrane, which permit the infection to reach the brain itself and form a cerebral or cerebellar abscess. On the other hand, if extension is rapid, the case is rather more likely to be one of extradural abscess or meningitis. This probably accounts for the fact that extradural abscess is relatively commoner after acute inflammation of the middle ear, and also for the fact that, when intracranial complications have developed as the result of violence, such complications are more likely to be of the nature of meningitis or extradural abscess than brain abscess. Exceptions to this general rule are, however, common.

Bacteriology of Intracranial Affections.—Various bacteria have been found in pyogenic conditions within the cranium, and, as might be expected, they are the same as those found in the middle ear. Streptococcus, staphylococcus, pneumococcus, tubercle bacillus, Bacillus coli, typhoid bacillus have all been recorded and doubtless others may be found. Von Bergmann stated at one time that the streptococcus is always present in brain abscess, but this has been proved to be incorrect, since pure cultures of staphylococcus have been recorded.[1] There is no doubt that in the great majority of cases the infection is mixed, but streptococcus and staphylococcus are most frequently present.

The causes which contribute to the invasion of the interior of the skull by pathogenic organisms are various, but there is no doubt that carious and necrotic processes in the temporal bone are by far the commonest. The infection, however, may proceed along the veins or lymphatics to the brain cavity without the presence of bone disease. It has been suggested that the removal of polypi from the ear in cases of middle-ear suppuration may give rise to intracranial trouble by opening small venules and allowing the organisms to pass inwards along them. Perhaps this may occur, but it must be so rare as to be negligible from a practical point of view; that is to say, such a possibility should not deter the surgeon from the removal of polypus for the cure of suppurative disease of the middle ear.

Obstruction to the outflow of pus from the affected part is

[1] Kyle, *The Laryngoscope*, vol. xviii., p. 113.

usually the direct cause of intracranial extension. Hence suppurative processes in the mastoid antrum, attic of the tympanum, and labyrinth are much more liable to be followed by dangerous sequelæ than those in the middle ear proper, since the possibility of obstruction is so much greater. It is for this reason that the aurist views with particular anxiety cases of otorrhœa in which recurrent attacks of pain occur, since this symptom is indicative of obstruction to the outflow of pus. The presence of caries in the temporal bone naturally favours the passage of infection to the interior of the skull, and injuries of the head, particularly those associated with fracture passing through the walls of the tympanum, are apt to have the same consequence in cases of otorrhœa. In a similar way, the performance of the mastoid operation for the cure of suppurative ear disease has been known to be followed by meningitis, but such an occurrence must be of great rarity (see p. 299).

It is interesting to observe that intracranial complications of middle-ear disease may occur even when the latter is serous and not purulent in character.[1] It is not even necessary that the tympanum itself should be affected at all, since cases have been recorded in which the mastoid antrum or cells alone were diseased. Both these contingencies are of the greatest rarity.

Diagnosis of Intracranial Complications in General.—In respect to diagnosis, the first and most important point is to ascertain, not the particular type of intracranial complication, but whether any such is present at all. A few remarks will therefore be made in respect to this general diagnosis before passing on to consider the detailed diagnosis, pathology and treatment of the different types of complications which may arise within the cranial cavity.

Occasionally the question as to whether an intracranial affection is or is not present in a case of suppurative disease of the ear cannot be answered at all. Thus, a brain abscess may be present for a comparatively long time without producing any symptom whatever. On the other hand, in a few cases of acute middle-ear disease symptoms such as giddiness, pain, vomiting, etc., may simulate in a remarkable way some intracranial form of disease.

[1] Donovan, Trans. Maine Med. Assoc., 1884.

In considering the question of diagnosis, it is desirable to lay stress upon the fact that the medical attendant should pay particular attention to the signs according to the degree to which they may be unequivocal, and not to their obtrusiveness in the case. Thus, pain, although a very obtrusive symptom, is a poor guide in comparison with optic neuritis.

Well-marked *optic neuritis* ('choked disc,' etc.) is one of the least equivocal signs of intracranial trouble, and therefore is of great value. It is true that some writers have found a slight degree of hyperæmia of the disc in very rare cases of acute middle-ear disease without apparent involvement of the structures within the cranium.[1] Some of the reports in this respect have been criticized, and it is difficult to prove that a localized serous meningitis is absent in any given case. Considered from the practical aspect, these exceptions—if they really are exceptions—are so rare that they can hardly be allowed to influence the diagnosis, and a well-marked choked disc, when present, may be looked upon as a quite unequivocal sign of intracranial infection.

Unfortunately, optic neuritis is very frequently absent in cases of serious intracranial disease, and the fact of its absence must in no case be allowed much weight.

Vomiting.—Vomiting is a very common symptom in intracranial affections, but, unfortunately, it is not at all uncommon in ear disease when the interior of the skull is quite free of infection, as, for example, in some affections of the labyrinth. It is, however, an important sign.

Pain.—Pain is probably the most constantly present symptom in endocranial diseases arising from otorrhœa. But it is so common in uncomplicated affections of the ear that it loses most of its value as a means of diagnosis. In general, it may be said that the pain of endocranial disease is not so definitely located in the ear itself as when the latter organ is the seat of the trouble, but there are many exceptions to this statement.

Giddiness is a common symptom in intracranial affections, but, since it is also common in diseases of the labyrinth, its value in diagnosis is not so great as might be supposed.

Paralysis.—Paralyses of various muscles are of great value

[1] Jansen, *Arch. f. Ohrenh.*, Bd. xxxvi.; Eversbusch, *Handb. d. Augenh.*, von Gräfe-Sämisch, 1903.

in diagnosis. The paralyses which are most common are those affecting the facial and ocular muscles. It must be pointed out, however, that paralysis of the sixth and seventh nerves is of little or no practical value in diagnosis, the reason being that these nerves are frequently paralyzed in the course of middle-ear suppuration without involvement of the structures within the cranium ; or, to state the matter more correctly, such intracranial trouble as may be present when the sixth nerve only is affected is usually so limited as to be of no practical importance. Facial paralysis, of course, is usually due to involvement of the nerve in the aqueduct of Fallopius.

Other signs and symptoms are usually present in cases of intracranial disease, but these will be described under the special types of such conditions.

Forms of Intracranial Complications.—The intracranial complications of middle-ear disease may take the following forms : extradural abscess ; thrombosis of the lateral, cavernous, or other sinuses ; meningitis, either purulent or serous ; cerebral abscess and cerebellar abscess. Unfortunately, more than one of these conditions is frequently present in one case, but for the purpose of description it will be assumed that there is only one form of intracranial complication present. The signs and symptoms of the numerous mixed cases will be referred to later.

EXTRADURAL ABSCESS.

Extradural abscess, or pachymeningitis externa, is the most common of the intracranial complications of ear disease. Further, it is the one exception to the general rule that intracranial complications are more apt to follow the chronic forms of ear disease than the acute ones. According to Leutert,[1] it is especially apt to follow acute inflammation of the tympanum when the pneumococcus is the cause of the latter condition. As a rule the abscess is small, but in rare cases it may be large, separating the dura mater from the bone over a considerable portion of the side of the skull. Its most common position is on the posterior surface of the temporal bone in the vicinity of the lateral sinus, but it is not unusual to find the abscess over the tegmen tympani. In rare cases the

[1] *Arch. f. Ohrenh.*, Bd. xliii., S. 1, 1899.

abscess cavity is found on the posterior surface of the temporal bone over the site of the posterior semicircular canal, and in still rarer cases it is found at the tip of the pyramid of the temporal bone. It is possible for an extradural abscess to discharge externally through a fistula over the mastoid process, or farther back through the mastoid vein, but such means of relief is rare.

Symptoms and Diagnosis.—The *general* symptoms are those of intracranial pressure, slowing of the pulse-rate to 50 or 60 per minute, headache (either general or localized to one side), giddiness, vomiting, constipation, malaise, loss of flesh, somnolence (more particularly in children), and optic neuritis. The last-named important sign is less frequently present in extradural abscess than in other forms of intracranial complication, being absent in 92 per cent. of the cases.[1] The temperature is usually normal or subnormal in uncomplicated conditions.

Localizing signs are not usually present, but tenderness to percussion over the region behind the mastoid process and stiffness of the neck indicate, with a certain degree of probability, a locality in the posterior fossa.

In some cases of extradural abscess no symptoms are present at all, the condition being discovered by accident during the performance of the mastoid operation. It is not difficult to understand that this should occur, when we remember that the pus may find an easy though precarious means of exit through the sinus in the bone which allowed it to form.

Treatment.—Operation affords the only means of relief, and every hour's delay in its performance increases the danger to life. The operation is described on p. 303.

THROMBOSIS OF THE SINUSES.

One of the frequent intracranial complications of otorrhœa s thrombosis of the various sinuses. Of these, the lateral or sigmoid is by far the most commonly affected, but the cavernous and petrosal sinuses, inferior or superior, may also be diseased. More than one sinus may be affected at the same time and, as with other intracranial complications, a combination of conditions may exist: in thrombosis extradural

[1] Hansen, *Arch. f. Ohrenh.*, Bd. liii., S. 196.

abscess is the most common associated condition. Further, as a result of septic emboli, it is not uncommon to have general septicæmia and pyæmia as a secondary complication.

Thrombosis is apt to occur as a result of chronic rather than acute middle-ear disease, and the direct cause may be, and most frequently is, an extradural abscess surrounding and eroding the wall of the sinus. It may, however, be a result of the erosion of the bone and sinus wall by a cholesteatoma, or by the direct spread of infection from the bone to the sinus without the formation of an extradural abscess.

Symptoms.—It is very much rarer for sinus thrombosis to remain 'latent' than extradural or brain abscess. Such a condition, however, has been known to exist. Headache, vomiting, malaise and mental depression are among the more general symptoms. Optic neuritis is more common than in extradural abscess, but less than in brain abscess. It is present in about 40 per cent. of the cases. Other symptoms of intracranial pressure are sometimes present, such as giddiness, slowing of the pulse and rigidity of the muscles of the neck. The pulse may be slow, slightly accelerated, or rapid.

The temperature in sinus thrombosis is usually very characteristic *if there be no accompanying leptomeningitis.* It is of a markedly remittent or intermittent type, and is associated with rigors and occasional profuse perspirations. It is not surprising, therefore, that the disease has sometimes been mistaken for malaria and for typhoid fever. Owing to the deposit of septic emboli, secondary inflammations and abscesses may form in the kidneys, spleen, joints, etc., and still more frequently in the lungs. In the lungs they give rise to pleurisy and pulmonary infarction. The physician, therefore, must constantly be on the alert for signs of disease in other organs and especially in the lungs. Hæmorrhages into the retina are not uncommon and are symptomatic of septic infection.

A sign of thrombosis of the sinus which is frequently mentioned in textbooks is the presence of a cordlike swelling along the line of the jugular vein. The author cannot help thinking that the belief in this condition is one of those surgical exaggerations which, having been handed down from textbook to textbook, have crystallized into a fetish. He has never seen such a condition, and his suspicions are shared by not a few other aurists.[1] Fagge suggests that any hardness in this region may result from adenitis, and the present writer considers it possible that it may sometimes be due merely to the rigidity of the sterno-mastoid muscle, which is not unfrequently associated with a similar condition in the other muscles of the neck when a patient is suffering from this disease or from meningitis. In any case the surgeon must lay no weight upon the absence of this cordlike swelling.

Œdema.—Dilatation of the veins on the side of the head and neck is suggestive of thrombosis, and if œdema be present this sign is of great value, not only as an aid to the diagnosis of thrombosis but also, to a certain extent, as to its locality. Thus, œdema over the mastoid process or over the point at which the mastoid vein makes its exit from the skull, 1½ to 2 inches behind the external meatus, indicates an obstruction in the lateral sinus. On the other hand, œdema of the eyelids is significant of cavernous sinus thrombosis.

Nystagmus.—Nystagmus may be present, but is not of much value as an aid to diagnosis, since its frequent occurrence in any labyrinthine affection renders it equivocal.

Tenderness over Mastoid.—Tenderness on pressure over the mastoid process does not help very much in diagnosis, as it may be present in any acute ear affection.

Mental Symptoms.—Though depression is frequently present, the mind usually remains clear almost to the end, so long as meningitis is absent. In this respect thrombosis is in striking contrast with meningitis and the later stages of brain abscess.

Leucocytosis is usually marked in thrombosis, but such is also the case in meningitis and even simple mastoiditis.

MENINGITIS.

Meningitis, or, to define it more accurately, leptomeningitis, may be serous or purulent in character. In the latter case it is the most dangerous form of intracranial disease resulting from otorrhœa. Clinically it is almost impossible to distinguish the two forms in the early stage, but the more severe constitutional disturbance and the wilder delirium of the suppurative form may help in prognosis.

[1] Permewan, Fagge and Cheatle, Trans. Otolog. Soc., vol. viii. p. 21.

Meningitis, whether of the serous or purulent type, differs from other forms of intracranial complications of ear disease, except thrombosis, in that there is but rarely, if ever, a latent stage; when the soft membranes of the brain become inflamed, the symptoms of disease appear without delay.

The direct causes which favour the occurrence of meningitis are much the same as those which lead to other forms of intracranial complications; that is to say, its occurrence is favoured by obstruction to the outflow of pus, caries of the walls of the middle ear, or erosion by cholesteatoma and suppurative processes in the labyrinth. The organisms found in meningitis are similar to those of other intracranial infective processes—staphylococcus, streptococcus, pneumococcus, etc.

Symptoms.—The onset of meningitis in any form is characterized by headache, which may be slight, but usually is very severe. Vomiting, stiffness of the neck and twitchings or pareses of various muscles are common, and, since the posterior fossa of the skull and the spinal canal are frequently implicated, symptoms of irritation or paresis of many nerves are sometimes present.

Opinion is divided as to the frequency of *optic neuritis* in uncomplicated cases of otitic leptomeningitis. Thus, Körner[1] finds it present in only 8 per cent., while according to Hansen's experience it is found in 57 per cent.[2]

Constipation is almost constantly present and the belly indrawn in meningitis, symptoms which may help to differentiate the disease from thrombosis, but not from brain abscess.

Temperature.—The temperature in meningitis is, except in rare instances, above the normal, and as the case proceeds the more certain is this sign to be present. It does not usually have the marked remissions which occur in thrombosis, and rigors are by no means so common as in the latter condition.

Pulse.—In the early stage of the disease the pulse may be normal, but is usually quickened. In the second stage, however, it is retarded; but after this it becomes irregular and smaller in volume, until in the later stages it is exceedingly rapid and correspondingly feeble.

[1] Körner, 'Die otit. Krank. d. Hirns,' etc., S. 45, 2. Aufl., 1896.

[2] Hansen, *Arch. f. Ohrenh.*, Bd. liii., S. 196.

Respiration.—The respiration may be of the Cheyne-Stokes type, or show other irregularity, especially in the later stages.

Vomiting.—Vomiting is a common symptom, and it is of considerable value in that it is often present very early in the history of the case.

Paralyses.—Paralyses or twitchings of various muscles are almost always present at some stage of the disease. It is unnecessary to enumerate the various muscles which may be affected, though particular attention should be paid to those of the eye and the face; but it must be remembered that paralysis of the *external rectus alone* is of little value in diagnosis. As regards facial paralysis, this sign is not of much help, since it is common in simple otorrhœa; but, so far as the writer's observations go, it is a curious fact that twitching of the facial muscles is very rare in simple otorrhœa, while it is common in meningitis. The pupils may be dilated or contracted, and are sometimes unequal. In meningitis photophobia is usually pronounced and is of help in diagnosis.

Mental Symptoms.—In most cases the mind is affected, and in severe types of the disease mental symptoms are always present in the form of delirium, depression or somnolence.

Glycosuria.—Transient glycosuria has been observed by the writer in a case of serous meningitis; it passed off in a few days and recovery ensued. The same condition has been recorded by Truckenbrodt.[1]

Kernig's Sign.—In meningitis the condition known as Kernig's sign is sometimes present. The patient, when lying on his back, is unable to flex the thigh upon the abdomen without at the same time flexing the leg; he is also unable to extend the leg completely.

Lumbar Puncture.—Valuable information may be gained by examination of the cerebro-spinal fluid obtained by lumbar puncture. The fluid drawn off may be perfectly clear, even in a case of purulent meningitis, and no importance must be attached to the absence of cloudiness.

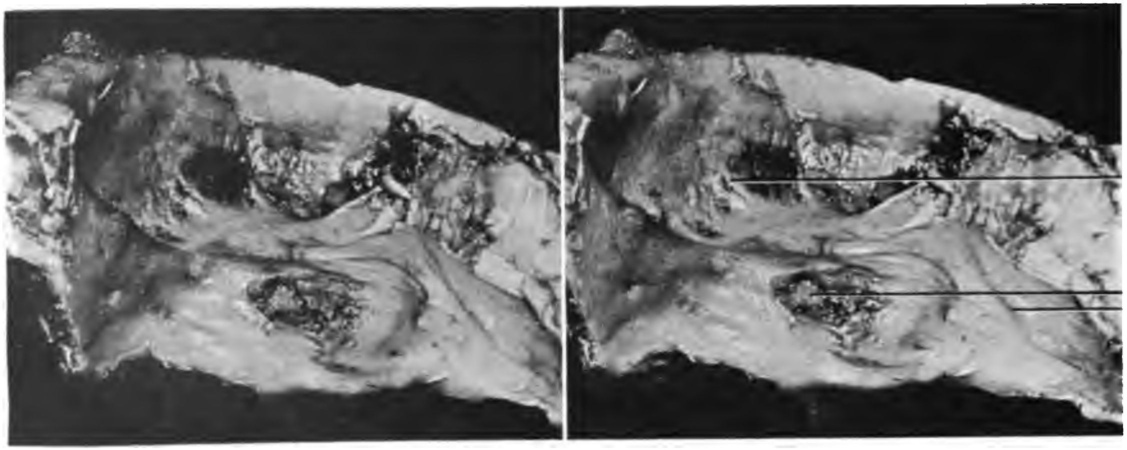
If organisms are found in the fluid, it is very probable that meningitis is present, and, according to some observers, is absolute proof of that condition. There are, however, equally experienced surgeons who have found organisms

[1] *Zeitschr. f. Ohrenh.*, Bd. xxi., S. 91.

Fig. 96.—Portion of Temporal Bone showing Carious Area in Tegmen Antri, through which Infection passed and caused Temporo-sphenoidal Abscess. From a Case of the Author's. Viewed from Above. × $\frac{2}{3}$.

(Prepared and photographed by the Author.)

a, groove of the lateral sinus. *b*, carious spot through which infection passed. *c*, internal auditory meatus.



[*To face p.* 254.

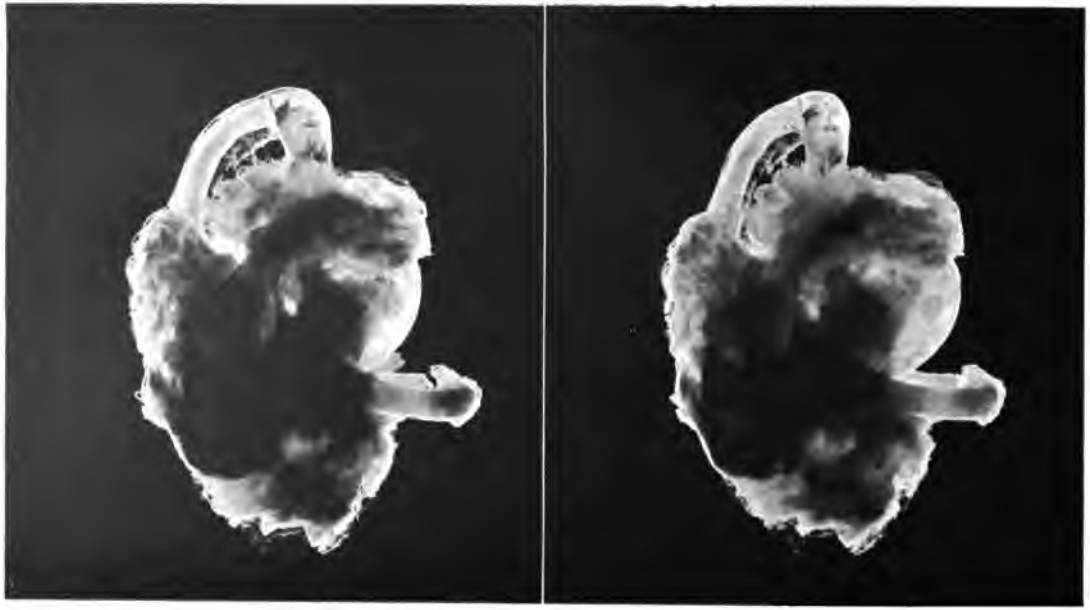


FIG. 97.—PREPARATION SHOWING ALMOST COMPLETE DESTRUCTION OF THE VESTIBULE AND SEMICIRCULAR CANALS BY SUPPURATIVE DISEASE IN THE MIDDLE EAR AND LABYRINTH. $\times 4\frac{1}{2}$.

(Prepared and photographed by the Author.)

The condition had lasted for very many years without causing any symptoms associated with disturbance of the functions of the vestibule and semicircular canals. The cochlea from the same case is shown in Fig. 98. The patient died of malignant disease elsewhere.

[To face p. 255.

present in the cerebrospinal fluid in uncomplicated cases of brain abscess. In spite of such observations, there is no doubt that examination of the cerebrospinal fluid is one of the most valuable means of diagnosis when a positive result is obtained. The absence of organisms in the fluid is by no means proof that there is no meningitis. The fluid should be examined for polymorphonuclear leucocytes, and its turbidity and coagulability should be noted, the presence of any of these conditions being in favour of a diagnosis of meningitis.

ABSCESS OF THE BRAIN.

Abscess in the substance of the brain, as a complication of middle-ear disease, is brought about in very much the same way as are the other intracranial affections. Thus, caries or erosion of the bony wall of the tympanum is by far the commonest predisposing condition and, indeed, is rarely absent. All causes which tend to prevent the outflow of pus may be factors in the production of brain abscess.

In the great majority of cases, chronic suppuration in the middle ear is the preliminary factor, though in some cases brain abscess has been known to form as a result of acute inflammation of the cavity.

The most common point at which perforation through the wall of the tympanum occurs is in the roof of the attic or aditus (Fig. 96). Hence the abscess is most commonly found in the temporo-sphenoidal lobe of the cerebrum. The situation next in frequency is the cerebellum, and in this case the abscess may be the result of suppuration in the labyrinth, infection having proceeded by way of the auditory nerve, by the aqueduct of the vestibule, or by perforation through the posterior semicircular canal. Cerebellar abscess may also result from infection through a fistula leading from the posterior wall of the antrum.

The proportion of cerebral to cerebellar abscess is about 2 to 1, and in children the proportion of cerebral abscess is much greater.[1]

As a general rule only one abscess is present, though cases have been recorded in which two, three, four, and even five have been found. The size of the abscess varies, the majority

[1] Körner, *op. cit.*

being small, but it may be so large as to destroy the whole hemisphere of the cerebrum. An average size is that of a large walnut.

The contents of a brain abscess usually have an extremely fœtid odour, but occasionally this is absent. In consistency the pus is commonly very thick, but if rupture into the lateral ventricle has occurred it is turbid, thin and watery, with, however, the usual fœtid odour. Such a case was recorded by the author (see p. 260).

The micro-organisms found in brain abscess may be streptococcus, staphylococcus, diplococcus, Bacillus pyocyaneus, Bacillus coli, and saprophytic bacteria. The abscess may be encapsuled by a firm lining membrane or it may have no definite capsule at all. The more recent the lesion, the less defined is the wall of the abscess.

Symptoms and Course.—The course of the disease is usually divided into four stages—the initial, the latent, the manifest and the terminal. The duration of any stage may vary within wide limits and occasionally a stage may be omitted altogether. In the *initial* stage there is slight fever, headache and vomiting, which usually subside rapidly and are not unfrequently attributed to the middle-ear disease from which the patient is suffering. The *latent* stage which follows is sometimes characterized by the complete absence of symptoms, but in many cases, on careful inquiry, there will be obtained a history of occasional attacks of headache and periods of mental depression. There may also be slight rise of temperature in the evenings. This stage may last over a period varying from several weeks to two years or more. It is followed by the *manifest* stage, in which the disease declares itself by the signs and symptoms which are described below. It does not usually last more than a few weeks, but in rare cases may extend over a year. The course of the disease is closed by the *terminal* stage, in which life is brought to an end by rupture of the abscess on the surface of the brain or into one of the ventricles, by œdema of the brain, or by the increased intracranial pressure.

The latent stage may be absent, so that after the initial illness there is no improvement. Further, the manifest stage may also be absent, especially if the patient receives a blow on the head, or if he is subjected to severe bodily strain or mental excitement. In this case the sufferer passes suddenly from a condition of apparent health to unconsciousness.

It is, however, in the manifest stage that the medical attendant is usually called upon to investigate the case, and it is to this stage that the following description, for the most part at least, applies.

Pain is almost invariably present in the manifest stage, and is usually severe and continuous. It may be diffused over the whole head, or may be limited to the side in which the abscess is seated. It is usually increased on percussion and occasionally on pressure. When the abscess is in the cerebellum the headache is frequently occipital, but in no case should too much importance be attached to the locality of the pain.

Temperature.—Apart from the slight feverish attacks in the initial and latent stages, the temperature in brain abscess is not usually raised, and is frequently lowered, a characteristic which is of great value in uncomplicated cases. If, however, meningitis or thrombosis is present as a complication, then the temperature is usually raised.

Pulse.—The pulse also is slow in brain abscess, falling to 50, 40, or even fewer beats per minute. This sign also, it must be understood, is subject to the same qualifications as the temperature in regard to the presence of meningitis and thrombosis.

Giddiness and Vomiting. — Giddiness and vomiting are common features in brain abscess, especially when the disease is located in the cerebellum; but the diagnostic value of these symptoms is largely discounted by their frequency in labyrinthine disease, and the same may be said of nystagmus. Obstinate constipation is more valuable as a sign of brain abscess than the two symptoms just mentioned, and the same is true of rapid loss of flesh, which is particularly characteristic of cerebellar abscess. Optic neuritis is found in about 50 per cent. of the cases. Its presence is, therefore, a great help in diagnosis, but a negative finding must be allowed little weight.

An individual suffering from brain abscess frequently undergoes changes both in respect to *character and intelligence.* He becomes irritable and hypochondriac in disposition, and his intellect suffers in the rapidity of its action, bringing about the condition which has been termed by Macewen 'slow cerebration.' Sleepiness associated with frequent yawning is a very common feature of the disease, especially when the abscess is in the cerebellum.

Localizing Signs.—The signs and symptoms described above are common to brain abscesses in general, though some may be rather more characteristic of disease in one part of the brain than in another. But in addition to those mentioned, there are other signs and symptoms which frequently guide us in attempting to locate the position of the abscess. Now, since the majority of brain abscesses are situated in the temporo-sphenoidal lobe or in the cerebellum, it follows that the locating signs will be the result of irritation or destruction of those portions of the brain or of the neighbouring parts. Hence *aphasia*, *amnesia*, *alexia*, etc., indicate disease of the temporo-sphenoidal lobe of the left side, or the region just in front of this (unless the patient be left-handed, in which case the right side is probably the seat of the lesion). Deafness in the ear of the side opposite to that in which the abscess is situated may occur, but it is a rare symptom. Temporo-sphenoidal abscess is frequently associated with twitchings, convulsions, or spasms of the limbs of the opposite side of the body, and pareses of these limbs may be indicative of the same lesion. So also *hemiopia*, *hemianæsthesia*, *hemiplegia*, *oculo-motor* and *other paralyses* may occur from an abscess in the temporo-sphenoidal lobe.

Cerebellar Symptoms.—When the abscess is situated in the cerebellum, one of the most prominent symptoms is *ataxia* associated with *giddiness*. *Stiffness of the neck* is a symptom more characteristic of cerebellar than of cerebral abscess, but in neither does it reach the same degree of rigidity of the muscles as is the case in meningitis.

Nystagmus is sometimes present in cases of cerebellar abscess. According to Neumann, when nystagmus which was previously more marked on turning the eyes towards the sound ear, changes and becomes greater on looking towards the diseased ear, abscess in the cerebellum is very probably present. Too much importance, however, must not be attached to this or any of the nystagmus tests.

While actual *paresis or paralysis* of certain muscles or groups of muscles is not so common in cerebellar as in cerebral abscess, there is greater diminution in the muscular strength as a whole in cerebellar disease, and this diminution in strength is associated with *prostration, frequent yawning* and *sighing.* A very characteristic feature of cerebellar disease is *rapid emaciation,* and this may occur when the appetite is so excessive that the patient may almost be said to suffer from bulimia.

The *slow pulse* so common in cases of brain abscess is particularly noticeable in cerebellar disease, and is sometimes associated with slowing of the respiratory movements.

Certain other symptoms are occasionally found in cases of abscess of the brain, whether these be situated in the cerebrum or cerebellum. Thus, *photophobia* may be present, but it is only rarely the distressing symptom which is manifest in meningitis. *Paralysis of the bladder* and *rectum* may occur in brain abscess apart from loss of consciousness, but such a condition is very uncommon.

Diagnosis.—If the patient be suffering from uncomplicated brain abscess in the manifest stage, the diagnosis of the condition is not usually very difficult. Unfortunately, however, the disease is frequently complicated by thrombosis or meningitis, and under such conditions its recognition is difficult, and sometimes impossible (see below). The slow pulse, the lowered temperature, the vomiting and optic neuritis, along with various paralyses and especially oculomotor palsy with ptosis, are among the most important guides to diagnosis.

Prognosis.—The prognosis in uncomplicated cases of brain abscess is fairly good if operation be performed before the terminal stage sets in, but without operation it is extremely grave. Cases have been recorded in which recovery has ensued without operation, the abscess having discharged itself through a fistulous opening in the bone; but the number of such is so limited that they may be considered negligible so far as prognosis and the indications for treatment are concerned. A patient suffering from brain abscess will die unless the condition be treated by operation.

Complications masking Intracranial Disease.—It has been stated above that in the intracranial complications of ear disease more than one condition may be present at a time. Under these circumstances it may be said in general that meningitis obliterates the clinical features of brain abscess almost entirely, and of septic thrombosis to a very great extent. Thus, the low temperature and slow pulse of brain abscess are not manifested when meningitis is present, and the marked oscillations of temperature associated with rigors in thrombosis become less pronounced, even if they indicate their presence to a certain extent.

If brain abscess be not treated in the 'manifest' stage, it passes into the 'terminal' one. This is frequently the result of rupture of the abscess, either on to the surface of the brain or into one of the lateral ventricles. When this occurs, the aspect of the case changes with great rapidity. The temperature becomes raised, the pulse-rate increases and intense headache, followed by delirium and coma, rapidly supervene, and Cheyne-Stokes respiration is usually present. If the rupture into the lateral ventricle be sudden, as it generally is, death occurs within twelve hours. But the opening of an abscess into the lateral ventricle does not always, as has been erroneously supposed, bring about so rapid a termination. The leakage may occur so gradually that shock is avoided, and if operation be carried out the symptoms may almost disappear, to be followed by those of meningitis, which in its turn brings about the death of the patient. An interesting case of this description was under the care of the author, and the following report of it illustrates the sequence of events. For these notes I am indebted to my house-surgeon, Dr. Douglas.

A girl, aged seven, was admitted to the Victoria Infirmary, Glasgow, in a comatose condition. The right ear had been the seat of purulent disease since infancy. Three weeks previous to admission pain was complained of in the right ear and across the forehead. The pain became much worse two days before admission, and left facial paralysis and ptosis occurred about the same time. There was no vomiting, twitching or convulsions.

On examination the child was seen to be deeply comatose, and apparently moribund. As a last hope, however, operation was decided upon, and no anæsthetic was necessary. The radical mastoid operation was performed, but no fistula leading into the cranium was found. The tegmen tympani was removed, the dura mater incised, and a tenotomy knife passed upwards and inwards into the temporo-sphenoidal lobe. At a depth of about 2 millimetres the abscess cavity was reached, and immediately a profuse, thin, watery, foul-smelling discharge appeared, the fluid being clearly the result of commingling of the contents of the abscess with the cerebrospinal fluid. The diagnosis of rupture of the abscess into the lateral ventricle was therefore made.

The wound was treated and dressed in the usual way. Immediate improvement was noticed in the pulse, and consciousness returned during the night. For the next three or four days improvement continued, and the child became quite intelligent, recognized her parents and answered questions without difficulty. Symptoms of meningitis, however, made their appearance and the patient died a fortnight after admission.

At the necropsy it was found that the fistula led from the posterior upper corner of the abscess into the lateral ventricle. Both lateral ventricles were filled with pus, as were also the third and fourth, the infection having evidently passed from one ventricle to another in the order mentioned. The membranes at the base of the brain were bathed in purulent exudation, the infection having passed outwards from the fourth ventricle.

From a perusal of the preceding pages, it will be inferred that the differential diagnosis of the intracranial complications of ear disease is by no means always easy, and sometimes impossible. For the purpose of helping the reader the table on pp. 262–264 has been drawn up, but it must be remembered that many signs and symptoms may be absent in any given individual case, and reliance must frequently be placed on a few points. Of these, optic neuritis, vomiting, headache, stiffness of the neck, rigors, paralyses of the muscles of the eyeball other than the external rectus, and photophobia are among the most important, and these taken in consideration with the pulse, temperature, and the nature of the cerebrospinal fluid as obtained by lumbar puncture, should form the basis for diagnosis.

While precision in diagnosis in these cases is desirable in the highest degree, it is only so when used to direct our action, never when allowed to delay it. To wait for certain signs in order to make a diagnosis more accurate is frequently to wait

SYMPTOMATOLOGY OF INTRACRANIAL INFECTIVE DISEASE.

	Extradural Abscess.	*Sinus Thrombosis.*	*Meningitis.*	*Abscess of Brain.*
Headache	Present. Increased on pressure over the mastoid region.	Present. Increased on pressure behind mastoid region.	Present. Generalized and very severe.	Present. Generalized. Sometimes increased on percussion over seat of abscess.
Temperature ..	Slightly or not at all affected.	Oscillating; rising high, but having marked remissions.	Fairly high, with slight and irregular remissions.	Normal or subnormal.
Pulse	Unaffected. Occasionally slightly retarded or increased.	Moderately fast, sometimes rapid. Rarely slow.	Rapid, and often irregular. But often retarded in second stage (See text).	Slow, sometimes falling to 40 per minute.
Respiration	Unaffected.	Unaffected, unless lungs are infected by septic embolism.	Increased in frequency except in last stages.	Sometimes slow.
Rigors and profuse perspiration	Absent.	Frequent.	Occasionally present at beginning.	Absent.
Vomiting	Not common.	Sometimes at beginning.	Almost always present in earlier stages at least.	Usually present, especially in cerebellar abscess.
Optic neuritis ..	Present in 8 per cent. of the cases.	Present in 40 per cent. of the cases.	Present in 57 per cent. of the cases.	Present in about 50 per cent. of the cases.

Giddiness	Common, but usually not marked.	Common, but usually not marked.	Common.	Common, especially in cerebellar abscess.
Œdema over and behind mastoid process, face, or eyelids	Sometimes present, but not so marked as in thrombosis.	Not uncommon, and a very important diagnostic point when found. (See text.)	Absent.	Absent.
Stiffness of muscles of neck	Not uncommon, but not usually very marked.	Common, but not very marked.	Very common, and usually very marked.	Absent in cerebral, common in cerebellar, abscess.
Pupils	Frequently unaffected.	Frequently unaffected.	Pupils unequal. Do not respond readily to light.	Pupils dilated, especially in cerebellar abscess.
Nystagmus	Not common.	Not common.	Common.	Common in cerebellar abscess.
Oculo-motor paralysis	Absent.	Absent.	Common.	Common.
Photophobia ..	Absent.	Absent.	Usually present, and frequently intense.	Not uncommon, but rarely severe.
Twitchings of face or limbs	Absent.	Absent.	Common, and of considerable diagnostic value.	Not very common.
Pareses of muscles of trunk or limbs	Absent.	Absent.	Not common.	Common, and of great diagnostic value.
Hyperæsthesia of portions of trunk or limbs	Absent.	Absent.	Commonly present, and of great diagnostic value.	Not common.

SYMPTOMATOLOGY OF INTRACRANIAL INFECTIVE DISEASE—*Continued.*

	Extradural Abscess.	*Sinus Thrombosis.*	*Meningitis.*	*Abscess of Brain.*
Tenderness in neck ..	Absent.	Sometimes present.	Common.	Absent.
Cerebrospinal fluid obtained by lumbar puncture	Almost always clear and free of polymorphonuclear leucocytes and micro-organisms.	Almost always clear and free of polymorphonuclear leucocytes and micro-organisms.	Sometimes clear, sometimes turbid. Coagulable. Micro-organisms and polymorphonuclear leucocytes usually present.	Almost always clear. Polymorphonuclear leucocytes and micro-organisms usually, though not always, absent.
Kernig's sign ..	Absent.	Absent.	Frequently present.	Absent.
Secondary infections in lung, joints, etc.	Absent.	Not uncommon, and of great diagnostic value.	Absent.	Absent.
Mental symptoms ..	Irritability and a slight degree of somnolence not uncommon.	Mental depression. In markedly septic cases, delirium; but usually the mind is clear.	Delirium very common and severe. Unconsciousness frequent. In later stage coma.	Intellect dulled. Slow cerebration. Depression and moroseness. Character altered. Delirium absent.
Constipation	Not characteristic.	Common; but occasionally diarrhœa.	Common.	Almost always present.
Emaciation	Present to a slight degree.	Present.	Present.	Present, and out of all proportion to constitutional disturbance, especially in cerebellar abscess.

too long. Cases have been recorded in which, though the symptoms of brain abscess were by no means immediately alarming, a night's delay entailed the death of the patient. It must be emphasized that, when intracranial complication of any kind is present, operation can hardly add any element of danger to the case, so that even if the complication be found to be purulent leptomeningitis, the patient is no worse off than before. Again, since the greater part of the operation which is undertaken for any given intracranial complication of ear disease is common to all such operations, an error in differential diagnosis does not result in loss of time or unnecessary injury of any importance.

In a matter such as the present, where differential diagnosis is so difficult and frequently impossible, probability must be allowed a certain weight in forming an opinion ; that is to say, the relative frequency with which a given condition is present may be allowed to help in the diagnosis. Extradural abscess is undoubtedly far the most common ; hence in cases in which, after careful consideration, no differential diagnosis can be made, the probability on the whole is in favour of extradural abscess, though possibly with some other complication present. According to Jansen, extradural abscess is four times more frequent than sinus thrombosis, and twenty-eight times more frequent than brain abscess. The same author found that extradural abscess was five times more common in the posterior than in the middle fossa of the skull.

SEPTICÆMIA AND PYÆMIA.

While the intracranial complications of suppurative ear disease include the great majority of the dangerous conditions which result from it, there remains a type which does not come under this category. This includes cases of septic infection which occur as the result of the passage of micro-organisms into the circulation without the intervention of thrombosis of the intracranial sinuses. Such cases are not common, but it is important to recognize their existence, and the following is an example of such.

A man, aged forty-five, was admitted to the Victoria Infirmary, Glasgow, under my care, on account of a chronic otorrhœa and of pain in the left ear of three weeks' duration.

A day or two before admission 'synovitis' occurred in the left ankle-joint and in the left great toe.

On admission the temperature was 99·8° F.; the pulse numbered 122 beats per minute, and the respirations were 26. Mentally the patient did not seem bright, but was able to answer intelligently. There was pain and œdema over the left ankle-joint and over the left great toe. Redness and tenderness were present over the right elbow, but there was no distension of the joint. The heart and lungs showed no evidence of disease. A considerable trace of albumin was present in the urine. Perspiration was profuse.

The patient rapidly became worse, and during the night after admission was wildly delirious. The profuse perspirations continued, and he began to pass urine in bed. The following day the symptoms became still worse and he died on the third day after admission.

At the post-mortem no intracranial infection was found, and the sinuses were healthy, no thrombosis being present. The thoracic organs were healthy. The pancreas, liver and kidneys were congested to a certain extent, but were otherwise healthy. The spleen was enlarged, soft and diffluent, and had the appearance which it usually presents in septic conditions. Metastatic abscesses were found at both elbow-joints and in the right first metatarso-phalangeal joint.

The middle ear on both sides was the seat of suppurative disease, but the appearances were different on the two sides. On the right the conditions usually found in cases of otorrhœa were present, such as swollen mucous membrane, granulation tissue and purulent secretion, but the bone was not necrosed and the mastoid antrum was not involved in the disease. On the left side the tympanum was found to be in a condition similar to that on the right. The mastoid antrum, however, was also affected and its walls were carious and showed a speckled, black-and-white appearance. On sawing through the mastoid process, it was seen that the appearances on the surface of the antrum just described extended into the substance of the bone, and that the blackish areas were due to thrombosis in the minute bloodvessels. No thrombosis was present in the bulb of the jugular vein.

This was a case, therefore, in which pyæmia of a very virulent type resulted from suppurative ear disease without the occurrence of thrombosis or any disease of the intracranial sinuses or of the veins into which they lead.

Pyæmia and septicæmia arising as in the case just described are not by any means so common as those which arise from septic thrombosis of the sinuses. It is necessary, however, that they should be recognized, for the prognosis is not so favourable as in those cases in which sinus thrombosis precedes the general infection. Some do, however, recover, and only rarely is the infection so virulent as in the case reported above.

Treatment.—The treatment will depend upon the stage of the disease and the condition of the patient. When abscesses are rapidly forming in various parts of the body, and the patient is in the last stage of infection, as in the case reported, operation would obviously be futile. In all the earlier stages, however, the patient should be given the chance which operation alone affords. Even the existence of metastatic abscesses is not a contra-indication, provided these are not particularly rapid in their formation. The operation consists of removing all the diseased bone in the mastoid region. There is probably nothing to be gained by ligaturing the internal jugular vein in these cases, the conditions being quite different pathologically from those in which a septic thrombus is present in the sinuses or in the jugular vein. Metastatic abscesses should be opened, and the general treatment suitable for septicæmia carried out.

EXTENSION OF SUPPURATIVE PROCESSES FROM THE MIDDLE EAR INTO THE LABYRINTH.

The transgression of infective processes from the middle ear into the labyrinth is, fortunately, not so common as might be expected when the extremely thin nature of the membrane of the round window is borne in mind, along with the great frequency of middle-ear suppuration itself. Suppuration in the labyrinth is, however, more common than is usually supposed, many cases not being diagnosed during life.

Although the condition was doubtless well recognized previous to the publication of Jansen's first paper on the subject,[1] that writer must be credited with the first exhaustive study of the condition.[2] Since that time many other surgeons have studied the matter, among whom are Milligan, Ballance, Lake, Scott and West, in this country, Richards and others in America, and many abroad.

Suppurative disease of the labyrinth is due to the entrance of the infective organism during either an acute or a chronic suppurative affection of the middle ear. It is, however, rare as a result of acute middle-ear inflammation, and when this does occur the middle-ear affection is frequently of the type characteristic of scarlet fever or diphtheria.

The extent to which the labyrinth is involved in suppurative disease of the cavity varies greatly. Fortunately, in a large percentage of cases it is limited to the portion near the vertex of the horizontal canal. In others the vestibule and all the canals are affected, while still more rarely the whole cavity is destroyed by the suppurative process.

The pathways of infection are the oval window, the arches of the horizontal or of the posterior canals, the round window and the wall of the promontory. It is also possible for the labyrinth to become infected from the cranial cavity during meningitis, the organism in this case being carried through the aqueduct of the cochlea. The commonest pathway of infection, when it occurs during acute middle-ear disease, is the oval window, but in chronic middle-ear disease a fistula into the arch of the horizontal canal is the usual passage for the organism.

The bacteria commonly found in suppurative labyrinthitis are streptococci and the tubercle bacillus, but it will naturally be understood that any pyogenic organism present in the middle ear may be found in the labyrinth.

Cases of suppurative disease of the labyrinth fall clinically into two groups—first, those which supervene upon acute inflammation of the middle ear; secondly, those resulting from a chronic process in that cavity.

Acute Labyrinthitis.—When in the course of acute middle-ear inflammation the labyrinth becomes involved, the symptoms almost always undergo a marked change. The pain does not abate, but may become worse and rather more

[1] Jansen, *Arch. f. Ohrenh.*, Bd. xxxv.
[2] *Ibid.*, Bd. xlv., S. 193.

diffuse. Giddiness, nystagmus, staggering gait and vomiting usually occur, and the aspect of the patient is that of one suffering from a serious disease. Tinnitus is usually severe, the condition in this respect differing from that occurring in chronic cases. In the early stage the deafness is not always very much increased, but before long it becomes greater than can be accounted for by the middle-ear affection.

Chronic Suppurative Disease of the Labyrinth. — Chronic suppurative labyrinthitis may result from the acute condition just described, or it may occur as the result of gradual extension of the process from the middle ear through the bone into the labyrinth. The diagnosis of the latter is frequently very difficult, and in perhaps the majority of cases there are no symptoms pointing to involvement of the inner ear. A large proportion are discovered by chance during the performance of the radical mastoid operation.

Deafness.—In proceeding to make a diagnosis, one of the most important points is to ascertain the degree of *deafness*. Thus, if the affected ear is absolutely deaf to loud conversation voice close to the ear, the inference is justified that the labyrinth is affected. This symptom, however, is of no negative value at all, since it has been found by repeated experience that the hearing-power may be only affected to a moderate degree, although the labyrinth is to a limited extent involved in the suppurative process. Bone-conduction of sound is usually shortened or lost altogether, but to this rule there are occasional exceptions.

Tinnitus.—Tinnitus is an unimportant symptom in the chronic condition, and is of little or no value in diagnosis. In this respect the chronic differ markedly from the acute cases.

Vertigo.—According to West and Scott, vertigo is the most important diagnostic symptom, but, like the others, it is frequently absent. Thus, in the list compiled by the writers just mentioned, it was absent in ten out of twenty-six cases; and when we remember that it is this particular symptom which frequently compels the sufferer to seek medical advice, it is probable that in a much larger proportion of cases of labyrinth suppuration the symptom is absent. Sometimes there is a general sense of giddiness, but occasionally the patient can refer to a definite plane in which surrounding objects appear to rotate. The patient tends to fall usually, though not always, towards the affected side. Vertigo may be constantly present, or may come in the form of passing attacks. In all cases it tends to disappear sooner or later, and after a few months or a year the patient becomes permanently free from the symptom.

Nystagmus.—Spontaneous nystagmus is only rarely present, but by the special methods of examination introduced by von Stein and Barany it can frequently be elicited, and is then of some value. The nystagmus tests for labyrinthine disease have already been described in Chapter IV., and there is no need to repeat the description here. It is, however, important to note that it is in suspected suppurative labyrinthine disease that the test for 'fistula nystagmus' is employed. This is carried out by compressing the air in the tympanum by means of an india-rubber bulb with a nozzle which can be tightly fitted into the meatus. If there is a fistula leading from the middle ear into the labyrinth, the pressure is transmitted to the fluids in the labyrinth more readily than under normal conditions, and nystagmus is more quickly produced, provided the neuro-epithelia in the canals and vestibule are not destroyed. If, however, these structures are destroyed no nystagmus is produced.

Romberg's Test.—This test is carried out by ordering the patient to stand with the eyes closed, first upon both feet, and then upon each foot separately. If the labyrinth is diseased the patient tends to fall towards the affected side. The test must be applied several times before attempting to draw conclusions, and it is not one upon which very great reliance can be placed. According to Körner, if the patient can jump backwards with the eyes shut, extensive suppurative disease of the labyrinth may reasonably be excluded.

Vomiting.—*Vomiting* is rarely present in chronic conditions, but, like the other symptoms, it frequently comes on during an acute exacerbation; and the same may be said of pain and headache. The temperature and pulse are unaffected in chronic suppurative disease of the labyrinth, the exception again being in the case of acute exacerbations.

From the description just given, it will readily be understood that chronic suppuration of the labyrinth is frequently difficult to recognize, except in those cases in which an acute

Fig. 98.—Cochlea from the same Case as shown in Fig. 97. × 4½.

(Prepared and photographed by the Author.)

The outline of the organ is preserved, but the soft parts are completely destroyed and replaced by pus and granulation tissue.

[To face p. 270.

Fig. 99.—Left Membranous Labyrinth from a Case of Otosclerosis. × 2 *circa.*

(Prepared and photographed by the Author.)

a, a small portion of the lower limb of the posterior semicircular canal which has been eroded by the new-formed bony tissue in the capsule.

[*To face p.* 271.

condition supervenes. Certain signs, such as Rombergism, nystagmus, very high degrees of deafness and the like, indicate that especial care should be exercised in searching for fistulous openings into the labyrinth during the performance of the radical mastoid operation which the coincident middle-ear affection may demand. The importance of this may be emphasized by mentioning a case in which the author obtained the labyrinth, and prepared it according to his own method. Figs. 97 and 98 show the portions of the organ thus obtained. The whole of the vestibule was destroyed by the purulent process, and replaced by granulation tissue and débris. All the ampullæ of the canals were destroyed in the same manner, and, indeed, all that was left of this portion of the organ were fragments of the arches of the canals, and even these were filled with pus and granulations. The outward shape of the cochlea was retained, but the tube was filled with pus and granulation tissue. In spite of this complete destruction in the various parts of the labyrinth, the patient had never had a symptom indicative of disease of the inner ear beyond the existence of complete deafness on the affected side. The author had not the opportunity of examining the patient during life, but there was no history of giddiness, vomiting, headache, or any other symptom which would lead him to seek advice, excepting the deafness and discharge. It is quite possible that Rombergism and the other signs of labyrinthine disease might have been discovered, had the patient sought relief at the hands of a surgeon, but apparently he did not think deafness and suppuration in one ear sufficiently important to require attention. The condition had lasted as long as the patient's friends could remember, and he died from malignant disease of the jaw at the age of sixty-one.

Prognosis.—In *acute* cases, according to Politzer, complete recovery may ensue even from suppurative disease of the labyrinth. At the same time, it must be very difficult to prove that this occurs, for it may well be that the effusion into the labyrinth is not purulent but serous, even when the coincident middle-ear affection is purulent. In any case, it is hardly conceivable that, if the suppurative process extends into the cochlea, the hearing can ever be completely recovered. There is little doubt, however, that it is not uncommon to have recovery from acute suppurative disease of the labyrinth to such an extent that the discharge ceases, the giddiness, nystagmus, vomiting and other symptoms disappear, and only a defect of hearing, greater or less, remains.

In chronic cases the hope of cure of the suppurative process is, naturally, not so great as in the acute ones. Nevertheless, there is no reason to doubt that local treatment of the accompanying middle-ear affection benefits the more deeply seated disease, and in rare cases may lead to the cure of both.

As in the acute so also in the chronic condition, the tendency to intracranial complications is considerably increased when the labyrinth is involved as well as the middle ear, and this must always be remembered in dealing with suppurative disease of the ear. (See Intracranial Complications, p. 245.)

When the suppurative process is associated with tubercle the hope of cure is remote.

Diagnosis.—The diagnosis of labyrinthine suppuration is made by a consideration of the signs and symptoms just described. But in acute cases and in acute exacerbations of the chronic disease the symptoms so closely resemble those of some intracranial complications that it is desirable to emphasize some of the points of difference. Sometimes in uncomplicated acute middle-ear inflammation there appears to be some considerable irritation of the structures in the labyrinth, with the result that the case presents all the signs and symptoms of the more serious disease, although such does not exist. A correct diagnosis is impossible until, by paracentesis or by other means, the inflammation in the middle ear is relieved. In these cases the labyrinthine symptoms disappear at once, whereas, if actual inflammation of the inner ear had been present, such symptoms would have continued for at least a little time.

But another difficulty which, though not greater than that just referred to, has a more serious bearing on the case is the diagnosis between intracranial (especially cerebellar) and labyrinthine disease. Of course the latter may give rise to intracranial complications, and then no differential diagnosis can exist. But in uncomplicated cases the issue of life and death may hang upon the diagnosis.

Optic Neuritis.—Of all the positive signs, optic neuritis is the most valuable. In labyrinthine disease well-marked optic neuritis is not present. Unfortunately, however, it is only present in a limited number of cases of intracranial disease, and its absence, therefore, is of little value in diagnosis.

Deafness.—Complete deafness in the affected ear is very suggestive of labyrinthine disease, provided that the condition did not exist before the onset of the acute symptoms. In labyrinthine disease bone-conduction is usually diminished, so that the tuning-fork held in the middle line of the head is heard best in the unaffected ear. This test is particularly valuable if, during the course of observation, it has previously been ascertained that the fork was heard best in the affected ear.

Disturbance of Equilibration.—According to Körner, disturbances of equilibration are very rare in cerebellar abscess, but common in labyrinthine suppuration. Politzer, however, does not confirm this statement.

Nystagmus.—In disease of the labyrinth, nystagmus is elicited when the eyes are directed to the healthy side, whereas in cerebellar abscess it occurs on directing the eyes to either side, and may even be stronger when they are directed to the affected side. Alexander is of opinion that very pronounced horizontal nystagmus arising spontaneously, and associated with disturbances of co-ordination, points to cerebellar abscess.

Other Symptoms.—Drowsiness, yawning, retardation of the pulse and lowered temperature point towards cerebellar abscess. Vomiting, on the other hand, may indicate disease either in the cerebellum or labyrinth, and is not of much use for the purposes of differential diagnosis.

The differential diagnosis between labyrinthine disease and meningitis, while sometimes difficult, is not so hard as in the case of cerebellar abscess. The presence of optic neuritis, stiffness of the neck, various paralyses, and the discovery by lumbar puncture of organisms in the cerebro-spinal fluid, will usually serve to indicate the existence of meningitis, even if labyrinthine symptoms are present, as they frequently are.

In conclusion, it must be constantly borne in mind that the severity of labyrinthine symptoms bears no relationship to the extent of the disease. A very small carious area, with perhaps a few granulations in the horizontal canal, may be the cause of symptoms so severe as to preclude the sufferer from taking part in the activities of life. On the other hand, the whole labyrinth may be destroyed without the patient being aware of any trouble beyond deafness and discharge from the ear. The preparations which are represented in Figs. 97 and 98, as described above, were obtained from a case of this nature.

Treatment — Acute Cases and Acute Exacerbations. — In acute cases and in acute exacerbations of the chronic suppurative disease the treatment is similar to that employed for the coincident middle-ear affection. So far as local applications are concerned, however, it is obvious that no medicaments can reach the inner ear. These must be employed in order to combat the middle-ear suppuration, and in so doing will no doubt benefit the deeper affection indirectly. Hence instillations of anilin with iodoform dissolved in it are useful, but the precautions mentioned on p. 112 must be very carefully observed. Equal parts of peroxide of hydrogen and water, or of rectified spirit and water, may also be employed, assuming, of course, that the membrane is perforated, so that the drugs can gain entrance to the middle ear. If the discharge is profuse, gauze may be packed deeply but lightly into the meatus, to act as a drain; and, indeed, any of the measures employed in treating acute middle-ear suppuration may be carried out, with one exception—the use of the air-douche. This treatment, which is only of doubtful value in acute middle-ear inflammation, is not justifiable at all if the labyrinth be involved.

Of local measures, short of operation, the application of cold to the regions behind and in front of the ear by means of Leiter's coil may be tried for eight or twelve hours, and those who have faith in Bier's method of producing venous congestion may employ it. The writer is not one of these, and would not care to take the responsibility of advising its use in acute labyrinthine disease. The abstraction of blood locally by means of leeches, living or artificial, certainly seems to give relief in some cases, and this line of treatment can do no harm. Two or three of the animals may be applied over the mastoid process and in front of the tragus.

Paracentesis.—In the very rare cases in which labyrinthine symptoms arise in the course of acute middle-ear disease before perforation has occurred, it is desirable to perform paracentesis at once, whether there is evidence of pus in the middle ear or not. The treatment of these cases, therefore, differs to this extent from that of acute middle-ear inflammation without labyrinthine symptoms.

Radical Operation.—If the symptoms of inflammation in the labyrinth do not rapidly disappear under the treatment described, it becomes necessary to use more drastic measures. The radical mastoid operation, as described on p. 287, must be performed. This lays open the field for further procedures, should these be necessary, and is therefore to be preferred to the simple opening of the mastoid antrum. Further, it permits of the removal of cholesteatomatous masses, which are so frequently a cause of the labyrinthine trouble, by their eroding effects upon the bony walls of the semicircular canals. During the operation the utmost care should be taken to ascertain whether there is a fistula leading into the inner ear by way of the semicircular canals.

For a description of the various operations upon the labyrinth the reader is referred to p. 302.

The indications for opening the labyrinth when the disease is in the acute stage have not yet been definitely agreed upon by aurists. Some authorities advise the performance of the operation if the labyrinthine symptoms do not disappear comparatively rapidly under ordinary treatment, while others recommend delay until symptoms of meningeal irritation present themselves. The latter point of view might appear at first sight to be unsurgical, but experience has shown that there is a very serious risk of meningitis occurring if the labyrinth be operated upon when it is in a state of acute inflammation. Again, it is not possible to make a differential diagnosis between purulent inflammation of the organ and non-purulent inflammation resulting from acute inflammation of the middle ear. The cases belonging to the latter category recover, and this frequently with fairly good hearing. On the whole, perhaps it is safer to wait for the first symptoms of meningeal irritation.

In chronic suppurative labyrinthine disease also difficulties present themselves when it has to be decided what line of treatment is to be adopted. A great deal depends upon the nature of the case. For example, when there are symptoms such as tinnitus, giddiness, or vomiting, so severe as to make life a burden, then it is desirable to operate without delay. On the other hand, in elderly people in whom there is good reason to believe that the condition has been in existence many years without causing trouble beyond the discharge and the deafness, the probability is that careful attention to cleanliness by means of local antiseptic solutions will be quite as likely to prolong their days as an operation, which is certainly not without some risk to life.

It will naturally be understood that in all cases of suppurative ear disease, except in the aged, the radical mastoid operation should be done if other means fail to give relief, whether the labyrinth is involved or not. But when the labyrinth is diseased, the further question arises: is it desirable to open that cavity as well? Politzer[1] has laid down the following canons for guidance, and, although in some special cases it may be advisable to depart from these rules, it may be said that at present they form good general indications for operative procedures when labyrinthine symptoms are present.

1. If the hearing-power for speech is still retained, and the response of the vestibular apparatus is present, it is undesirable to open the labyrinth, even although a fistula leading into one of the canals is found.

2. If the hearing-power is completely lost and the vestibular apparatus does not respond, and particularly if the condition is associated with tuberculosis or cholesteatomata in the temporal bone, the labyrinth should be opened even although no fistula is found at the radical mastoid operation. The reason for this is that in these cases the performance of the radical mastoid operation alone is apt to be followed by meningitis, whereas if the operation be extended into the labyrinth and the diseased focus removed, this grave complication is less likely to occur.

3. Obvious caries of the wall of the labyrinth associated with facial paralysis is an indication for opening the cavity.

4. If symptoms of meningeal irritation occur after the ordinary radical mastoid operation, the labyrinth should be opened without delay.

5. Symptoms of intracranial complications demand the opening of the labyrinth, as well as the cranial cavity, at once.

[1] 'Lehrb. d. Ohrenh.,' S. 497, 5. Aufl., 1908.

Before leaving this subject, it is desirable to emphasize the second of the statements just made. When the labyrinth as a whole is infected, as evidenced by complete deafness and the loss of the vestibular reflexes, or by the discovery of caries on the wall of the promontory or in the region of the oval window, then the performance of the radical mastoid operation alone is fraught with a certain amount of danger. It is in such cases that meningitis is apt to occur as the result of the operation. When the above signs and symptoms are present, therefore, the canals and vestibule should be opened as described on p. 302, at the same time as the radical mastoid operation is done. In this way the risk of meningitis, though not entirely removed, is considerably diminished.

CHAPTER XIII

OPERATIVE PROCEDURES FOR THE TREATMENT OF MIDDLE-EAR SUPPURATION AND ITS COMPLICATIONS

In some cases of chronic middle-ear suppuration, and much more rarely in acute suppurative disease, it becomes necessary to operate in order to bring about the cessation of the discharge. The various operations devised for this purpose may be conveniently divided into two categories—minor and major. To the first belong those involving the removal of the ossicles and the outer wall of the attic; in the second category are included the various operations which involve the removal of the walls of the mastoid process to a greater or less extent.

REMOVAL OF THE OSSICLES AND OUTER WALL OF THE ATTIC.

The removal of the ossicles is indicated in cases in which the bones are carious or in which milder measures have failed to stop the suppurative process.

Nothing is to be gained by employing local infiltration anæsthesia, but if the patient likes to hear the bones of his head being ground into powder or chiselled away, his curious taste may be indulged. The parts are prepared for operation by the instillation of antiseptic drops two or three times daily for several days. A few minutes before operation, ½ drachm of a solution of adrenalin chloride in water (1 part in 3,000) should be instilled, and a strip of gauze then pushed deeply into the meatus. This should be removed when the patient is under the influence of the anæsthetic, and the ear should then be carefully cleaned.

The operation must be carried out by means of light reflected through a speculum in the usual way. The patient, however, must be in the horizontal position if chloroform be the anæsthetic employed.

If a portion of the membrane still exists, it should be removed by a circular incision made as close to the margo tympani as possible. The tendon of the tensor tympani is then cut through by a specially curved knife (Fig. 100). The malleus is gripped firmly near the neck of the bone by a pair of aural

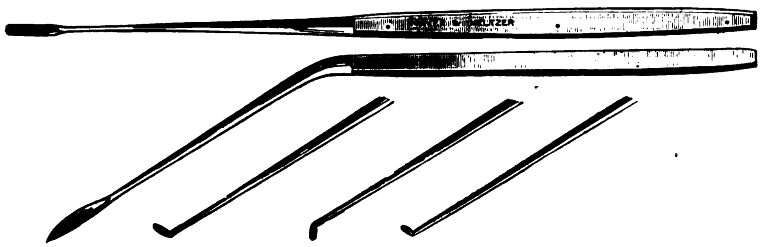


FIG. 100.—SEXTON'S KNIVES FOR EXCISION OF THE OSSICLES.

forceps, and dragged first of all downwards and then outwards. Instead of using forceps, the surgeon may pass the wire loop of a snare as high up the bone as possible, and, after tightening it, drag the bone downwards and outwards. The removal of the incus is sometimes, but not always, easy. The tip of the incus hook (Fig. 101) is passed up behind the long process of the bone, if this be visible, and is then rotated forwards and downwards, carrying the ossicle before it into the lower part of the tympanum, from which it can be picked out with forceps. Before

FIG. 101.—LUDEWIG'S INCUS HOOK.

removing the incus some aurists divide the incudo-stapedial joint with a fine knife, but this procedure seems superfluous. The stapes is held firmly by means of the stapedius muscle and the annular ligament, so that there is no fear of dislocating it when the incus is dragged away.

The outer wall of the attic may be removed by means of a small rotating burr, or by the sliding chisel devised by Krause (Fig. 102). In skilled hands a small gouge and mallet suffice for the purpose. The attic wall should be freely removed both in front and behind, but in removal of the posterior portion great care should be taken not to allow the instrument to impinge upon the inner wall of the tympanum, for fear of injuring the facial nerve (see Fig. 14).

Granulations, if present, should be removed, and if carious bone is found in the walls of the tympanum it should be curretted, but great care should be taken not to dislocate or injure the stapes. The whole cavity should be syringed, carefully cleansed and packed with antiseptic gauze. The ear should be cleansed and dressed daily, and instillations of various kinds may be employed as in the ordinary local treatment for otorrhœa.

The two operations of removal of the ossicles and removal of the outer attic wall have been included above in one description. This has been done for the purpose of emphasizing the

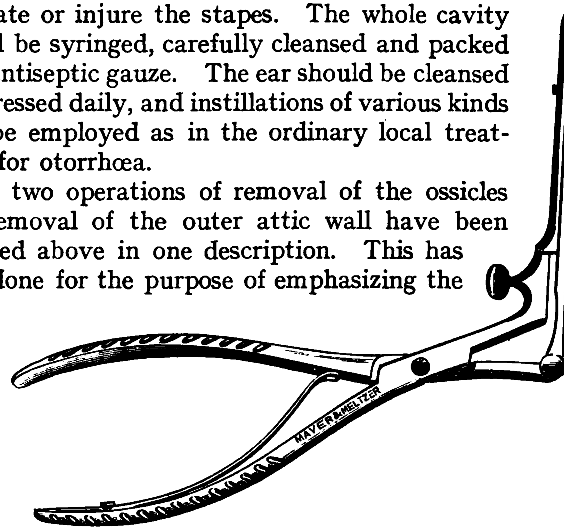


FIG. 102.—KRAUSE'S SLIDING ATTIC CHISEL.

fact that, in practice, it is always wise to do them together. Removal of the ossicles alone is very uncertain in its results, and the hope of cure is much greater when the outer attic wall is at the same time removed. Moreover, nothing is gained in the way of better hearing by leaving the attic wall in position, and neither the shock of the operation nor the duration of the after-treatment is increased by its removal.

There is occasionally slight giddiness after operation, but this soon passes away. Facial paralysis may occur either as the result of injury to the nerve during operation, or from the pressure of inflammatory products during the reaction. The first is always avoidable by the exercise of proper care and a knowledge of the anatomy of the parts. The second is beyond the control of the surgeon, but fortunately is an unimportant complication, since recovery always ensues if the nerve has not been actually cut.

The results of operation may be described as fairly good. There is no doubt that in a considerable proportion of the cases the discharge continues, and the radical mastoid operation has ultimately to be performed. When successful, however, the results of excision of the ossicles and outer attic wall are better than those obtained by the radical mastoid operation, because the hearing is far less seriously affected in the great majority of cases, and usually is considerably improved. The uncertainty of the result in respect to cessation of suppuration is the one great drawback to ossiculectomy.

THE MASTOID OPERATIONS.

Several operations have been evolved for the treatment of suppurative disease in the middle ear and its complications; but all of these, with the exception of removal of the ossicles and attic wall, are in a sense extensions of one operation into adjacent regions. This operation is the opening of the mastoid antrum and cells, and it will therefore be described first. The various extensions of this, such as the radical mastoid operation with its variations, the operations upon the labyrinth and those designed to treat intracranial complications, will naturally follow.

Before attempting any of these operations, the surgeon should be satisfied that he is possessed of a thorough knowledge of the anatomy, both gross and minute, of the parts included in the field of action. Not only is this absolutely necessary, but he should also be acquainted from personal examination and dissection with the variations which may exist. It is not too much to say that the safety and success of these operations are in direct proportion to the anatomical knowledge of the operator.

The Simple Mastoid Operation.—The object of this operation is to open the mastoid antrum and the mastoid cells.

The usual preliminaries to surgical operation, such as the administration of a laxative the night before operation and the prohibition of food for three or four hours before beginning, are understood to have received attention. In addition to these, it is necessary to have the head shaved for a space of at least 2 inches round the auricle, and it is desirable to have the whole of the hair cropped close, though in the case of women this may be omitted. The side of the head should be rendered as aseptic as possible by the application of an antiseptic dressing for some hours before operating, and the meatus should be cleansed as far as possible by the frequent instillations of peroxide of hydrogen. It is, of course, quite impossible to obtain an aseptic condition in the tympanum or

Fig. 103.—Metal Hammer.

antrum, but on general surgical principles it is desirable to reduce the septic area to the smallest possible dimensions.

Instruments.—The instruments required for operation are: a sharp-pointed and short-bladed knife, a periosteal elevator, a few pairs of pressure forceps, two retractors, two or three gouges of different sizes (flat chisels may be used, but they should never have sharp corners, as shown in some instrument

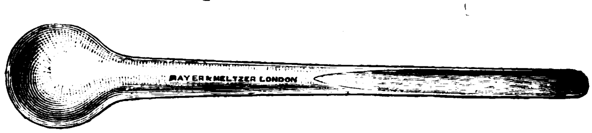


Fig. 104.—Macewen's Gouge.

catalogues), and a small hammer. Instead of chisels, many operators employ a rotating burr driven by an electric motor.

Operation.—An incision is made from the tip of the mastoid process upwards into the angle formed by the auricle with the skin over the mastoid process. The incision is then carried farther upwards in this angle, or, if preferred, $\frac{1}{8}$ inch or $\frac{1}{4}$ inch farther back. The incision curves forward a little at its upper portion, following the line of insertion of the auricle until its tangent is almost horizontal. The incision should pass through all the soft tissue, and through the periosteum except at its uppermost portion; and if there is a sinus through the skin, it is desirable that the incision should pass through the sinus, thus splitting it to the bone. The bleeding is usually sharp when the tissues are œdematous or inflamed, but bleeding points may be secured by catch-forceps. The soft parts, including the periosteum, are then reflected forwards until the entrance to the meatus is reached, and backwards for a shorter distance. This will bring into view the spine of Henle at the upper posterior margin of the entrance to the meatus, and immediately behind it a shallow depression in the bone. The soft parts are held apart by retractors, and these landmarks may be made out—the spine of Henle, the suprameatal ridge and, in some subjects, the squamo-mastoid suture. The area of bone which is to be removed from the surface will vary according to the case. Thus, if there is reason to suppose that the mastoid cells are affected, it may be necessary to remove the whole outer surface of the process. Probably most surgeons begin by removing the bone over an area of about 1 square centimetre, the anterior superior corner of which nearly reaches the suprameatal ridge. This area can be enlarged downwards later to reach the cells at the tip of the mastoid process, or to allow freer access to the deeper parts. It will naturally be understood that, if there is a sinus through the bone, the surgeon will follow it towards the antrum.

The bone is removed by gouge and mallet, the chips being small. Some surgeons prefer to use the burr, but it is slower. The wound in the bone is continued inwards and forwards, the outer portion being enlarged in area the deeper the wound becomes. But this enlargement of the opening in the bone should be made in a direction downwards and backwards. The lateral sinus may be laid bare in the posterior part of the wound; but this is no disadvantage and may be a help, since it forms another landmark in directing the operator. It is of the greatest importance, however, not to puncture the sinus. Probing should be done very frequently, and this will enable the surgeon to know if the sinus or dura mater have been exposed. It is also desirable in the highest degree to keep the wound as dry as possible by the use of absorbent gauze plugs. The application of adrenalin has been suggested for this purpose by some surgeons, but it must be remembered that it only diminishes the oozing of blood from the soft tissues. Adrenalin has no effect upon the bloodvessels in bone, for two reasons : first, these vessels have no muscular coat ; second, their walls are closely adherent to the bony channels through which they run.

It is an unfortunate anatomical fact that the distance of the antrum from the surface of the mastoid process varies greatly, so that no definite rule can be laid down as to the depth at which the operator may expect to reach it. According to Broca,[1] in the adult the depth varies from 15 millimetres to 29 millimetres. In the young child the cavity is much nearer the surface, and in the first year of life it is only from 2 millimetres to 4 millimetres deep. Sometimes it is very small and deeply placed, so that it amounts to little more than a bulbous termination to the posterior extremity of the aditus. Probably it is never, in the strict sense of the term, quite absent, and the operator must not rest content until he is able to pass a bent probe forwards into the aditus. It is important that this be done very gently, in order that the incus be not dislocated. When the antrum is of ordinary size and not deeply situated, there is but little danger of wounding the facial nerve ; but in the case of small deeply-placed antra great care must be exercised as the wound in the bone becomes deeper. The chips removed by the gouge must be very small, and the assistant or anæsthetist must be instructed to keep his eyes constantly fixed upon the face, to observe if the slightest momentary twitching occurs. If the spine of Henle be present it forms a good landmark, since it marks the lowest level at which it is safe to work in the deeper parts of the wound in the bone. But even if it be removed or is congenitally absent, an equally good landmark is found in the horizontal tangent to the superior pole of the meatus ; the wound in its deeper parts should not pass below this. The upper limit to which the bone may be removed in its deeper parts is defined by the temporal ridge, for if the surgeon trespasses higher than this he is apt to injure the dura mater of the middle fossa. If, however, the outer surface of the dura mater of the middle fossa be merely laid bare, no par-

[1] 'The Surgical Anatomy and Operative Surgery of the Middle Ear,' translated by Yearsley, p. 9, 1901.

ticular harm results. Care must be taken to avoid puncturing the dura mater with the gouge or by any sharp spicule of bone that may be lying in the wound. Fortunately, the membrane is thick and tough, and not easily penetrated except by a very sharp object. When the antrum has been found the opening into it though the wound should be widened, so that its outer wall is obliterated. The other walls of the cavity should, after having been cleaned by syringing and mopping, be carefully examined by the probe, in order to find out if there is any carious or necrotic bone or fistula. If diseased bone is found it must be removed, and it is the wisest course in such a contingency not to rest content with having done the simple mastoid operation, but to do the radical operation or one of its modifications which will be described later. Sinuses leading out of the antrum should be traced to their termination, and this may necessitate the opening of the cranial cavity.

If, after the antrum has been opened in the way described, the conditions be such that the surgeon is satisfied that a complete cure of the disease will follow without further intervention, he then cleanses the cavity from all blood and débris by means of syringing. When the fluid is injected into the antrum, some of it usually returns by way of the tympanum and external meatus ; but this does not always occur, because the passage from the aditus to the tympanum is occasionally occluded by the swollen tissues. This is apt to be the case in acute conditions. The syringing into the antrum should be done gently, for if force be used some of the fluid may find its way down the Eustachian tube into the pharynx, and be sucked into the larynx. The operator should therefore be ready to lower the head at once if a gurgling sound is heard coming from the throat of the patient during the act of syringing. When the cavity is thoroughly clean, its walls and those of the wound in the bone should again be examined, and bony ledges or pockets should be obliterated, so that the surface is rendered as smooth as possible (Fig. 105). For this purpose the burr is more satisfactory than the gouge or chisel. The cavity is then cleaned again carefully, and the wound in the skin is stitched in its upper and lower portions, care being taken that no puckering occurs along the stitched portion. In its middle third the wound should not be stitched, but left open, and a gauze drain passed down through it into the antrum.

The wound is dressed in the course of a few days, and after a week or two a drainage-tube should be inserted instead of the gauze drain, and should be used until there is no discharge either from the antrum through the tube, or from the middle ear through the meatus. In order to keep the sinus open long enough, it may be necessary to employ a metal drainage-tube.

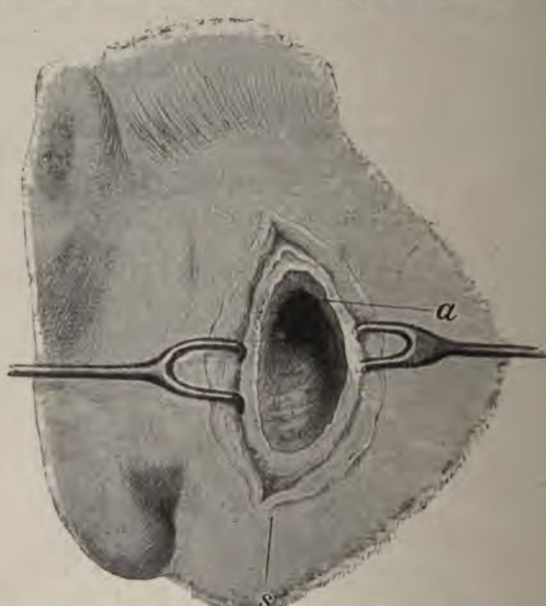


FIG. 105.—THE SIMPLE MASTOID OPERATION (POLITZER.)

a, antrum. *s*, position of tip of mastoid process.

The simple mastoid operation is suitable, speaking in general terms, for acute cases of middle-ear disease in which the symptoms do not subside under milder treatment, such as instillations, paracentesis, etc. The operation may, under certain circumstances, be justified in cases of chronic suppuration, as, for example, when the hearing-power of the opposite ear is very seriously affected, while that of the ear operated upon is good. In these it is of the utmost importance not to diminish the hearing-power, which is sometimes one of the results of the radical mastoid operation. Even in such cases, however, some modification of the radical operation may be done which will leave the ossicles in their place. The surgeon therefore should be averse to performing the simple mastoid operation when the discharge from the ear has been of long duration, while the presence of cholesteatomatous masses, caries of the wall of the antrum, or abundant granulation in the cavity, indicate clearly the advisability of performing the radical operation.

The Radical Mastoid Operation.—The frequent failure of the simple mastoid operation to bring to a cessation the suppurative processes in the tympanum and antrum necessitated the devising of some other procedure. Küster, therefore, in the year 1889 extended the simple mastoid operation in such a way as to throw the tympanum, the aditus, and the antrum into a single cavity with a wide opening into the meatus. This not only gave a much better opportunity for the permanent cure of the discharge, but even when the operation failed in that respect it still left the patient in a condition of safety, since the pus could obtain free exit. On the other hand, the simple mastoid operation, if it failed to bring about a cessation of the suppurative process, left the patient in just as great danger, when the retro-auricular wound was healed, as he was before operation.

The principle of the radical operation, as just stated, consists of throwing the tympanum, the aditus and the antrum, into one cavity. This is done by extending the simple operation by removal of the posterior and upper wall of the bony meatus.

The skin incision is the same as that for the simple mastoid operation, but it is to be extended a little forwards along the upper margin of attachment of the auricle. By so doing a freer access is gained to the superior wall of the meatus. The periosteum, with all the soft parts, is reflected forwards and downwards, and this reflection of the periosteum does not stop short, as in the simple operation, at the entrance to the meatus, but is carried right down to the tympanic membrane. Thus, the soft parts, with the auricle attached, are quite freed from the mastoid process. To separate the periosteum in the meatus a rather small periosteal elevator is necessary. After the epidermis and soft parts of the meatus have been separated on their upper, posterior and lower attachments over the whole length of the channel, a strip of gauze is passed inwards through the now loosened membranous meatus, and brought out through the wound. Thus, the strip of gauze forms a convenient retractor to hold the auricle and soft parts downwards and forwards, and allow of inspection of the deeper parts as the operation proceeds. All bleeding should now be stopped by pressure forceps and if necessary, by ligature, though the latter is seldom necessary.

The removal of the bone is now begun, and in its earlier stages this part of the operation is exactly similar to that of the simple mastoid operation, and the description need not be repeated. It is only necessary to emphasize the importance of observing the landmarks, keeping the wound as clean as possible by constant mopping out, and, above all, the necessity of repeatedly using the probe. The antrum having

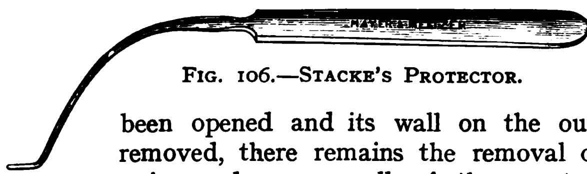


FIG. 106.—STACKE'S PROTECTOR.

been opened and its wall on the outer surface removed, there remains the removal of the posterior and upper wall of the meatus and the outer wall of the attic and aditus. The posterior wall of the bony meatus is first attacked. In the outer parts it is removed downwards to the level of the floor of the meatus, and upwards to the superior pole; but as the wound becomes deeper it is necessary to leave the inferior posterior wall intact, to avoid injuring the facial nerve. In the simple mastoid operation the nerve is rarely in danger, and then only in cases in which the antrum is deeply placed; but in the radical operation, if it be done properly, the wound in the bone must of necessity come close to the nerve, and it is when working in this region that the greatest care must be exercised. In order to act both as a guide and, to a limited extent, as a protection to the facial nerve, a probe bent at right angles for a distance of $\frac{1}{4}$ inch at its tip is inserted into the aditus, so that the tip reaches the attic of the tympanum, and the bent portion of the probe lies along the floor of the aditus. Instead of the probe, the protector designed by Stacke may be employed (Fig. 106). As the posterior wall of the meatus is removed from without inwards, the edge of the wound in the bone should gradually slope upwards until, when within $\frac{1}{8}$ inch or $\frac{1}{6}$ inch of the upper pole of the tympanic ring, the gouge or burr should not be below the level of the bent portion of the protector. The cut edge of the posterior wall of the bony meatus thus forms an incline upwards and inwards, until at its innermost point it touches the lowest portion of the outer wall of the aditus. In this way the facial nerve is avoided. As the wound becomes deeper, it will naturally be understood that more bone may, if necessary, be removed from the outer lower and posterior edges of the opening of the wound on the surface of the mastoid process. This allows more light to penetrate to the deeper parts.

As much bone as is safe having been removed from the posterior and upper walls of the meatus down as far as the outer wall of the aditus, the ledge of bone formed by the latter is then taken away. This is done, as before, by keeping above the level of the tip of the protector, which is still held in position along the floor and outer wall of the aditus. Hence the gouge cannot be driven through the bone against the inner wall of the aditus, where it might injure the horizontal semicircular canal. The outer wall of the aditus is thus taken away, and, continuing forward in the same direction, the outer wall of the attic of the tympanum is removed, the tip of the protector being held on the inner surface of the ledge, so that the gouge cuts through on to it. At this stage the hammer and anvil may be looked for, and if present they should be extracted. The outer wall of the attic is removed forward right to its anterior margin. This is a point which is not always sufficiently observed, but it is important; for if a pocket be left in the anterior superior part of the tympanic cavity, healing is sometimes delayed.

In this way, tympanum, attic, aditus and antrum are thrown into one cavity, and it now remains to give the cavity as wide an opening as possible into the meatus. The part at which this is most difficult to accomplish is that above the facial nerve, as it is passing outwards below the floor of the aditus (Fig. 14). It is obvious that the lower and outer part of the floor of the aditus cannot be removed to any great extent, so that here the bone must be taken away from the upper and outer wall. This may even be done until the dura mater is reached, but it is not always desirable to do so, and care must be taken not to penetrate that membrane.

The cavities having thus been opened to the widest possible extent and thrown into one, careful examination must be made over the whole surface of the middle ear, aditus and antrum, in order to discover any area of carious bone. The inner wall of the tympanum should be specially carefully examined, and it is advisable to remove the inner portion of the floor of the meatus in order to make it flush with the floor of the tympanum. In doing this, however, the surgeon must

FIG. 107.—CAVITIES OF THE MIDDLE EAR LAID BARE (POLITZER).

an, antrum.
cs, horizontal semicircular canal.
at, attic.
st, stapes.
ot, opening of Eustachian tube.
pr, promontory.
o, round window.
f, facial canal.

first ascertain by means of a probe if there be a dehiscence in the bony floor of the tympanum, as is not very uncommon. If such be present, then it must be remembered that the bulb of the jugular vein lies unprotected against the floor of the tympanum, and the greatest caution must be observed in removing the bone of the inner portion of the floor of the meatus. The very much rarer, but far more dangerous abnormality in which the carotid artery projects outwards and backwards unprotected into the anterior part of the tympanum is also to be remembered. Any carious portions of bone in the promontory or in any part of the cavity must be removed by scraping with the sharp spoon, but care should be taken not to injure the stapes.

The walls of the whole cavity are now smoothed down so that no pockets or ledges of bone are left, and for this purpose the burr is preferable to the gouge, since it leaves a surface more free from ridges and furrows than does the latter (Fig. 108).

Before cleaning the wound finally the soft parts must be dealt with. This is very simple, in spite of the great amount

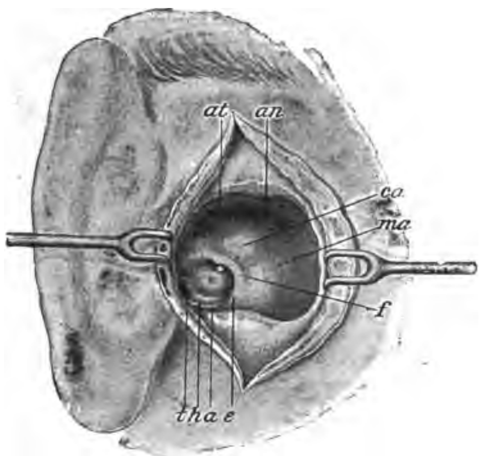


FIG. 108.—THE RADICAL MASTOID OPERATION (POLITZER).

at, attic.
an, antrum.
ca, prominence of horizontal canal.
ma, positon of lateral sinus.
f, position of facial nerve.
e, portion of wall of tympanum.
a, sulcus tympani.
h, floor of tympanum.
t, opening of Eustachian tube.

of descriptive writing that has been devoted to the subject. Since the posterior and superior walls of the bony meatus have been removed, it follows that the periosteum and epidermis, which formerly covered this surface, will be available for covering a small area of the wound in the bone. Various incisions have been recommended in order to utilize the soft parts to most purpose. It probably does not make any great difference which of these methods is employed; the area of the epidermis available is exactly the same in a given case, and no artifice can make it more. On theoretical grounds, of course, Körner's method is perhaps the best, since it gives the longest free margin of skin from which the epidermis can grow in over the wound, but in practice it will be found that the rate of healing does not vary much in the three methods.

Körner's method of utilizing the soft parts is to make two parallel horizontal incisions from within outwards. The upper incision is through the posterior superior wall of the membranous meatus, and the lower one is through the

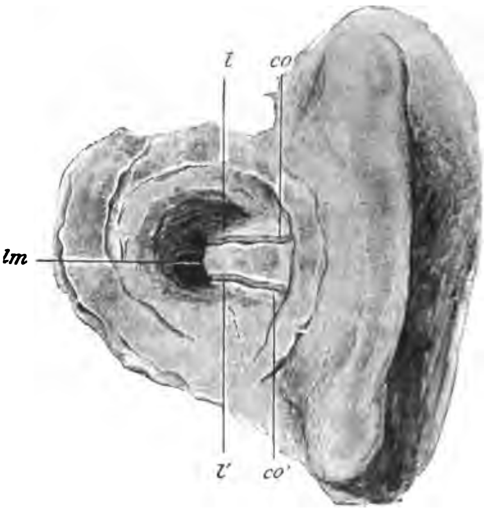


FIG. 109.—KÖRNER'S PLASTIC METHOD (POLITZER).

co, co', parallel incisions along the membranous meatus. *l*, upper wall of membranous meatus. *lm*, inner extremity of flap. *l'*, lower portion of membranous meatus.

posterior inferior wall. Both incisions reach well into the concha, where the long rectangular flap is attached (see Fig. 109). The cartilage is removed from the posterior surface of the flap before the latter is folded back on to the raw bony surface as described below.

In *Stacke's method* a horizontal incision is made from the inner extremity of the soft parts, along the superior posterior wall, well outwards into the concha. From this point a vertical incision is made downwards in the concha for a distance of about ½ inch. After removal of the cartilage from its posterior surface, the flap is folded backwards and downwards.

Panse employs a slightly different method. A horizontal incision is made through the middle of the posterior wall of the soft parts, and is carried out well into the concha. A vertical incision is then made in the concha of about ¾ inch in length; the middle of this incision passes through the outer termination of the horizontal incision. There are thus two flaps, an upper and a lower, and these are

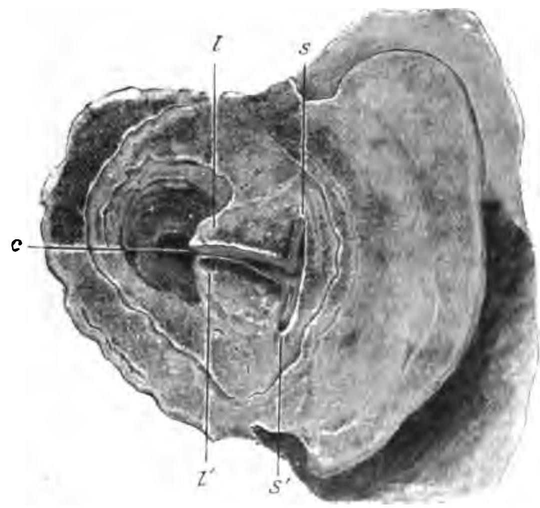


FIG. 110.—PANSE'S PLASTIC METHOD (POLITZER).

s s', vertical incision in concha.
l l', upper and lower flaps respectively.
c, inner extremity of horizontal incision through the posterior wall of membranous meatus.

folded upwards and downwards respectively after removal of the cartilage on their posterior surface.

Ballance makes the outer extremity of the incision in the concha curved.

As stated previously, the surgeon need not trouble himself seriously as to which method of cutting flaps he will adopt. At the most the flaps cover a very small portion of the raw surface, and the healing will not be more rapid with one method than with another.

If the possibility of intracranial complications can with certainty be excluded, the auricle is then replaced in its position, and the wound behind the ear closed by silkworm-gut stitches in its whole extent after the parts have all been thoroughly cleansed. A small gauze drain may be inserted in the middle of the wound; but this is not really necessary, and, if employed, should be removed at the first dressing.

The cavity is now packed gently with antiseptic gauze inserted through the meatus, the skin flaps formed by the incisions along the membranous meatus being folded down on to the surface of the bone, and held in position by the gauze. The ear and side of the head are covered with a thick layer of antiseptic absorbent dressing, which is held in place by bandages. Some surgeons leave the first dressing in place for a week, and until recently the writer pursued this course. He has found, however, that healing proceeds more rapidly if the case be dressed daily, and if peroxide of hydrogen be poured on to the dressing half an hour before removal, the pain of the procedure is insignificant.

At the first dressing the gauze packing is removed from the meatus, and from the wound behind the ear if it has been inserted there. The cavity is cleaned through the meatus either by syringing or mopping out, according to the preference of the surgeon, and a strip of gauze to act as a drain is inserted through the meatus, and the ear dressed as before. The dressing should be carried out daily in order to keep the surface as clean as possible, and thereby assist healing. As the discharge diminishes the amount of gauze is lessened, until in the course of a fortnight or three weeks a plug of gauze in the meatus is all that is necessary.

Modifications of the Radical Mastoid Operation.—The description just given is that of the typical radical mastoid operation, but there are certain modifications which have been introduced, and these may be mentioned briefly.

Stacke's Modification.—Stacke achieves the same end as in the operation just described, but he begins the removal of bone from within outwards. Thus, the external wall of the attic along with the ossicles are first removed, then the outer wall of the aditus, and finally the upper and posterior walls of the bony meatus, until the antrum, aditus, attic, and middle ear, are thrown into one smooth-walled cavity. The supposed advantage of this method of procedure is that, having found the aditus early, the position of the facial nerve can be more accurately located, and is therefore less liable to injury. During the removal of the outer walls of the attic and aditus, the beak of the protector is held against the inner surface of the bone, while the gouge is applied to the outer surface. Thus the gouge cuts down upon the beak of the protector. It will be observed that, in removal of the outer wall of the attic, the beak is in the vertical plane, but later, when removing the outer wall of the aditus, it is turned into the horizontal plane. The instrument assists in protecting, not only the facial nerve but the stapes also, and further acts as a guide to the aditus.

One of the advantages claimed for Stacke's operation is that the difficulty of finding a very small and deeply-placed antrum is avoided, because the surgeon is led to it by way of its natural opening, the aditus.

There is no doubt that Stacke's modification is quite as good as the typical operation when there is no reason to suppose that intracranial complications exist in the posterior fossa of the skull. If, however, the presence of such lesions is suspected, or even considered remotely possible, it is obviously better to approach the antrum through the mastoid process, as will be seen later.

Other modifications of the radical operation have been made with the purpose of retaining the ossicles and the remains of the tympanic membrane, in the hope that the hearing-power would ultimately be better than it is when they have been removed. Such modifications are those of Schönemann, Bryant and Heath.

Schönemann[1] makes a vertical incision through the tympanic membrane immediately behind the handle of the hammer, and continues this incision upwards to the tympanic ring, then outwards along the whole length of the meatus to its outer extremity. The soft parts behind and below this incision are separated from the bone, as in the radical operation, and the latter procedure is then carried out as usual, except that only the posterior portion of the outer attic wall is removed. The wound behind the auricle is kept open, and the dressing is done through it.

[1] Schönemann, Verhandl. d. Deutsch. Otolog. Gesellsch. xv., S. 248 1906.

Bryant's[1] procedure is somewhat similar, but he removes the outer attic wall more completely, and even a portion of the bony tympanic ring itself, but leaves the ossicles intact.

Heath's[2] modification appears to be practically the same as that of Bryant, but, while removing almost entirely the outer attic wall, he retains the annulus. Heath also directs special attention to the careful removal of granulations from the tympanic cavity, and to the use of the air-douche at every daily dressing.

There is probably some value in these modifications by means of which the ossicles are left, but it is extremely difficult to estimate the extent to which the hearing-power is retained, as compared with the results obtained by the ordinary radical operation. Thus, every aurist knows that the hearing-power varies within very wide limits after the radical operation, the variation being in all probability due to the extent to which the stapes remains movable, and this factor remains present whether the two outer ossicles be removed or not. Still, it is desirable, on general surgical principles, not to remove more than is necessary; and if the operator is quite convinced that the two outer ossicles are not in themselves diseased, and that their retention does not interfere with the complete removal of diseased areas in the tympanic cavity and attic, they may well be left. The conditions which will guide the surgeon in this case are the extent of the hearing-power before operation, and the position of the diseased parts, which should be ascertained both before and during operation by very careful probing. The better the hearing-power before operation, the more desirable it is to leave the two outer ossicles. In all cases, save those in which the labyrinth is the seat of suppurative changes, the stapes must of course be left.

When the discharge after any of these operations has diminished to such an extent that there is no longer any necessity to bandage the head, the case must be carefully treated on the same principles as an ordinary suppurating ear. Thus, the secretion must be removed at least once daily, either by mopping out or by first syringing and then drying out carefully. The syringe with the opening at the

[1] Trans. Amer. Otolog. Soc., vol. xxxviii., p. 152, 1905.

[2] *Lancet*, August 11, 1906.

side of the nozzle, which was designed by Urban Pritchard, is particularly useful for the removal of pus and débris in these cases. The use of rectified spirits, peroxide of hydrogen, boracic acid powder, anilin and other medicaments which are used in otorrhœa, should be employed in the same way and *with the same precautions* as in the latter condition. If exuberant granulations appear, they should be removed with the snare or destroyed by chromic acid fused on the end of a probe.

The great drawback to the radical mastoid operation is the slowness of the healing process, and the consequent long-continued after-treatment. Even under the most favourable circumstances, the new-formed cavity is rarely dry within six weeks of the operation, and ten to fifteen weeks is very frequently required for the process. Many cases take months, and even a year, before the discharge completely ceases, and in about 20 or 25 per cent. the discharge, though greatly diminished in amount, goes on indefinitely. When the discharge still continues, it must not be supposed that the operation has been a total failure. The chief object of the operation is to put the patient in a condition of safety, and this has been achieved if the new-formed cavity in the bone retains its shape, and does not have its outlet narrowed, even although the discharge continues. It is, however, unfortunate if the patient is still troubled by the necessity of keeping the cavity clean, and everything must be done to bring the discharge to an end by the methods described.

The condition, however, is more serious when portions of the cavity become shut off, so as to form pockets which cannot be reached by the surgeon, and therefore allow the discharge to collect. This happens when adhesions form between the roof of the cavity and the floor where the latter merges into the lower or posterior wall of the meatus. It is especially liable to occur where the wound in the bone is narrowest—that is, between the tegmen aditus et antri and the projecting knee of bone which covers the facial nerve. The obvious way to prevent such an occurrence is to make this space as wide as possible during the operation without injuring the facial nerve below and the tegmen or dura mater above. Rapid healing of the wound, moreover, tends to prevent this unfortunate result, and it is important, therefore, to carry out the after-treatment rigorously.

Skin-Grafting.—Attempts have been made to hasten the healing of the wound by means of grafting skin on the raw surface of the wound. The method devised by Ballance is that most frequently employed, and is carried out in the following manner. At a period when granulations have formed over the surface of the raw bone—that is, ten to twenty days after the operation—the wound behind the ear is opened up, and the granulations are removed from the surface of the bone. A skin-graft is then removed from the inner surface of the arm or other convenient place, and carefully pressed down over the inner wall of the raw surface of the cavity in the region of the attic, aditus and tympanum. The graft is kept in position by means of small pledgets of sterilized cotton-wool, and the ear is again dressed as before. Some surgeons do not reopen the wound behind the auricle in order to apply the graft, but introduce it through the now wide meatus. Ballance has added yet another stage to the skin-grafting operation, in that he advises the removal of the dead portions of the graft.

Certain modifications of the grafting operation described above have been devised, but they are unimportant and need not be referred to.

The success of the skin-grafting method depends upon the complete removal of all diseased bone at the radical operation, and the degree of asepsis obtained in the wound and graft when the latter is applied. It is also desirable that the surface of the bone be as smooth as possible when the radical operation is finished, and that the living cells both of the graft and of the mastoid wound are not killed by the use of strong antiseptics. The value of grafting in these operations has been called in question, and very many surgeons have given it up. The objections to it are obvious. It is a severe enough tax upon any patient to subject himself to the radical operation alone, and to ask him to undergo a further operation is not a pleasant duty for any surgeon. If it could be shown that by means of grafting the after-treatment could *always* be very much shortened, then there would be no cause to hesitate in recommending it; but this cannot by any means be guaranteed, for in many cases the wound heals as quickly without grafting as with it. Further, there is no doubt that, even when grafting is satisfactorily carried out, the discharge continues for many months, or even indefinitely.

In short, it may be said that the rapidity of healing depends for the most part upon the complete removal of all diseased parts at the operation, and the absence of pockets in which the secretions can lodge. To these may be added the careful after-treatment of the wound, and attention to the general health of the patient.

General Remarks upon the Results of the Radical Operation.—Before leaving the subject of the radical mastoid operation, it is desirable that some practical hints be given as to what the patient should expect in the way of result. If these are not attended to, he may be grievously disappointed sometimes, and the reputation of the surgeon may consequently suffer at his hands.

In the first place, the patient must be made clearly to understand that the primary object of the operation is to remove him from a position of danger to one of comparative safety. Next, he should always be told that, however carefully the operation be done, no definite promise can be given that the discharge will completely cease. Complete cure is only obtained in about 70 or 80 per cent. of the cases. In all, however, the amount of the discharge diminishes very considerably if the operation has been properly carried out, and the foul smell can, so far as the author's experience goes, always be made to disappear.

The duration of the healing process can never be defined, and it is both unjust and inadvisable to subject a patient to operation if he is under the impression that his troubles will certainly be at an end in four or five weeks, or even in eight, ten or twenty. Every aurist has cases which are completely dry in four or five weeks, or even less, but he knows perfectly well that these are the exceptions. It is, however, justifiable to say that the bandaging of the head may be dispensed with in two or three weeks, for this is practically always true; and the patient may then be able to go about his work.

Before undergoing the radical mastoid operation, the patient will probably ask if it is dangerous to life. In this respect the surgeon can honestly reassure him that the operation is a safe one if the labyrinth is not involved (see p. 276). Death must be very rare as a result of the operation, and the fatal cases recorded in the literature of the subject are extremely few. It might be thought that the opening of the lateral sinus or of the dura mater would be dangerous; but although such accidents are highly undesirable, it is a curious fact that no serious result seems to follow in the vast majority of cases. The author has only heard of one instance in which death resulted from accidental opening of the dura mater, and even in this case it is possible that the labyrinth was diseased.

As regards hearing-power after the operation, the results vary in a remarkable way. Occasionally there is a certain amount of improvement, in others there is no difference, while in some the hearing is distinctly worse.

Facial Paralysis.—Facial paralysis may be found after the radical mastoid operation, but the cause of the condition varies in different cases. In many it is not due to mechanical injury to the nerve during operation, but is the result, probably, of effusion into the bony canal, and consequent pressure upon the nerve; or it may be a neuritis affecting the nerve-trunk. In these cases the paralysis does not appear until some hours, or it may be a day, after operation, and the condition seems invariably to pass off in the course of some weeks or in a month or two. In other cases the paralysis may be due to an injury to the nerve during the operation; but this, fortunately, is now rare, probably owing to the fact that a more accurate knowledge of the anatomy of the parts is possessed by the surgeon than was formerly the case. When facial paralysis is due to injury at the operation, it appears immediately. It is therefore of importance to ascertain at once, after every operation, whether the facial muscles still respond to stimulus. This is done by squeezing the nose or pinching the cheek as soon as the effects of the anæsthetic begin to pass off. If the cartilages of the nose or the corner of the mouth move in response to the stimulus, then the operator knows that, even if subsequent facial palsy should appear, it need cause no anxiety, but will pass off sooner or later. If, on the other hand, the muscles on one side of the face respond to the stimulus, while those on the side corresponding to the ear operated upon do not respond, then the nerve has been injured in some way during the operation, and the question arises, what treatment is to be adopted ?

In the first place it must be noted that, even if the paralysis be complete, it does not necessarily mean that the nerve has been cut right across. It may be that it has only been bruised, or perhaps partially cut. In this case recovery will almost certainly occur, although the complete restoration of function may be long delayed. This happened in the only case which the writer has had in which facial paralysis occurred as the direct result of injury at the operation, and it was more than a year before the facial muscles completely regained their power, though faint movements began in the course of four months.

When, therefore, facial paralysis occurs as the result of injury during the performance of the radical mastoid operation, the case should be treated by applications of the faradic or galvanic current for several months before giving up hope of recovery or undertaking surgical procedures for the relief of this distressing condition. After the lapse of six months, however, if the paralysis shows no signs of disappearing, the patient should have the option of undergoing further surgical treatment. There are three means by which a certain degree of relief may be obtained. The first of these consists of suturing the distal portion of the injured nerve to the spinal accessory ; the second, of suturing the distal end of the nerve to the hypoglossal ; and the third and most recently devised is the method of Sydenham,[1] which was also independently devised by Marsh.[2] This method consists of laying bare the cut ends of the nerve in their bony canal, fraying them, adjusting the frayed ends as nearly as possible, and protecting them with gutta-percha tissue. Sufficient time has not as yet elapsed to allow the surgeon to offer an opinion on the merits of the last method. If success can be achieved by it in a sufficient number of cases, it will undoubtedly prove the best, since it does not involve ungainly associated movements of the tongue or shoulder, as do the other methods. Even if it fail, it does not prevent the subsequent operation of making a junction between the facial and spinal accessory or hypoglossal nerves.

[1] Sydenham, *British Medical Journal*, May 8, 1909.

[2] Marsh, *British Medical Journal*, June 5, 1909.

In regard to facial paralysis, the question sometimes arises, within what period after the onset of the paralysis is it possible to restore activity to the facial muscles by nerve suture? Unfortunately, this question cannot be answered satisfactorily. Cases have been recorded in which recovery of the movements of the facial muscles occurred when the operation was undertaken four years after the onset of the paralysis. But such must be exceptional, and there are many failures in cases in which only one year has elapsed.

OPERATIVE PROCEDURES UPON THE LABYRINTH.

In certain cases of suppurative, and in still rarer ones of non-suppurative disease of the ear, it is necessary to open the cavity of the labyrinth. Without exception, these operations are destructive in character, the object being to destroy the whole or a portion of the organ in order to obliterate a source of infection and danger, or to cause the disappearance of severe giddiness or tinnitus.

The radical mastoid operation should first be performed, and when the wound has been thoroughly cleansed the opening of the labyrinth is undertaken. An electric forehead light is of considerable assistance in the operation. The most usual line of advance is by way of the posterior limb of the horizontal canal, the facial nerve being in front and outside of this. The bone is drilled away until the vestibule is reached, and from this cavity the posterior canal is destroyed by drilling outwards and backwards, and the superior canal by drilling upwards. The ampullæ of the superior and horizontal canals are next destroyed by drilling forwards and outwards, but this part of the operation must be undertaken with the greatest care, since the facial nerve lies close to these structures (Fig. 40). This operation is termed superior vestibulotomy.

The other direction in which the surgeon may approach the labyrinth is by way of the oval window, and the operation is termed inferior vestibulotomy. The bone between the oval and round windows is removed by the burr, and the vestibule is thus reached. The ampullæ of the superior and horizontal canals can hardly be reached with safety by this operation—at least, so far as removal of bone is concerned.

On the other hand, it allows of easy access to the cochlea, which is difficult or impossible by superior vestibulotomy. The choice of operation will therefore depend to a great extent upon the case. When the patient suffers from incurable giddiness and staggering gait, but not from tinnitus, superior vestibulotomy is indicated; but when unbearable tinnitus is the symptom, it is obvious that the cochlear nerve must be destroyed. In suppurative disease both operations may be required, and in this case a bridge of bone containing the facial nerve is left between the two openings into the labyrinth. In all cases the wounds are treated on the same principles as in the radical mastoid operation.

Operations on the labyrinth are associated with considerable shock, and are much more serious undertakings than the radical mastoid operation. The surgeon is well advised to think very seriously before subjecting a patient to these risks. Above all, it must be pointed out that, so far as the relief of tinnitus is concerned, the operation frequently fails.

The surgery of the labyrinth has been designed and studied by Milligan,[1] Lake,[2] and West and Scott,[3] in this country, by Richards[4] and others in America, and by several operators abroad.[5] For a more detailed account of the subject, the reader is referred to the papers by these writers.

OPERATIVE PROCEDURES FOR THE RELIEF OF INTRACRANIAL AFFECTIONS DUE TO OTORRHŒA.

Until the epoch-making work of Sir William Macewen, infective disease within the cranial cavity was looked upon as practically a hopeless condition. It is true that a rare case here and there recovered after surgical intervention, or still more rarely by natural processes, but these were solitary examples. The foundations of brain surgery were laid by Macewen.

In the very great majority of cases of intracranial disease due

[1] Milligan, *Journal of Laryngology, Rhinology, and Otology*, 1904.

[2] Lake, Proceedings of the Otological Society, 1905, p. 60.

[3] West and Scott, 'The Operations of Aural Surgery,' Lewis, 1909.

[4] Richards, *Laryngoscope*, October, 1907.

[5] Hinsberg, Verhandl. d. Deutsch. Otolog. Gesellsch., 1906; Bourguet, Thèse d. Toulouse, 1905; Jansen, *Annals of Otology, Rhinology*, etc., June, 1908.

to otorrhœa, the procedure demanded is an extension of the radical mastoid operation in such a way that the cranial cavity is opened at the requisite spot. Only when the patient is *in extremis* and every instant of time is important, is it desirable to trephine directly into the cranial cavity and relieve the pressure, while at the same time attempting to find and treat the lesion.

The first stage, therefore, consists in the performance of the radical mastoid operation as described above, but it is of importance that during this stage any fistulæ should be carefully searched for. If any such is present, it should be followed by removal of bone until its source is reached. In this way many *extradural abscesses* are found, as well as other diseased conditions. Sometimes, however, no fistula will be discovered until the bone has been so far removed that the tegmen tympani et antri is fully exposed. When this has been done, a very careful search must again be made with the probe, especially over the tegmen, in order to make sure that no fistula is present. It is surprising how these fistulæ may be concealed, and sometimes they are so minute as to escape detection, even on most careful examination.

Should no such fistula be discovered, the surgeon must proceed farther according to the nature of the case, whether extradural abscess, thrombosis of one of the sinuses, cerebral abscess, or cerebellar abscess. From a practical point of view, however, the most important matter at this stage of the operation is to decide which to open first—the posterior or the middle fossa. If thrombosis of the lateral sinus or cerebellar abscess be suspected, then obviously the posterior fossa should first be opened.

Thrombosis of the Lateral Sinus.—The posterior fossa is opened by continuing the removal of bone from the posterior wall of the wound made by the mastoid operation, so that the dura mater is brought into view. In cases of thrombosis of the lateral sinus it will frequently be found that an extradural abscess is present and in contact with the wall of the sinus. If this be so, the abscess should be very thoroughly opened and every trace of pus and débris removed, before the sinus itself is interfered with. The sinus is recognized by its faint blue or purple colour, while the dura mater proper is of a sinewy white or buff tint. But if there be much inflammatory activity with the formation of granulation tissue, the wall of the sinus and the dura mater are hardly distinguishable to the eye, and in this case the surgeon must proceed according to his anatomical knowledge. A small longitudinal incision is then made in the sinus. If no thrombus is present the blood will flow freely, but it is easily stopped by pressure. If a thrombus is present, then the opening in the vein is enlarged in the direction of the torcular Herophili, and the clot removed until blood flows. It may be necessary to enlarge the opening in the bone backwards. Similarly, the clot is removed in a direction inwards towards the foramen lacerum posticum. The opened sinus is packed with iodoform gauze and the wound treated as in a radical mastoid operation, but the post-auricular opening must not, of course, be closed.

The fear of air embolism need not be considered in opening the sinus, whether thrombosis has occurred or not.

The question of ligaturing the jugular vein in the neck before opening the sinus arises in many cases. Some surgeons recommend it as a matter of course, but it is difficult to see what is gained by ligaturing the vein when the sinus may be found to be quite healthy. Macewen advises the ligature in those cases in which the thrombus reaches so far that it cannot be completely removed after opening the sinus; Jansen applies the ligature if, after the operation on the sinus, rigors and febrile temperatures continue; while Horsley recommends its use only if metastases have already occurred. The author ventures to doubt whether anything is gained by the procedure except under the circumstances mentioned above by Macewen, Horsley and Jansen. If it be decided to ligature the jugular vein, then the ligature should be applied below the lowest point to which the thrombus reaches.

In cases in which the thrombus in the sinus extends so far inwards that it cannot be completely removed, Grunert advised removal of the mastoid process and opening of the jugular bulb. Piffl modifies this procedure by removing the bone from the lower and inner wall of the meatus and the floor of the tympanum until the bulb is laid bare, so that it can be opened and obliterated. These certainly seem rational surgical procedures, but the author cannot speak from experience concerning their value. Should the surgeon desire to perform them, he must bear in mind the close proximity of the facial and spinal accessory nerves to the field of operation.

Although operation is the only justifiable way of treating sinus thrombosis, it must not be forgotten that subsequent recovery may be assisted by suitable nutritious diet, and it is possible that the administration of quinine may be of some help.

Cerebellar Abscess.—The field of operation for the evacuation of cerebellar abscess coincides to a great extent with that for the opening of the lateral sinus, and it may therefore be conveniently described here. The bone is removed from the posterior wall of the wound, as described above, until the dura mater is laid bare. This may be done either internal to the lateral sinus, and therefore between the latter and the posterior semicircular canal, or it may be done external to and behind the lateral sinus. The former possesses the advantage of being, in the great majority of cases, nearer to the seat of the abscess, but in all cases it will naturally be understood that if a fistula is present it should be followed.

When the dura mater is laid bare, a small incision is made in it, so that the cerebrospinal fluid may escape and its nature be observed. The operator should also note if pulsation of the brain is still present; but although its presence usually excludes the existence of brain abscess, it does not always do so, as was pointed out by Macewen in the case of some deep-seated abscesses. The abscess is then searched for by means of a trocar and cannula or a sharp-pointed tenotomy knife. The operator must see that the point of the instrument is very sharp, so that it is certain to penetrate the wall of the abscess should it meet with one. When searching for the abscess, the instrument must not be moved in a lateral direction, but be withdrawn and then reinserted into the brain substance in a different direction. When the abscess is found, it should not be syringed out, but a drain, either in the form of a thick-walled rubber tube or a strip of iodoform gauze, should be inserted and the wound dressed. At first the wound may be dressed daily, but after a few days it may be done every two or three days, the drain being shortened as is desirable.

The anæsthesia during an operation for cerebellar abscess always gives rise to more or less anxiety, for it is in these cases especially that the respiration is apt to cease. If this should happen, the surgeon must continue the operation as fast as possible while artificial respiration is being kept up; and when the intracranial pressure has been relieved, it will frequently be found that natural respiration is restored.

Cerebral Abscess.—When abscess in the cerebrum is suspected the surgeon's objective is, of course, the middle fossa. The radical mastoid operation is performed, and after the wound has been thoroughly cleansed the tegmen tympani et antri is searched very carefully for a fistulous opening. If such be discovered it is followed through the bone and into the abscess, wherever the latter may be situated. If there be no fistula, then the tegmen is removed and the dura mater exposed. The wound is then thoroughly cleansed, and an incision is made through the dura mater so as to expose the brain. The nature of the cerebrospinal fluid should be observed, and the presence or absence of pulsation in the brain substance should also be noted. The abscess is then searched for in the way described above, and it will usually be discovered a few millimetres below the surface of the temporo-sphenoidal lobe. The wound is drained and treated in the way described for cerebellar abscess.

Operation for Diffuse Purulent Meningitis.—Until comparatively recently, diffuse purulent meningitis has been considered to be inevitably fatal. A few cases have, however, been recorded by Barker,[1] and West and Scott,[2] in which operative procedures brought about a cure under circumstances which appeared to be hopeless. Previous to this cases had been reported abroad by Laurens, Widal and Ramond, and others, in which the same principle of draining the arachnoid space had been successfully employed in purulent meningitis.

According to the nature of the case the middle or posterior

[1] Barker, Transactions of the Royal Society of Medicine, vol. i., No. 6, 1908.

[2] West and Scott, Transactions of the Royal Society of Medicine, Otological Section, 1908.

fossa of the skull is opened, as in the ordinary operation for cerebral or cerebellar abscess, and a drainage-tube, preferably made of some rigid substance such as pewter, is introduced into the arachnoid space. The infected cerebrospinal fluid can therefore escape and be absorbed by the dressings, which must be very frequently changed. The arachnoid space in the spinal column may be drained in one of two ways. Barker's method consists in tapping the space frequently by ordinary lumbar puncture, and removing 10 to 20 c.c. of the fluid. The tappings are repeated every two or three days, according to the symptoms. The second method of draining the arachnoid space was employed by West and Scott. It consisted in introducing a fine cannula between the fourth and fifth lumbar vertebræ and leaving it in position. The outer end of the cannula is enveloped in a Keith's dressing.

In these operations symptoms of collapse are apt to supervene, and the nursing and medical attendance must therefore be of the best. When collapse occurs the drainage-tube must be removed, the pelvis raised and stimulants administered.

It must further be remembered that in all cases it is important to remove the original focus of disease in the temporal bone.

Although it is always desirable, if possible, to treat the intracranial complications of ear disease by following the line of infection through the temporal bone, it is sometimes necessary, owing to the grave condition of the patient, to open directly into the skull by means of the trephine. Further, it is desirable in some cases, in which drainage by the ordinary route is not satisfactory, to establish a second opening in the skull. It is necessary, therefore, to describe briefly the methods employed for this purpose.

If the abscess is suspected to be in the cerebrum, and there are no localizing signs, the point at which the trephine should be applied is found by drawing a line for the distance of 1¼ inches vertically upwards from the centre of the meatus, and then measuring ¼ inch horizontally backwards. A flap is then made in such a way that this point is in the centre, and the flap is reflected upwards until the bone is laid bare and the trephine may be applied. The disc of bone being removed, the dura mater is incised and the abscess searched for in the way described previously. When it is found, the abscess is evacuated, the drainage-tube introduced, and the wound is treated and dressed in the same way as when the lesion has been reached through the mastoid process (p. 307).

When abscess in the cerebellum is suspected, the centre of the trephine opening should be 1½ inches behind, and about ½ inch below the centre of the meatus. When the brain is exposed, the trocar or tenotomy knife should first be directed inwards, downwards and forwards, as this is the direction in which the abscess will usually be found. The wound is treated in the way adopted for other brain abscesses.

Before leaving the subject, it may be of value to the reader to refer to certain difficulties frequently met with in the after-treatment of cases operated on for intracranial disease due to otorrhœa.

Drainage.—The drainage of a brain abscess is frequently a source of great trouble owing to the soft consistency of the tissue, which allows the pressure to close the lumen of the drainage-tube or to occlude the opening. A drain of iodoform gauze does not act any better. One method of getting over the difficulty is to use a rubber drainage-tube with particularly thick walls and without any lateral openings, or at most a single opening near the end which lies in the abscess cavity. In this way the resistance of the tube to the surrounding pressure is greatly increased. A second difficulty associated with the drainage is encountered when the tube is removed after the first dressing, for it may not be easy to find the abscess cavity again. Perhaps the best way to overcome this contingency is to abstain from removing the tube at all for the first few days, unless, of course, the progress of the case indicates the necessity for so doing.

Hernia Cerebri.—Another trouble frequently encountered is the occurrence of hernia cerebri, the soft brain substance being driven out through the opening in the bone by the intracranial pressure. This does not arise, as might at first be supposed, as a result of too large an opening in the bone. Its occurrence indicates that the intracranial pressure is excessive, and consequently it usually disappears as the case progresses. Not infrequently, however, the prolapsed portion must be cut away. The only way in which hernia cerebri can be avoided is to ensure the best drainage possible, and thus relieve the pressure to a certain extent. Unfortunately, however, other factors causing the increased pressure cannot always be removed.

Prognosis.—The prognosis of cases operated upon for the intracranial complications of ear disease is not, it need hardly be said, so favourable as surgical statistics would lead us to infer. Human nature affects the statistics of operative procedures in this as in other regions of the body, and the operator need not be unduly depressed because his list of cures does not reach the supposed standard indicated on paper. Neither need he be unduly elated if by good fortune his statistics appear to be particularly favourable. This probably means merely that he has had a succession of cases suitable for successful operative treatment.

Uncomplicated cases of extradural abscess are by far the most favourable from the point of view of prognosis. Indeed, the great majority of these recover after operation. Of the cases of septic sinus thrombosis operated upon, about half recover, and the same proportion of cases of uncomplicated brain abscesses also run a favourable course. The prognosis of diffuse purulent meningitis is distinctly bad, but that of serous meningitis is favourable. The occurrence of two lesions together naturally increases the gravity of the case, and when diffuse purulent meningitis is one of the complications the outlook is particularly gloomy.

CHAPTER XIV

OTOSCLEROSIS

The term 'otosclerosis' is of comparatively recent origin, for the very good reason that the condition which it indicates has only been recognized as a pathological entity within recent years. Indeed, the differentiation of the anatomical changes from those found in other conditions is not yet quite complete, and clinically not a few cases occur in which it is difficult to say whether the patient is suffering from otosclerosis or from middle-ear catarrh on the one hand, or from an affection of the labyrinth on the other. The chief reason for the use of the term 'otosclerosis' is that a certain proportion of cases which were formerly included under the name of 'dry catarrh of the middle ear' had no anatomical association with the middle ear at all. In these the symptoms result from very definite pathological changes in the bony capsule of the labyrinth, which almost invariably produce ankylosis of the stapes. And it is because the clinical picture depends to a large extent upon this anatomical change that these cases were not distinguished from middle-ear disease, which also sometimes causes fixation of the stapes.

History.—The fact that deafness was sometimes associated with fixation of the stapes was first demonstrated by Valsalva, and the condition was also recognized by Morgagni and Meckel. There were, however, no worthy successors to these early pioneers for many years, until Joseph Toynbee, as a result of the most patient labour, collected a large number of cases, and showed that fixation of the stapes was one of the common causes of deafness. It was then unjustifiably assumed that the fixation of the ossicle was a necessary result of inflammatory action in the middle ear. The first suspicion that this assumption might be incorrect was voiced by Moos, who in

1861 published the results found on examination of a temporal bone in which fixation of the stapes had taken place without any sign of past or present middle-ear disease. In 1885 Bezold was enabled to associate the clinical symptoms observed during life with the anatomical changes found post mortem. Since that time it has been shown by Politzer, Siebenmann, Katz, Habermann, Bezold, Panse and others that in many cases at least fixation of the stapes is the result, not of middle-ear disease at all, but of changes in the bony capsule of the labyrinth.

Incidence.—In respect to *age*, it is commonly stated that otosclerosis begins most frequently in middle life. It is certainly rare under twenty, and very rare in childhood, if, indeed, it occurs at all. Politzer, however, states that he has sometimes seen it in subjects between the ages of ten and fifteen. Panse states that the disease most frequently begins during the fourth decade, but it must be remembered that in the case of a disease of such insidious onset there is probably a slight diminution in the hearing-power long before the patient is aware of it. Taking all the facts into consideration, we shall not be far wrong in concluding that in the great majority of cases the disease first manifests itself between the ages of twenty and forty.

Sex undoubtedly plays a part in the etiology, for it is clear from the statistics of Bezold, Denker and others that about 60 per cent. of the cases occur in women.

As regards *heredity*, while all observers agree in admitting that the affection may be inherited, the extent to which this is the case appears to be very difficult to ascertain. Bezold [1] put the percentage of inherited cases as high as 52·0 per cent., Denker [2] at 40·5 per cent., and Siebenmann [3] at 35·0 per cent. Some time ago the author [4] ventured to question the accuracy of these statistics, on the ground that, although a patient may be able to say that certain of his progenitors were deaf, he cannot say what the cause of the deafness was. Thus, a large number of individuals may be deaf as a result of present or

[1] Bezold, 'Die Funktionel. Prüf. d. Menschl. Gehör.'

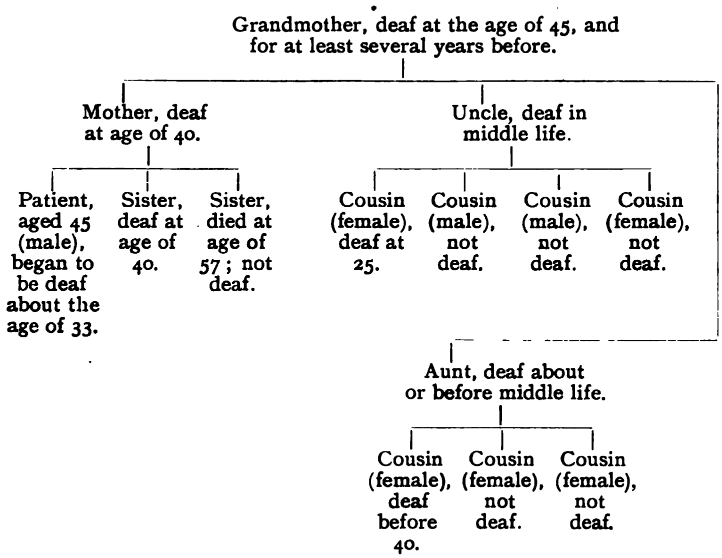
[2] Denker, 'Die Otosclerose.'

[3] Siebenmann, *Zeitschr. f. Ohrenh.*, Bd. xxxiv.

[4] Gray, 'System of Medicine,' edited by Clifford Allbutt, vol. iv., art ii., p. 512.

previous suppurative disease of the middle ear, and of these it is not at all improbable that some may have children who ultimately suffer from otosclerosis. Such cases would be included in the statistics above cited as showing the hereditary tendency towards otosclerosis, unless the utmost care were taken to exclude them, and would thus lead to error. Hammerschlag,[1] as the result of actual investigation, has independently shown how justifiable these suspicions are.

If these high percentages are true, then, judging from the author's experience, otosclerosis must, in Scotland at least, be a much rarer disease than is supposed.



There can, however, be no doubt that heredity does play a part in the incidence of the disease. The truth of this statement is forced upon the aurist when, in certain families, one after another of the members come to him after they have entered upon the critical decades. Körner relates what appears to be a striking example of this, in which two individuals suffering from otosclerosis married and had twelve children, and all of the twelve were deaf. For the reasons given above, therefore, we may conclude that at present no

[1] Hammerschlag, *Monatsschr. f. Ohrenh.*, Bd. xl., 6, S. 443.

statistics of sufficient value are available, that the ones given are probably rather too high, but that at the same time heredity does play a considerable part in the incidence of the disease. The genealogical tree on p. 313, which was drawn up by the writer with the help of one of his patients, illustrates the hereditary nature of the disease in some cases.

Pathology.—In this as in other diseases a careful distinction must be made between the morbid anatomy and the pathogenesis. The first is concerned with the anatomical changes which occur, and is therefore a matter of direct, though frequently difficult, observation; the second relates to the physiological conditions which are responsible for the anatomical changes, and is for the most speculative. Our knowledge of the morbid anatomy is due to the investigations of Moos, Politzer, Bezold, Katz, Habermann, Siebenmann, Panse, the author and others.

The disease begins by the process of absorption of bone in some part of the capsule of the labyrinth. The region which is supposed to be most commonly affected is that immediately above and in front of the oval window. But, as the author has suggested,[1] it is possible that too much has been made of this point. In the cases which have been examined, it is true that this is the part most frequently affected; but it must be remembered that, owing to its proximity to the oval window, disease in this region would be the most likely to lead to fixation of the stapes, and therefore such cases would, on the whole, most frequently come under the observation of the aurist and pathologist. In recent times Katz[2] has recorded a case of otosclerosis occurring in a deaf cat, in which there was no fixation of the stapes, although the capsule of the labyrinth, the hammer and anvil, and other portions of the temporal bone were affected. While, therefore, it is probable that the region of the oval window is the part of the labyrinthine capsule most frequently affected, we cannot say that this is definitely proved. And it is further possible that cases may occur in which the bony changes of otosclerosis are present without causing any symptoms, because these changes may have taken place in regions where they do not

[1] Gray, *loc. cit.*

[2] *Arch. f. Ohrenh.*, Bd. lxviii., 1 and 2, S. 122, 1906.

affect the functions of the organ of hearing (Fig. 99). In regard to the regions in which the pathological changes may take place, Katz [1] has offered some interesting though, it must be admitted, speculative views. He considers that there are two pathological types of otosclerosis—one with ankylosis of the stapes, and the other without. In the cases with ankylosis he is of opinion that this is the first change, and that it is of the nature of an arthritis. In the cases of otosclerosis without ankylosis of the stapes, on the other hand, he considers the underlying condition to be of the nature of osteomalacia, syphilis, or of senile changes in the bone. These, however, are merely speculative suggestions.

The change may occur in any part of the temporal bone, and even in the other bones of the head. Thus, Katz[2] has recorded a case in which the anvil and hammer had suffered, and the author has recorded another in which the bones of the skull were affected.[3] The pathological changes are, however, most frequently found in the petrous portion of the temporal bone, but this may merely mean that they are probably only looked for in this region. In the petrous portion they may occur at any part, and frequently several foci are present. Thus, they may occur in the walls of the porus acusticus, in the modiolus, the spiral lamina, the edges of the round window, the walls of the semicircular canals, or on the outer surface of the promontory. Small exostoses are frequently found on the surfaces of the bone, and one such, of a spurlike shape, is seen in Fig. 111. The extent to which the process may cause distortion or obliteration of the labyrinthine cavity varies greatly, but as a rule the latter is not very much affected. The changes in the region of the oval window which cause fixation of the stapes, and in that way produce the chief clinical features of the disease, are also variable in degree. In many cases the fixation is caused by an extremely delicate lamina of bone which has come to replace the annular ligament, as may be seen in Fig. 112. In others the stapes and adjacent walls of the labyrinth may be united into one dense mass of bone. Exostoses may also be found limiting the movement of the stapes in the oval

[1] Katz, *loc. cit.*

[2] Katz, *Arch. f. Ohrenh.*, Bd. liii., S. 68.

[3] Gray, *British Medical Journal*, 1905, vol. ii., p. 1187.

window, or encroaching upon a large portion of the round window.

Microscopic Changes.—The finer changes revealed by the microscope are seen to consist essentially in the absorption of the old compact bone, followed by the deposition of new-formed spongy bone, which in its turn also becomes compact. The diseased area is at first sharply differentiated from the surrounding normal bone by a line of demarcation, and within this area the Haversian canals become enlarged, their walls being absorbed by osteoclasts. As this process of absorption is going on, an almost simultaneous deposition of new-formed spongy bone occurs, the process being carried out by osteoblasts. This new bony tissue is characterized by its strong affinity for staining reagents. The new-formed bone then gradually becomes more compact, the medullary spaces get narrower, and the bloodvessels become smaller in calibre. The tissue then loses its affinity for staining reagents, and ultimately presents an appearance similar to the old bone surrounding it. During the process of absorption, the cartilages lining the oval window and the edge of the footplate of the stapes, along with the annular ligament, disappear and are replaced by bone, so that the stapes becomes fixed. Moreover, the amount of new bone deposited is sometimes more than that of the old bone which has been absorbed, so that exostoses occur.

It is important to observe that no sign of inflammatory action is present throughout the whole process. In the majority of cases the middle ear shows no indication of disease, past or present, but sometimes there is evidence of pre-existing disease either in the form of suppuration or of cellular exudation in the muco-periosteum.

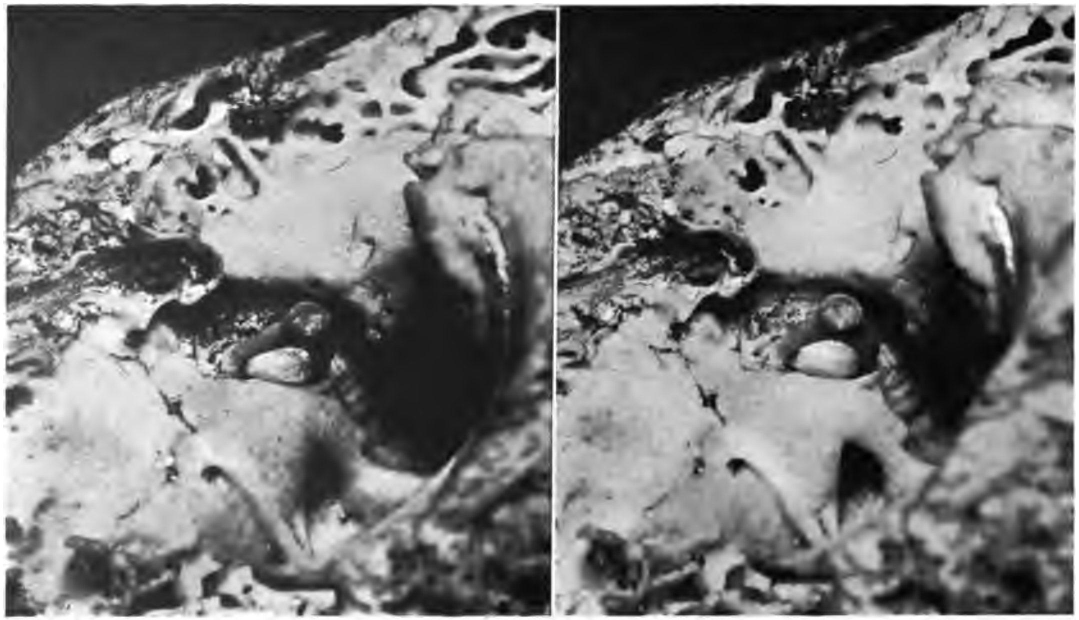
When we leave the region of anatomical investigation and begin to consider the pathogenesis of the disease, we enter upon a portion of the subject in which speculation predominates. This fact must be borne in mind by the reader, and it is possible that in none of the following hypotheses will the true explanation of the anatomical changes be ultimately found.

Habermann[1] and Katz[2] maintain that the changes in the

[1] Habermann, *Arch. f. Ohrenh.*, Bd. lx., S. 37.
[2] Katz, *Arch. f. Ohrenh.*, Bd. liii., S. 68.

FIG. 111.—THE INNER WALL OF THE TYMPANUM, SHOWING BONY ANKYLOSIS OF THE STAPES IN A CASE OF OTOSCLEROSIS. $\times 6\frac{1}{2}$. (Prepared and photographed by the Author.)

The soft parts have been removed by maceration, and the stapes is held in its place by new-formed bone, which bridges over the space between the foot-plate and the wall of the fenestra ovalis. A spur-shaped exostosis is seen below the posterior crus of the stapes.



[*To face p.* 316.

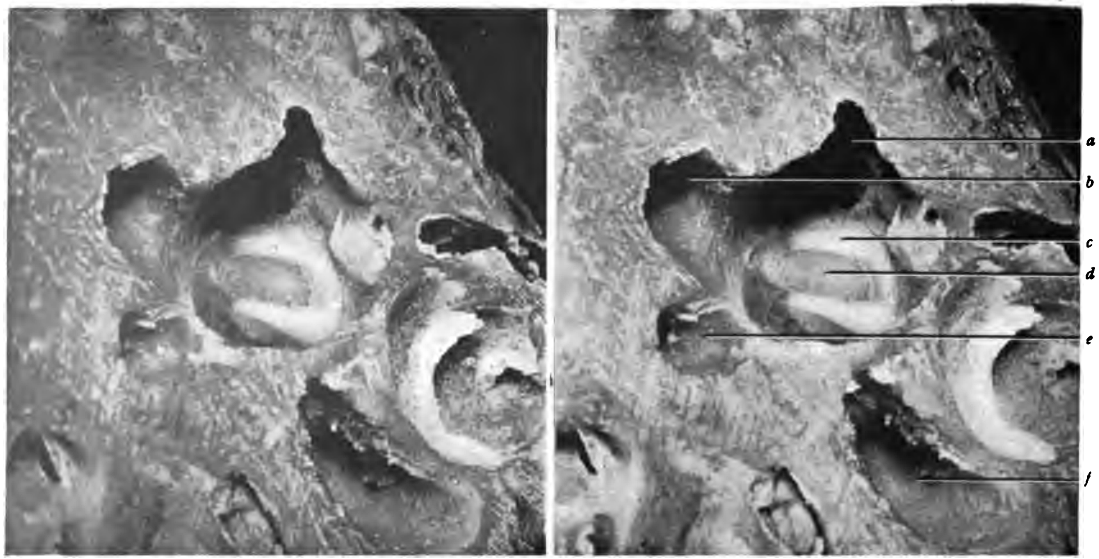


FIG. 112.—THE OUTER PORTION OF THE VESTIBULE FROM THE SAME CASE AS SHOWN IN FIG. 111: VIEWED FROM THE INNER ASPECT AND BEHIND. ×5.

(Prepared and photographed by the Author.)

The soft parts have been removed by maceration.

a, ampulla of superior canal.
b, opening of common crus of superior and posterior canals.
c, new-formed bone in the region of, and in large part encircling, the fenestra ovalis.
d, footplate of the stapes united to the walls of the fenestra ovalis by trabeculæ of new-formed bone.
e, ampulla of posterior canal.
f, lowest whorl of the cochlea.

[*To face p.* 317.

labyrinthine capsule are the result of inflammatory action in the tympanum, and Scheibe[1] is also of opinion that some cases may be explained in this way. In support of this view, Habermann points out that the foci of the disease in the bone tend to group themselves round the bloodvessels which pass inwards from the periosteum of the tympanum. Katz also draws attention to the fact that this would account for the occasional occurrence of the disease in other parts of the temporal bone, such as the malleus and incus. The chief argument against this hypothesis is the fact that otosclerosis is most commonly found without any evidence of inflammatory action, present or past, in the tympanum. Further, foci of disease in the capsule of the labyrinth are frequently found at points remote from the tympanic cavity, and not in communication with it.

Siebenmann[2] has come to the conclusion that the anatomical changes are due to a process of ossification occurring in the layer of cartilage cells which normally lies between the bony capsule of the labyrinth and the surrounding bone. This layer of cartilage cells does not under ordinary circumstances undergo ossification during life at all, and, according to Siebenmann, otosclerosis occurs when ossification does take place there. This view has one distinctive point to recommend it : it accounts for the fact that there is, throughout the course of otosclerosis, no sign, clinical or pathological, of inflammatory action in the bone. It does not, however, explain one very important feature of otosclerosis—that is, the striking tendency of the disease to affect the cartilage of the stapedio-vestibular articulation. Neither does it account for the fact that foci of the disease are sometimes to be found in the malleus and incus and other parts, far removed from the layer of cartilage cells mentioned above.

Politzer[3] has expressed the opinion that the affection is to be looked upon as a disease of the bone itself—that is to say, a form of osteitis—and that it is independent of disease in the tympanum or in any other part of the temporal bone. The obvious objection to this, as to several of the other views put forward, is that throughout the whole course of the

[1] Scheibe, Verhandl. d. Deutsch. Otolog. Gesellsch., 1901.

[2] Siebenmann, *Zeitschr. f. Ohrenh.*, Bd. xxxiv., S. 291, 356.

[3] Politzer, *Zeitschr. f. Ohrenh.*, Bd. xxv., S. 309.

disease there is no evidence of inflammatory action either clinically or pathologically.

The subject may be considered in the form of a problem put before a pathologist in the following way—What would he suspect when he found in any tissue a combination of the following features: a sharp line of demarcation, absorption of the tissue within that line of demarcation, and the subsequent laying down of tissue to replace that which had been absorbed? The answer which I venture to think most pathologists would probably give is, that death had occurred among the cells within the line of demarcation, and that the dead tissue was in process of absorption, infection not having occurred. This, accordingly, is the hypothesis suggested by the author.[1] It accounts for the sharp line of demarcation, for the absence of inflammatory activity, for the deposition of bone in place of cartilage, because, when the latter dies, it is, as is well known to pathologists, not replaced by cartilage, but by bone. It further accounts for the fact that foci of the disease are sometimes found in other places than in the capsule of the labyrinth. Necrosis of small areas in the bone might well take place under various circumstances, such as syphilis, where the walls of the arteries were liable to disease, with consequent malnutrition of the tissues supplied, in chlorosis with enfeebled circulation, in the puerperium and other exhausting conditions.

Limits of space forbid further discussion of this interesting matter, but the reader who wishes for more detailed consideration of the subject will find it in the references mentioned above, and in the monographs by Panse[2] and Denker.[3]

Some remarks may be made concerning the constitutional conditions which have been supposed to be related to the incidence of otosclerosis. Syphilis has been looked upon by some as a cause, as also have rheumatism, gout and tuberculosis. As regards the last-mentioned, the author has never been able to find any connection between it and the local disease in the ear. With respect to syphilis and rheumatism also, he cannot say that he has been able to trace any very direct evidence of relationship; and, so far as syphilis is

[1] Gray, Trans. Otolog. Soc., vol. vii., p. 71, 1906.
[2] Panse, 'Die Starrheit. d. Paukenfenster,' 1897.
[3] Denker, 'Die Otosclerose.'

concerned, it is significant that this is less common in women than in men, the reverse being the case in regard to otosclerosis. Nevertheless, there may be indirectly some relationship of cause and effect, owing to the tendency of the smaller bloodvessels to become affected in these constitutional states, so that the nourishment of the bone may be affected in the way suggested by the author.

Dundas Grant[1] and the author have found that otosclerosis shows a certain tendency to appear in young women suffering from anæmia, and this may be explained in the way described above—viz., that small areas of necrosis occur in the temporal bone or elsewhere because of malnutrition. When it is remembered that fatty degeneration in the muscles is a well-known condition in anæmia, it would not be surprising if the bone suffered as a result of the general condition. The same explanation may account for the occurrence of otosclerosis during pregnancy and the puerperium. This relationship between anæmia and otosclerosis may account for the fact that the latter is decidedly more common in women than in men.

Another factor which has been suggested as bearing a relationship to otosclerosis is exposure to intense cold. Such an association, however, must be so very rare as to be almost negligible.

It must be admitted that otosclerosis cannot be attributed to any single known constitutional condition, and we are almost driven to the conclusion that any factor which lowers the general nutrition may be the exciting cause in those who are disposed to the disease. Further, there remains a considerable proportion of cases in which otosclerosis develops even when, in every other respect, the individual is in apparently perfectly good health.

In addition to the anatomical changes mentioned, which may be described as the essential characteristics of the disease, it remains to mention other changes which are frequently but not always present, and may be considered to be, sometimes at least, a secondary result of the fixation of the stapes and other changes in the bone.

The most important of these is degeneration of the fibres

[1] Dundas Grant, Transactions of the Otological Society of the United Kingdom, vol. vii., 1906.

of the auditory nerve. It is quite impossible to give any satisfactory figures showing the frequency with which this condition is present in otosclerosis, because the number of cases examined post mortem is too small. The writer has found it twice, and it is a noteworthy fact that in both cases the deafness was so extreme that the patients had to communicate with their friends by signs or by writing. It is also important to observe that in both only the cochlear division of the auditory nerve was affected. No clinical history of either was obtained, as information concerning the deafness was only received after the death of the patient.

It is not possible at present to give a really satisfactory explanation of the degeneration of the cochlear nerve which not infrequently occurs in otosclerosis. It does not depend on the severity of the lesion in the bone, for, as will be seen in Fig. 112, the bony change is comparatively slight. And it is just as difficult to explain why the cochlear branch should suffer while the vestibular and ampullary nerves should escape. It is probable that in some cases the pressure of new-formed bone in the modiolus or spiral lamina may cause destruction of the nerve fibres.

Another condition which is probably secondary to the bony changes is the deposition of calcareous crystals in various parts of the labyrinth. The author, in 1905, first demonstrated these deposits in the labyrinth, both in cases in which symptoms associated with disease of the organ had been present during life, and also in others where no such symptoms had existed. In only one example, however, has he found these deposits present in the cochlear portion of the labyrinth, and that was in a patient who was the subject of otosclerosis. This occurrence may have been merely a coincidence, but more probably it was one of the secondary results of otosclerosis, and at any rate, the condition is worth recording. Fig. 113 shows the labyrinth from this case, the calcareous deposit occupying a portion of the basilar membrane in the lowest whorl of the cochlea.

Symptoms and Signs.—The most obvious and usually the most distressing symptom of otosclerosis is *dulness of hearing.* The onset of this symptom is so gradual that the patient is usually very indefinite in his statements with regard to its first appearance. It is also frequently the first symptom,

FIG. 113.—RIGHT MEMBRANOUS LABYRINTH FROM A CASE OF OTOSCLEROSIS, SHOWING A DEPOSIT OF CALCAREOUS SALTS IN THE BASILAR MEMBRANE OF THE LOWEST WHORL OF THE COCHLEA. × 3½.

(Prepared and photographed by the Author.)

a, deposit of calcareous salts.

[*To face p.* 320.

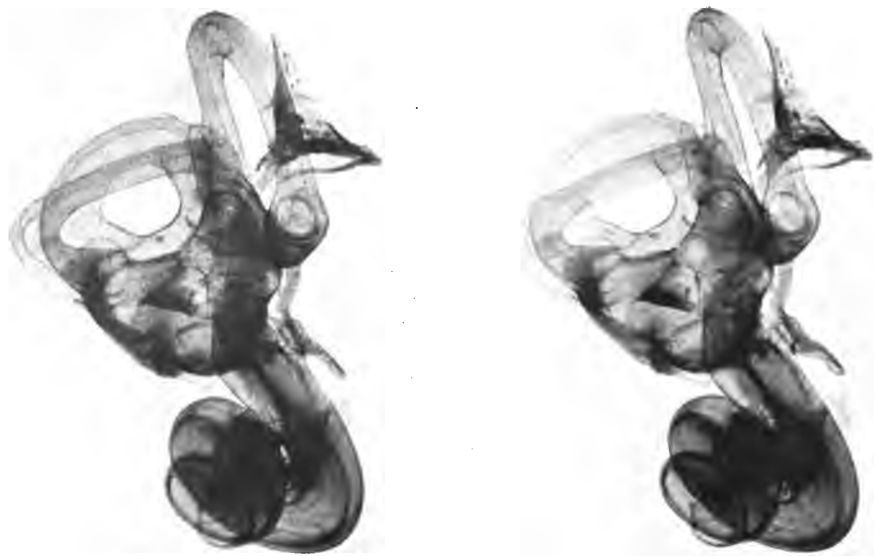


FIG. 114.—LEFT MEMBRANOUS LABYRINTH SHOWING A LARGE CALCAREOUS DEPOSIT, SHAPED LIKE AN ARROWHEAD, IN THE VESTIBULE: VIEWED FROM BELOW AND IN FRONT. ×4.

(Prepared and photographed by the Author.)

The patient suffered from giddiness, etc., during life (see text).

[To face p. 321.

though occasionally tinnitus precedes it. Often, however, when the patient complains only of tinnitus, it will be found on careful examination that there is a slight loss of hearing, of which the sufferer has not been aware. The degree of deafness varies considerably, but only rarely does it become so marked that a loud conversational voice in close proximity to the ear cannot be heard, and when this happens it may be safely assumed that the auditory nerve is affected. A sense of fulness in the ear is sometimes complained of, but pain is conspicuous by its absence.

Tinnitus is complained of in about two-thirds of the cases, but if close inquiry be made, it will be found that the proportion is somewhat higher. The attempt to classify the various kinds of subjective noises, with a view to assistance in the diagnosis, has not met with very much success, and not uncommonly the same patient will complain of two different kinds of noises occurring synchronously. The symptom is in some continuous, and in others intermittent, and in all cases it varies in intensity. One of the factors which render it worse is exhaustion, whether of the body or of the mind. Want of occupation also accentuates it, because the patient is apt to listen for it, whereas if his mind be occupied with other matters the symptom becomes less distressing. The same explanation may account for the fact that many patients only notice the subjective noises when lying in bed; the surrounding silence accentuates them. Several drugs affect these patients adversely, and the effect of salicylates and quinine is well known. Alcohol and tobacco, even in small amounts, have a pernicious effect.

Most patients, fortunately, become accustomed to the noises, but in a few this does not happen, the symptom becoming more severe as time passes, until life may become almost unendurable. So terribly may the noises affect the individual that suicide has been resorted to in order to escape the affliction. It has been suggested that insanity may result from the continuous mental irritation, and there is no doubt that, in those in whom a predisposition in this direction exists, severe tinnitus will be a potent factor in making the weakness manifest. But it is doubtful if such a result would occur where there is no predisposition, and it is noteworthy that tinnitus of the severest type may exist for many years, and wreck the patient's life in so far as doing work or enjoying existence is concerned, without actually causing insanity.

It is not possible to say why in one case of otosclerosis tinnitus should be so severe, and in another completely absent or trivial in degree. It does not appear to depend on the extent to which the nerve structures are involved, for it by no means bears a very direct relationship to the extent of the deafness. It is possible that changes of which we are ignorant occur in the various nuclei in the brain with which the auditory nerve is related, or in the cells in the cerebral cortex. But any such suggestions are speculative, and on the whole such evidence as we have would rather cast doubt upon the correctness of such hypotheses. Tumours in the floor of the fourth ventricle or in the pons which cause deafness are only occasionally associated with tinnitus, and even in these cases the symptom is usually insignificant in degree. This point must be emphasized, as it is a common but quite unjustified assumption that severe tinnitus necessarily indicates a lesion involving the nerve in some part of its course. Fixation of the stapes appears to be the condition, above all others, which is most apt to produce severe tinnitus, and it is therefore probable that the symptom occurs as the result of some physical interference with the normal pressure in the labyrinth, or in the bloodvessels within that organ. It is, of course, quite possible that other factors play a part in the production of tinnitus. For more detailed consideration of the cause of tinnitus, the reader is referred to the chapter on General Semeiology.

Paracusis Willisii is the term given to the curious faculty possessed by some deaf people of hearing better in the midst of surrounding noise. The term owes its origin to the description by Willis of a case in which a deaf wife, in order to hear her husband speak, would order a servant to beat a drum during the conversation. The symptom appears to be characteristic of fixation of the stapes, and of that condition alone. It only occurs when the deafness is bilateral, is not too slight in degree, and is yet far from being absolute. It is not confined to fixation of the stapes resulting from otosclerosis alone, but may occur in cases in which the ossicle is fixed as the result of previous suppurative changes in the middle ear. For the explanation of this curious symptom, the reader is referred to the chapter on General Semeiology.

Vertigo.—Giddiness is a rare symptom in otosclerosis, Panse having estimated that it is present in 9·5 per cent. of the cases. It may be due to implication of the cristæ acusticæ in the vestibule and ampullæ, or sometimes, perhaps, to calcareous masses in these situations. It is interesting to note that the implication of portions of the canals other than the ampullæ does not seem to cause vertigo, for, in a case of otosclerosis in which there had been no history of vertigo during life, the writer found, on examination of the ear after death, that the posterior canal was almost obliterated at two places by calcareous deposits.

Nystagmus.—Nystagmus is not a feature of otosclerosis even when the membranous labyrinth is undoubtedly affected. Indeed, it may be said that the symptoms usually associated with other affections of the labyrinth, such as vomiting and giddiness, are not present.

Course.—The course of the disease varies greatly in different cases, except in one particular, this being the peculiarity that permanent improvement never occurs spontaneously. The deafness may become extreme in the course of a few months, and, on the other hand, the patient may not be very deaf even after the disease has lasted twenty years or more. When the loss of hearing advances rapidly, the probability is that the auditory nerve or its terminations have become affected early, and it has been suggested, further, that such cases are frequently associated with syphilis, either inherited or acquired. Ill-health, the abuse of alcohol and tobacco, childbirth and exhaustion all tend to hasten the progress of the disease.

In the very great majority of patients both ears are affected, though it usually happens that one ear shows evidence of disease a considerable time before the other, the interval sometimes being of several years' duration.

Diagnosis.—The diagnosis of otosclerosis is not usually difficult in uncomplicated cases. The free passage of air up the Eustachian tube by means of the catheter, together with the absence of any improvement thereafter, excludes Eustachian catarrh or serous catarrh of the middle ear. Adhesive processes in the middle ear produce changes in the appearance and position of the membrane, whereas in otosclerosis the membrane is normal, or at most there is a faint rosy tint present.

The results of the tuning-fork tests vary according to the condition of the nerve-terminations in the labyrinth. If these are not affected, the bone-conduction is either normal or increased, so that either a negative or a diminished positive Rinne is found. But when the auditory nerve becomes involved the bone-conduction is diminished, and Rinne's test becomes valueless, so far as the diagnosis of otosclerosis is concerned. When Gellé's test is applied, it will be found, if the stapes be fixed, that there is no change in the intensity of bone-conducted sound when the air in the meatus is alternately compressed and rarefied, and this is independent of implication of the nerve. On employing Schwabach's test, it will be found that the bone-conduction is increased relatively to that of a normal hearing person, but this test, like that of Rinne, is valueless if the nerve is implicated.

On testing the hearing with different notes, it is found that there is a considerable loss for the low notes. With respect to the hearing-power for the high notes, these are heard well so long as the auditory nerve and its terminations remain intact.

Bezold has grouped together the results of the tuning-fork tests, and formulated a symptom-complex consisting of these conditions : prolonged bone-conduction, negative Rinne, and loss of hearing for the low notes. These form 'Bezold's triad of symptoms,' and the originator maintained that when all three are present fixation of the stapes may be diagnosed with certainty, provided that suppurative and catarrhal conditions in the Eustachian tube and middle ear can be excluded. There can be little doubt that Bezold has been justified in his opinion, since in every case examined, in which the diagnosis has been made on these conditions during life, fixation of the stapes has been found after death.

It is unfortunate, however, that in many cases of otosclerosis Bezold's triad is incomplete, for the obvious reason that in these the auditory nerve is implicated, and the tests therefore fail. In spite of this incompleteness, however, the diagnosis is not usually difficult. The history of the case, the occurrence of tinnitus and paracusis, and the absence of vertigo, nystagmus, vomiting, pain, etc., taken in conjunction with the normal appearance of the membrane and the absence of Eustachian or middle-ear affections, make up a clinical picture which the aurist knows only too well.

Prognosis.—The question of the prognosis is not easy to answer. It is true that in many cases the disease very often comes to a standstill while the patient has a fair degree of hearing left, but, unfortunately, it is not always possible to say beforehand which cases fall within this category. The following considerations may help the surgeon to form an opinion. The more rapid the progress of the disease, the more severe will the ultimate loss of hearing be. Cases in which there is a distinct hereditary tendency towards the disease are said to reach, on the whole, a greater degree of deafness than those in which there is no such tendency. There are, however, a considerable number of exceptions to this rule. Otosclerosis occurring in patients in whom there is a history of syphilis causes severe deafness, and the exceptions to this rule are few. This pronounced deafness is probably owing to the fact that the auditory nerve and its terminations are very apt to become involved. Cases in which the tinnitus is very severe usually become more deaf than those in which this symptom is insignificant in degree. On the other hand, the form of otosclerosis associated with anæmia in women is not quite so unfavourable, provided the anæmia is treated without delay. It need hardly be said that exhausting occupations, and the use of alcohol and tobacco in excess, or even in moderation, will affect the prognosis unfavourably.

In all cases of otosclerosis senile deafness tends to make its appearance earlier than in those who are not affected by the disease. In this way an individual who is the victim of otosclerosis, but in whom perhaps the deafness has not become worse for the previous ten, fifteen or twenty years, finds that about the age of sixty or sixty-five his deafness is again beginning to increase. These patients, therefore, should learn to cultivate interests which are, so far as possible, independent of intercourse by means of the ear and voice.

Question of Marriage.—Associated with the question of prognosis is the question of the marriage of those who suffer from otosclerosis. The subject falls under consideration from two points of view: first, the effect upon the patient; second, the effect upon the offspring. The subject has been considered by Milligan[1] in this country, and by Körner[2] abroad.

With respect to the effect upon the patient of pregnancy and the puerperium, the question of actually advising a certain course should not rest with the aurist, properly speaking, at all. It is only his duty to inform the contracting party that the very probable effect of pregnancy will be to make the hearing somewhat worse. Those who contemplate marriage have presumably reached years of discretion, and if they are willing to take the risk of injury to the hearing which pregnancy entails, the affair is their own. Many very happy and useful lives have been lived in spite of severe deafness in husband or wife, and when it is remembered what marriage means to most women, it is a serious thing to forbid it. At the same time the woman should be told that, in justice to her future husband, he should be informed of the possible consequences of maternity.

With respect to the second point, the effect upon the children, the matter is rather different. Milligan and Körner are both in favour of giving the advice, to the victims of otosclerosis, not to have children. Milligan considers the subject rather from the point of view of the woman, which has just been discussed, while Körner views the matter rather from the hereditary tendency characteristic of the disease.

The extent to which the tendency towards otosclerosis is inherited has already been discussed and, as stated above, has probably been rather exaggerated. For that, among other reasons, there is perhaps not so much necessity for forbidding maternity as Körner suggests. Again, the disease does not appear sufficiently early in life to cause mutism, or, with the rarest exceptions, even so early as to prevent the individual from learning a trade or calling. In practically no case, therefore, does the subject of otosclerosis need to become a burden on others and, as a matter of fact, many of these patients live very useful lives. The gain to the world by the music of Beethoven, whose deafness appears to have been the result of otosclerosis, would surely more than balance the loss which it might sustain from the presence of individuals suffering from the disease.

[1] Milligan, Trans. Otolog. Soc., vol. vii., p. 110, 1906.

[2] Körner, *Archives of Otology*, vol. xxxv., p. 441.

One point which the aurist should consider, in giving advice on this subject, is the part which the hereditary element plays in the individual patient. Thus, if in any given case it could be shown that the family history is very bad in respect to otosclerosis, the warning should be the more urgent. On the other hand, where no such history can be obtained over two or more generations, then the probabilities are that the children which the patient may have will escape.

In all cases, therefore, the patient should be informed of the facts and possibilities, while the emphasis of the warning should vary according to the hereditary element in the case. And it must always be remembered that the gratification of the maternal instinct will, with many healthy-minded women, outweigh the loss which they may suffer from increased deafness.

Treatment.—While the study of otosclerosis from the point of view of pure science is one of the most interesting aspects of otology, the treatment of the condition is unsatisfactory in the extreme. There is no drug known which will dissolve bone without at the same time affecting other tissues injuriously. Thiosinamin and fibrolysin, which may possibly do some good in cases in which the ossicles are fixed by fibrous bands resulting from middle-ear affections, are quite useless when the stapes is rendered immovable by bony ankylosis. The same is true of all other drugs, including phosphorus, for which some claims were made a few years ago.

But although it is hopeless to look for any improvement in the direction of rendering the stapes movable, it is of the greatest importance to try by every means to improve the general health, and, as has been pointed out, the serious error of failing to recognize the presence of even the slightest manifestations of anæmia must be avoided. In chlorotic patients there is usually a slight improvement in the hearing when the blood is restored to its normal condition, the improvement being the result, not of any increased mobility of the stapes, but of the improved circulation in the labyrinth. And if the suggestion of the author in regard to the pathogenesis of otosclerosis be correct, the cure of the anæmia may prevent the further advance of the disease. Some slight improvement occasionally follows the administration of strychnine, either from its effect upon the nervous system or upon the circulation, or from both these causes ; but, as may readily be understood, the improvement usually passes off when the drug is discontinued.

Of drugs for the relief of tinnitus there appears a long list, which, in all branches of medical science, usually carries with it the ominous significance that none are of much value. Bromides and bromoform are perhaps the least useless of these, but they must be given in fairly large doses, and many patients prefer the tinnitus to the disagreeable effects of the drug. The administration of quinine, which has also been suggested for this distressing symptom, must be carefully watched, lest it do more harm than good. Potassium iodide, nitroglycerin and the nitrites, are occasionally of use on account of their effect upon the circulation, but it must not be forgotten that the last two are potent drugs and may cause very objectionable symptoms.

In practice the physician will find that in many cases no medicine does any good, while in the remaining ones benefit may be obtained by trying various drugs until one is found which may do good in the particular case.

Alcohol and Tobacco. — Far more important than the administration of drugs is the abstention from them. Thus, alcohol and tobacco should be indulged in very sparingly, or, better still, not at all. It is a remarkable fact that such small quantities of these articles as would have no perceptible effect whatever upon a healthy individual will make the subjective noises much worse in those who suffer from otosclerosis.

Since the course of otosclerosis is influenced very unfavourably by physical or mental exhaustion, it is of the utmost importance that the patient should protect himself in this respect. Overwork and worry should therefore be avoided so far as possible, and plenty of time should be given to sleep.

Turning to the mechanical and surgical treatment of otosclerosis, we find that the story is still gloomy. Attempts to loosen the ossicle by inflation of the middle ear, either through the catheter or by the use of the air-bag alone, are of no avail, and sometimes even harmful ; and the same may be said of the introduction of vapours and fluids of various kinds which have been injected through the catheter. A more rational method of attempting to loosen the ossicles is that of employing rapid vibrations of small amplitude to act upon the drumhead. The vibrations are produced by means of the various pneumo-massage instruments, one of which is depicted (Fig. 94). The results obtained in this way are certainly not very striking, and often no improvement is obtained at all. This method of treatment is of no value in advanced cases of otosclerosis, but in the early stage it may do good. Even where no positive improvement results, it may have the effect of staying the advance of the deafness and alleviating the tinnitus.

Operative Procedures.—Numerous operative procedures have been devised and carried out for the relief of the symptoms caused by otosclerosis. The stapes has been removed or mobilized, but without producing any permanent result. The tympanum has been 'exenterated,' by which is meant, in plain language, the removal of the contents of the cavity; but the results have been, to say the least, equivocal. Section of the auditory nerve within the cranial cavity has been performed in order to relieve the tinnitus; but the ultimate results of all these undertakings have not been satisfactory.

Ablation of the labyrinth has been performed for the relief of tinnitus and vertigo, but not successfully, so far as the author's knowledge goes, in a case of otosclerosis. The best-known case in which the operation was performed is that described by Lake, and in it the real reason for operation was, not the distressing tinnitus, but the severe and constant vertigo. In this case the operation was performed on both ears, and the ultimate result was successful, in that both the tinnitus and vertigo disappeared. Although this was not a case of otosclerosis, yet it gives a ray of hope in so far as the removal of tinnitus is concerned, but, of course, the hearing is completely lost. The cases, therefore, in which such an operation is justifiable in otosclerosis will always be very rare.

CHAPTER XV

DISEASES OF THE LABYRINTH AND AUDITORY NERVE

WHILE the study of diseases of the middle ear can be carried out with a certain degree of scientific accuracy, the same cannot, unfortunately, be said of disorders affecting the labyrinth and its associated nerve structures. This state of matters is due, for the most part, to two factors: (1) The organ cannot be examined by the eye during life; (2) the great majority of diseases of the labyrinth are not fatal in their effect, and therefore the opportunity of examining the organ in diseased conditions after death rarely arises. Thus, our knowledge of the anatomical changes upon which the nomenclature of disease, diagnosis and treatment should rest is necessarily limited. Owing, however, to the painstaking work of several observers, much has been discovered in regard to this subject within the last few years, and with improvements in methods of pathological examination, and more attention in following up their cases on the part of aurists, it is certain that a considerable increase in knowledge will ensue.

In considering diseases of the labyrinth in general, it must always be remembered that the organ subserves two totally different physiological functions. The vestibular apparatus, which includes the structures contained by the vestibule and semicircular canals, gives us information as to the movements of the head, and, to a certain extent at least, those also of the body. The cochlea alone is concerned with hearing. Both portions of the organ may be affected simultaneously, or each separately. Therefore, when the cochlea alone is diseased, deafness and tinnitus are the symptoms to be expected. When the vestibular apparatus alone is affected, the symptoms may be giddiness, staggering gait and nystagmus. But with these there is sometimes associated nausea, vomiting and vasomotor disturbances, which are due to reflex stimulation.

Symptomatology.—The *deafness* of labyrinthine disease, as also that of the nerve supplying the organ, may be very slight, or it may be absolute. In the latter respect it differs from the deafness due to middle-ear affections, in which there is always some power of hearing left.

Tinnitus is a common symptom of disease of the labyrinth, but as a rule it does not reach that extremely distressing degree which is characteristic of ankylosis of the stapes. With regard to tinnitus, it is a curious fact that disease of the nerve itself or of its projection fibres within the brain, is frequently unattended with tinnitus, and even when the symptom occurs it is usually slight, and often fleeting. This is important to remember, for, as stated previously, it is a common mistake to assume that lesions of these nerve tracts are usually associated with marked tinnitus. Hallucinations in respect to voices and musical tunes are very rarely met with except in the insane or in those of unstable mental equilibrium.

Giddiness is a common symptom of disease of the labyrinth. It may take the form either of a general sense of giddiness or of the illusion that surrounding objects appear to be rotating in a particular plane. The giddiness is the cause of the staggering gait which is so characteristic of many cases of disease of this organ. It must always be remembered that the degree of giddiness bears little or no relationship to the extent of the disease in the ear. Indeed, when the organ is completely destroyed the symptom disappears.

Nystagmus due to disease of the inner ear and its nerves has a special character by which it is distinguished from that due to diseases of the eye or brain (see p. 92).

Nausea and Vomiting are not uncommon symptoms of disease of the labyrinth. Indeed, as will be pointed out later, there is little doubt that seasickness is due to excessive stimulation of this organ.

Disease of the inner ear sometimes causes ordinary sounds to become distressing, and even painful, to the patient. This condition of *hyperæsthesia* is usually associated with deafness.

In certain rare circumstances a musical note is heard incorrectly. That is to say, the patient hears it as if it were a note of a different pitch from that which it really is. This phenomenon is known as *paracusis*, and must be distinguished from paracusis Willisii. A still rarer condition is that known as *diplacusis*. Diplacusis binauricularis dysharmonica is the form in which a tone is heard simultaneously in both ears, but in the one ear it gives the sensation of a pitch different from that which it gives in the other ear. The second form of diplacusis is known as diplacusis echotica. In this condition the sound, whether it be a note, a noise or a word, is heard with the same pitch and quality by both ears, but it is not heard simultaneously in each. A very rare form has been recorded by Gradenigo, in which one ear hears a single pure tone as though it were two tones of different pitch. This is known as diplacusis monauralis.

Colour-Hearing.—In some rare cases tones of a certain pitch produce subjective sensations of colour. This is known as colour-hearing, and is not usually associated with any other defect of hearing, but is found most frequently in neurotic subjects.

Menière's Symptom-Complex.—Before leaving the symptomatology of diseases of the labyrinth, it is desirable to make the reader's mind clear concerning a term frequently used by aurists and medical men in a somewhat vague way. The term referred to is 'Menière's disease.' The origin of this expression is to be traced to the common mistake of assuming the existence of a pathological and clinical entity from a paucity of observed facts. In the year 1861 Menière examined carefully the case of a young woman who suddenly became affected by deafness, vomiting and violent giddiness. The attack was apparently due to exposure to cold during a menstrual period. The patient died on the fifth day, and at the autopsy it was found that the labyrinth was filled with a plastic hæmorrhagic exudate. *No cause for the death of the patient could be found.* This fact alone should have prevented physicians or aurists from giving a special name to a group of symptoms resulting from anatomical changes in the inner ear which there is no reason to doubt was brought about by some other more serious malady. Further, it was unjustifiable to assume that the symptoms were necessarily due to hæmorrhage into the labyrinth. The truth is that any condition which suddenly interferes with the various functions of the labyrinth may produce the symptoms described, whether hæmorrhage occurs or not.

It is desirable, therefore, to abolish the term 'Menière's disease' altogether, and to speak of 'Menière's symptom-complex,' a phrase which is understood to embrace the symptoms of deafness and giddiness of instantaneous origin, and often associated with nausea and vomiting. This phrase very properly proclaims our ignorance generally of the pathogenesis of the condition, and at the same time indicates a clinical picture by the conventional use of the name of an individual who has a right to be remembered in the history of medicine. In special circumstances, when the cause of the symptoms can be stated with a reasonable degree of probability, the phrase may be qualified by a statement indicating this.

General Diagnosis of Diseases of the Labyrinth.—Before passing on to consider affections of the labyrinth in detail, it is necessary to make some remarks upon the differential diagnosis between these and diseases of the middle ear.

Hearing-Power.—It may safely be said that no disease of the outer or middle ear alone causes complete deafness. Further, in any disease of these two portions alone, a loud conversation voice in close proximity to the ear can always be distinguished.

Very marked deafness of instantaneous onset is almost always significant of labyrinthine disease, and if the symptom be accompanied by giddiness and other characteristics of Menière's symptom-complex, the diagnosis of internal ear disease is certainly correct.

Bone-Conduction.—In diseases of the inner ear the bone-conduction is diminished; hence Rinné's test will give a shortened positive result. To this rule there may be exceptions, but they are rare. So also with Schwabach's test it will be found that the bone-conduction is shortened in comparison with that of a normal ear; and with Weber's test the sound of the fork will be heard best in the healthy ear.

Test with High and Low Notes.—The high notes are not well heard in diseases of the inner ear, whereas the low notes are comparatively less affected. In diseases of the nerve tracts the hearing-power is usually diminished to an approximately equal extent for all notes.

Inflation of Air.—If the labyrinth alone is affected, inflation of air into the middle ear by means of the catheter either produces no effect at all upon the hearing, or a deleterious one.

Inspection.—In diseases limited to the labyrinth or auditory nerve, the tympanic membrane presents a normal appearance.

In the diagnosis of disease of the ear, the nystagmus tests described in the chapter on Methods of Examination are frequently of value.

Before leaving the subject of diagnosis, it must be pointed out that such symptoms as giddiness, nystagmus, staggering gait and vomiting, even when they are clearly of labyrinthine origin, do not always indicate that the labyrinth is actually diseased, but only that it is being subjected to abnormal stimulation of some kind. Thus, suppurative disease of the middle ear, or even a plug of wax in the meatus, may produce the symptoms by their mechanical effect upon the labyrinth through the chain of ossicles.

The auditory nerve and its terminal organ, the labyrinth, seem peculiarly susceptible to noxious elements present in the blood. Indeed, what may for practical purposes be termed 'local diseases' are relatively uncommon, and their pathology but little known. It must be understood, moreover, that the term 'local diseases' is used for purely practical purposes, to indicate those pathological and clinical conditions, referable to the labyrinth, which cannot be definitely associated with a known constitutional disturbance. The local affections will be described first.

LOCAL AFFECTIONS.

Congenital Defects.—Various congenital defects have been found in the labyrinth by many observers. These are sometimes associated with corresponding defects of the outer or middle ear, but frequently these parts are quite normal.

Complete absence of the labyrinth has been described by Schwartze and Michel, while a considerable number of examples of defect, either in number or development, of the semcircular canals have been recorded. The author has found a supernumerary ampulla at the posterior end of the horizontal canal to be comparatively common, but in no case has a nerve been found supplying this ampulla. This abnormality has an interesting phylogenetic significance, but space does not permit of its discussion here.

Absence of the vestibule and cochlea has been recorded, but perhaps more interesting than any of these is absence of one of the whorls of the cochlea, as described by Hyrtl. Defective development of the organ of Corti and of the corresponding nerves has been recorded. These conditions, with the exception of the supernumerary ampulla, are usually associated with complete deafness. When the defects are bilateral and associated with almost complete deafness, the patient becomes a deaf-mute.

Senile Deafness.—Probably in all old people there is a characteristic form of deafness for the higher notes of Galton's whistle, even when for conversation and all the practical affairs of life there is no evident defect. This condition is probably due to changes in the ligamentum spirale, as was suggested by the author after the examination of several labyrinths of subjects who had died at late periods of life. In these labyrinths it was found that the ligamentum spirale showed signs of atrophy, and as that structure plays its more important rôle in the lower whorl of the cochlea, the basilar membrane in this region would tend to become less tense than under normal conditions, and hence the high notes would not be heard so well.

The condition just described cannot properly be spoken of as senile deafness, for these individuals are for all practical purposes not deaf at all. There is, however, a form of real deafness which, along with other troubles incidental to old age, is so beautifully referred to by the writer of Ecclesiastes. In this condition there is progressive deafness for notes of all pitch, and the auditory nerve undergoes atrophy. In senile deafness the sufferers are usually, if not always, spared the presence of really distressing tinnitus. Indeed, if this symptom be complained of to any marked extent, it may reasonably be assumed that something more than senile deafness is present. In particular, arterio-sclerosis or valvular heart trouble should be suspected.

In connection with the subject of senile deafness, a condition described by Manasse[1] as 'chronic progressive labyrinthine deafness' may be mentioned. Manasse examined thirty-one temporal bones of individuals who had suffered from chronic progressive deafness of typical labyrinthine type, without any affection of the sense of rotation or equilibration. In these he found fairly constant anatomical changes, such as atrophy of the organ of Corti and of the tectorial membrane, collapse of the membrane of Reissner, and degeneration of the ligamentum spirale. Other changes, such as atrophy of the ganglion spirale, the presence of pigment cells in the modiolus, and degeneration of the fibres of the cochlear branch of the auditory nerve were sometimes present.

Manasse claims that this is a very common form of deafness, but he probably over-estimates its frequency when he suggests that it is perhaps the most common type of progressive deafness.

There is little doubt, however, that he has described a group of cases which presents clinically a fairly definite picture of a slowly progressing labryinthine deafness. Brühl[2] and Alexander[3] have described similar types.

The affection is most incident in the later registers of life. It is bilateral, and is more common in men than in women. It differs to this extent from senile deafness, that it can frequently be traced to a definite constitutional condition, such as syphilis, nephritis, tuberculosis and, above all, arterio-sclerosis.

In Alexander's case the arteries of the cochlea were found to be the seat of arterio-sclerosis. The ligamentum spirale was atrophied, as were also the stria vascularis and the cells of the ganglion spirale. In at least one of Brühl's cases, and probably in some others, arterio-sclerosis was present, and in some marasmus was the associated constitutional defect. From the relative frequency with which arterio-sclerosis is present, some writers have referred to the condition under the name of 'arterio-sclerosis of the labyrinth'—a rather unfortunate example of the application to an organ of a term which can only apply to an artery.

The disease, as stated above, is characterized by its slow

[1] Manasse, Verhandl. d. Deutsch. Otolog. Gesellsch. S. 121, 1905.

[2] Brühl, *Zeitsch. f. Ohrenh.*, Bd. l., 1, S. 5, 1905.

[3] Alexander, *Zeitsch. f. Ohrenh.*, Bd. lii., 3, S. 239, etc., 1906.

progress, the loss of hearing for the high notes of the scale, diminished bone-conduction and a normal appearance of the drumhead. As is common in chronic labyrinthine disease, tinnitus is not a marked feature. There are no disturbances of equilibrium.

Treatment.—Neither local nor constitutional measures can bring about any improvement in the hearing. In spite of treatment, the disease usually progresses; but everything should be done to improve the general health and avoid local irritation, in order to render its progress as slow as possible. If arterio-sclerosis be present it must be treated on general grounds, and the same may be said of syphilis and other conditions. The ear should be protected from loud noises by the wearing of cotton-wool in the meatus, this being one of the very few affections of the ear in which that popular method of treating all ear diseases is permissible. For the same reason, the use of ear-trumpets is not desirable, owing to the vibrations which they produce. The use of the air-douche, the catheter and pneumo-massage must be avoided.

Calcareous Crystals in the Labyrinth.—At a meeting of the British Medical Association at Oxford, July, 1904, the author demonstrated a condition not previously recognized. This was the existence of calcareous crystals of a pathological nature in the labyrinth. They were discovered by chance in the organ of an individual who had suffered in no way from symptoms referable either to the sense of hearing or to that of equilibration; but, as was pointed out, the deposit was in the semicircular canals at a point where there is no nerve-supply. The possibility was suggested of such a crystal producing symptoms if it were situated over any of the cristæ acusticæ, and were movable. Since that date further examinations have been made, and among these a case was found which appears to bear out the correctness of the author's suggestion.

A. B., a woman of the age of eighty-three, had suffered from gradually increasing loss of hearing during the last ten years. In the early stages of the affection she had suffered from a slight degree of tinnitus, but this had slowly disappeared. She also suffered from attacks of giddiness at that time, and these were associated with the tinnitus, and disappeared with the latter symptom some years previous to examination. So far as she could remember, there was no sensation of rotation in any particular plane during the attacks of giddiness. Paracusis Willisii had never been present.

On examination of the drumheads, both were found to be normal.

In the *left* ear the watch was not heard at all, even on contact. Rinne's test was + 12 with a fork which in a normal ear is + 8. Gellé's test showed that bone-conduction was diminished when the membrane was driven in by means of Siegle's speculum. The low notes were heard as low as si_1. The high notes were lost to a great extent, the patient not being able to hear tones of above 8,000 vibrations per second. The whisper was heard at 60 centimetres' distance.

In th *right* ear the watch was not heard either by air or bone conduction. Rinne's test gave a result of + 15, and on applying Gellé's test it was found that bone-conduction was diminished on driving in the membrane. The high notes were lost above 10,000 vibrations per second, and the low notes below ut_1. The whisper was heard at a distance of 45 centimetres.

Air entered the middle ear of each side freely on inflation, but there was no improvement thereafter. There was no family history of deafness.

The patient died a few months after the examination just described, from cancer of the uterus. At the post-mortem examination both temporal bones were removed. The middle ear on each side was found to be healthy in every respect, the Eustachian tubes patent and the stapes movable.

Both labyrinths were prepared by the author's method and revealed the following conditions. The *right* labyrinth showed an outline normal in every respect. The ligamentum spirale was to a certain extent atrophied. A few minute calcareous crystals were found in the vestibule. The auditory nerve was examined by means of the microscope, but it was not noticeably affected. In the *left* labyrinth the conditions were similar to those in the right, with one marked difference. In the middle of the vestibule there was a large calcareous, crystalline deposit, in shape like an arrow-head, with the point directed forwards towards the ampullæ of the superior and horizontal canals (Fig. 114). The ligamentum spirale was atrophied, but no recognizable pathological change was found in the auditory nerve.

FIG. 115.—MEMBRANOUS LABYRINTH SHOWING FEATHER-LIKE CALCAREOUS DEPOSITS IN THE AMPULLÆ OF THE SUPERIOR AND HORIZONTAL CANALS. $\times 2\frac{3}{4}$.

(Prepared and photographed by the Author.)

The patient did not suffer from any labyrinthine symptoms at all.

a, calcareous deposits. *b*, saccus endolymphaticus.

[*To face p.* 338.

FIG. 116.—TRANSVERSE SECTION THROUGH THE PONS, SHOWING THE PRESENCE OF A GLIOSARCOMA LIMITED TO THE LEFT SIDE. $\times 3\frac{1}{2}$.

(Prepared by Dr. J. McKenzie Anderson. Photographed by the Author.)

a, semitransparent portion of the tumour, in which there are no hæmorrhages.
b, portion of the tumour in which minute hæmorrhages have occurred.

[*To face p.* 339.

In this case it is clear that the giddiness was due to irritation of the cristæ acusticæ in the vestibule. Probably this irritation was due to the crystalline deposit described above. But such a conclusion is not definitely proven, since it might be said that the calcareous deposit is only the final result of a previous pathological change in the vestibule. Although, therefore, the case indicates the probability of these crystals being occasionally the cause of giddiness and other phenomena included in the term 'Menière's symptom-complex,' it will be necessary to find other similar cases before accepting them as definitely proven causes of these symptoms. Furthermore, it is important to observe that the presence of these deposits, even in the region of the cristæ acusticæ, is not in itself sufficient to cause symptoms. In the case, for example, from which the labyrinth illustrated in Fig. 115 was taken, there were no symptoms of disease of the ear at all, in spite of the fact that there were calcareous deposits in the ampullæ of the superior and horizontal canals. It is probable therefore that, in order to produce symptoms, the crystal must be moveable.

Seasickness, etc.

There can be little doubt that the cause of seasickness is to be found in the excessive stimulation of the nerve-terminations in the cristæ acusticæ of the semicircular canals and vestibule. At first sight it might be supposed that, if this suggestion were correct, giddiness should be a pronounced symptom ; but a moment's consideration will show that the absence of severe giddiness in no way invalidates the explanation of seasickness just given. Vestibular giddiness is produced by excessive stimulation of the nerve-terminations in the labyrinth, but such stimulation must be kept up in one direction for a certain time before the symptom appears. Thus, in revolving round a pole, the revolutions must be sufficiently numerous and rapid before giddiness is produced. Furthermore, if the revolutions be continued for a little longer, vomiting occurs. It is this symptom which sometimes puts a period to the amusement which young children get from spinning round and becoming giddy. In this case there is excessive stimulation of the nerves of the labyrinth, and it is constantly carried out in one direction. But in the case of swinging on a swing or being on a ship which is rolling at sea, there is excessive stimulation of the nerves, but it is constantly being changed in direction; hence, nausea and vomiting occur, because the stimulus is excessive in degree, whereas giddiness, though present, is usually slight, because the direction of the forces acting on the nerve-terminations is never continued sufficiently long in one direction. In the same way train-sickness is produced, owing to the rocking movements of the train.

Treatment.—In view of these facts, and also from actual experience, it is advisable in treating seasickness to direct attention to the cause. Of course, no drug can completely abolish the sensitiveness of the cristæ acusticæ without producing effects as undesirable as the seasickness itself. At the same time, such nerve sedatives as bromoform or the bromide of sodium or potassium in fairly large doses will sometimes prevent the occurrence of seasickness, and in other cases will mitigate the symptoms. It is desirable, however, to take the drug an hour or two before the traveller goes on board, and in this, as in all other similar conditions, fresh air is an advantage, probably on account of its tonic effect upon the central nervous or vasomotor systems.

Diseases of the Inner Ear associated with Conditions affecting the Body generally.

The auditory nerve and labyrinth appear to be peculiarly susceptible to noxious elements in the blood. Hence it is found that the majority of disordered conditions of the organ are usually associated with either a past or present affection of the body as a whole.

Fevers.—Any of the *acute specific fevers* may cause disease of the labyrinth. Some, however, are particularly noticeable in this respect, and among these may be mentioned epidemic cerebrospinal meningitis, acute rheumatism, mumps, typhoid fever, scarlet fever, influenza, diphtheria and pneumonia.

In proportion to the numbers affected, *cerebrospinal meningitis* is by far the most frequent of the specific fevers in producing deafness. It is a curious fact that the frequency with which the labyrinth is affected by the disease appears to depend upon the character of the epidemic, and not upon the severity of the fever in the individual case. In the visitation which affected this country two or three years ago, about 10 to 16 per cent. of those suffering became deaf. In previous epidemics in other countries the percentage appears to have been much higher.

The deafness resulting from the disease is almost always of the highest degree, and as frequently bilateral. Hence, when it occurs in children under five they become deaf-mutes. The symptom manifests itself within the first two weeks of the disease, and rarely later. Disturbances of equilibration occur in more than half the cases, but this symptom passes off in the course of a few weeks or months, or it may be in a year.

Tinnitus is not unfrequently complained of in adults and, according to Moos, is relatively not an unfavourable symptom. In a few rare cases the hearing-power for speech returns to a limited extent and is then again lost.

Prognosis.—The prognosis is highly unfavourable, and restoration of useful hearing rarely occurs.

Pathology.—The anatomical changes which are found in the labyrinth naturally depend upon the period of time which has elapsed since the organ was first affected. In those patients who die in the course of the fever, pus is found in the labyrinth in varying quantities, and petechiæ are not unfrequently present in the membranous structures. The auditory nerve itself is infiltrated with pus, and frequently the whole of the soft structures of the labyrinth are destroyed and replaced by granulation tissue. The *Diplococcus meningitidis cerebro-spinalis* is found in the labyrinth, and it gains entrance thereto usually by way of the aqueduct of the cochlea, but sometimes along the channels which accommodate the branches of the auditory nerve, or by the aqueduct of the vestibule. Occasionally the middle ear is affected as well as the labyrinth.

When the patient recovers from the fever, the inflammatory products in the labyrinth become transformed into connective tissue, and the auditory nerve may undergo degenerative changes.

Treatment.—Treatment is of but little avail. Nevertheless it is desirable, when deafness occurs during the acute stage of the disease, to make cold applications to the ear by means of Leiter's coil, and the head should be steadied between sand-pillows. After the fever has passed, potassium iodide may be ordered in fairly large doses. Hypodermic injections of pilocarpine, in doses of $\frac{1}{12}$ grain, may be given daily or every second day for a week or two. This treatment, however, is of the nature of a forlorn hope, and before beginning it the patient's friends should be informed of the fact.

In recent times an attempt has been made to treat cerebrospinal meningitis by means of a specially-prepared serum, but whether this method will be successful or not remains to be seen. In any case it is difficult to see how such a serum could have a beneficial effect upon the deafness when it is already established. It requires a superabundance of faith to believe that any substance will restore a dead ganglion cell or create a new organ of Corti.

The hearing is occasionally affected in *typhoid fever* owing to disease of the labyrinth or auditory nerve, as well as to suppurative disease of the middle ear. According to Wittmaack, when the deafness is not due to middle-ear disease it is caused by degenerative changes in the auditory nerve. This form of deafness in typhoid fever usually appears in the third or fourth week of the disease. Fortunately, it is by no means always severe in degree, and the patient can usually hear the spoken voice without very much difficulty. The deafness usually disappears completely.

Besides its disastrous effects upon the middle ear, *influenza* not uncommonly disturbs the functions of the sound-perceiving apparatus. In this respect the auditory nerve shows the same vulnerability to the poison as do other nerves, and consequently the deafness may be associated with facial, oculomotor, or hypoglossal paralysis, and sometimes with sensory paralyses due to the effect of the poison upon the trigeminal and the glosso-pharyngeal nerves. Giddiness is not common, and when present is usually slight. Tinnitus, however, is frequently a distressing symptom. In the opinion of Haug, the nerve deafness of influenza is due to a localized meningitis.

In *acute rheumatism* the hearing is sometimes affected and, more rarely, the sense of equilibration is disturbed owing to neuritis of the cochlear portion or of the whole of the auditory nerve respectively. Sometimes other nerves, such as the facial and trigeminal, are coincidently affected.

The diagnosis is arrived at by the consideration of the general symptoms, associated with the absence of middle-ear disease and the presence of symptoms pointing to involvement of the auditory nerve such as deafness, tinnitus and giddiness.

Prognosis.—The prognosis is much better than in most forms of disease of the inner ear and its associated nerves. The giddiness disappears within a comparatively short period, and somewhat later the hearing begins to improve and ultimately returns to the normal. In some cases a slight defect of hearing remains.

Treatment.—The treatment is for the most part that of the general infection. Blisters applied over the mastoid process appear to hasten the recovery, and it is possible that the application of the galvanic current may help.

Mumps.—A very serious form of deafness occasionally results from mumps. The affection is bilateral in about 50 per cent. of the cases, and the deafness is very marked and sometimes absolute. It is not usually accompanied by giddiness or other symptoms of vestibular disease. The deafness comes on suddenly between the third and fifteenth days, and recovery is very rare. Alt[1] and Barnick,[2] however, have recorded cases in which there was more or less complete restoration of hearing—one in which the recovery took place without any treatment directed to the auditory affection, and another in which iodide of sodium was administered.

The pathology of the affection has not yet been elucidated. A suggestion has been made that it is of the nature of a metastasis, with exudation into the labyrinth, and another hypothesis is that the auditory centres in the brain are affected.

Diphtheria.—Apart from the serious middle-ear complications of diphtheria, the disease occasionally affects the inner ear. The anatomical changes which occur are hæmorrhages into the labyrinth and auditory nerve, and degeneration of this nerve and of the cells of the ganglion spirale. Clinically the affection of the auditory nerve is usually associated with paralyses of other cranial nerves, such as the facial, the oculomotor, etc. The vestibular functions are usually affected to

[1] Alt., *Monatschr. f. Ohrenh.*, xxxi., S. 372, 1897.
[2] Barnick, *Arch. f. Ohrenh.*, xlv., 1, 2, S. 81, 1898.

a greater or less extent. On the whole, however, it must be admitted that, considering its peculiar specific action upon the nervous system, diphtheria does not affect the auditory nerve so often as might be expected.

The prognosis is uncertain. Cases certainly sometimes recover, but many do not, and there is no sign at present known which will afford any clue as to the future. The symptom is late in making its appearance.

It is open to question whether treatment has any effect. Ecman[1] employed pilocarpine hypodermically, and in his case one ear recovered the hearing-power, but the other did not. In view of the tendency to syncope which is present in patients who have recently recovered from diphtheria, it is very doubtful if the use of pilocarpine is justifiable.

Acute Osteomyelitis. — Siebenmann[2] has described a rare form of labyrinthine deafness which may result from acute osteomyelitis. The deafness usually arises late in the disease, and may occur during convalescence. It is most commonly bilateral. The deafness is very marked, and is sometimes accompanied by tinnitus, and by giddiness, vomiting and other symptoms referable to disease of the vestibule and semicircular canals. The middle ear is usually unaffected. The symptoms are due, in Siebenmann's opinion, to a destructive process in the labyrinth owing to the influence of the toxins absorbed from the original focus, and not to bacterial infection of the labyrinth.

Other Acute Infectious Diseases.—Pneumonia, scarlet fever, measles, whooping-cough and smallpox may all act as causative factors in the production of diseased conditions of the sound-perceiving apparatus, irrespective of their tendency to excite suppurative disease of the middle ear.

Treatment of Labyrinthine Complications of the Acute Fevers.—The treatment of the conditions just described is unsatisfactory in almost every respect. It must always be remembered that during and for some period after recovery from these fevers, the heart is in a weak condition, and it is therefore necessary to draw attention to the risks incurred in the administration of pilocarpine. The value of this drug in the treatment of labyrinthine affections has been perhaps over-

[1] Ecman, *Presse Otolaryngol.*, Belgium, January, 1908.

[2] Siebenmann, *Zeitschr. f. Ohrenh.*, Bd. liv., 1, S. 1, 1907.

rated, and to give it as a forlorn hope to a patient recently convalescent from diphtheria, typhoid fever or pneumonia, is to run into a grave danger. For it must be remembered that, if any beneficial effect upon the hearing is to be obtained, the drug must be given in such doses as to produce marked physiological effects.

Labyrinthine Affections resulting from Constitutional Diseases other than the Acute Fevers.

Several chronic constitutional disorders are responsible for local changes in the inner ear and auditory nerve. Of these, syphilis is by far the most common, but arterio-sclerosis, leukæmia, diabetes and pernicious anæmia may also affect the organ.

The inner ear may be damaged by the poison of *syphilis*, as manifested either in the acquired or the inherited form.

In the *acquired* form the labyrinth may become involved at almost any period after the primary stage, and it has even been recorded within seven days of the first observation of the chancre. The affection manifests itself perhaps most commonly about the end of the secondary and beginning of the tertiary stages, but not infrequently the onset is delayed for many years. The symptoms, deafness and tinnitus, may appear quite suddenly, in which case Menière's complex usually accompanies them, or a sudden or rapidly increasing deafness may be the only indication of the implication of the labyrinth. As an example of the former type the following case may be taken:

A. B., aged forty-two, while in apparently good health, and possessed, so far as he knew, of normal hearing, awoke one morning with a sensation of intense giddiness. On attempting to walk he fell down, and found that on repeated efforts he always tended to fall to the left side. The giddiness was increased on moving the head even when lying down. The hearing was affected in the left ear to such an extent that the watch was only heard on contact. The conversation voice was heard at a distance of 6 yards. There was fairly severe tinnitus in the left ear.

His previous history showed that he had had a chancre nine years before, and a year before the present illness he suffered from an ulcer on the shin, which only healed after the patient was subjected to a course of iodide of potassium.

On testing the hearing with the tuning-fork, the bone-conduction was found to be markedly diminished. The tympanic membrane was normal in appearance, and no sign of disease was found in the mouth, throat or nose.

The patient was kept in bed, and the movements of the head were restricted as far as possible. Mercury and iodide of potassium were administered in large doses, and at the end of a week the hearing was considerably improved, and the giddiness had disappeared to such an extent that he could walk, though not quickly. In the course of another week the hearing had returned almost to the normal, and the giddiness had quite disappeared. Three years later the patient was reported as being well, and there was no noticeable deafness.

In this case the cochlear portion of the organ was obviously not so severely affected as the vestibular portion, and there is no doubt that it was owing to this fact, and to the immediate resort to antisyphilitic remedies, that the patient recovered. Sometimes, however, the deafness is equally sudden and is far more severe, and treatment frequently has but little effect, even when begun at once. In other words, the prognosis depends on the severity of the deafness, not upon the severity of the vestibular symptoms. In fact, some of the worst examples are those in which the latter are absent, or at least unnoticed.

Pathology.—The few cases in which reliable investigations have been made regarding the anatomical changes which are responsible for the symptoms, show that there is a round-celled effusion into the labyrinth and the nerve structures therein. Hæmorrhages are found in various parts, and the cells of the ganglion spirale undergo atrophy, as also may the nerve fibres in the lamina spiralis and in the auditory nerve.

Both ears are sometimes affected, though one may be more so than the other ; and it is not uncommon to find the hearing perfect on one side.

The diagnosis is made by a consideration of the symptoms and the results of the tests for labyrinthine disease, and by the evidence of syphilis, past or present, in other organs. The sudden onset is undoubtedly suspicious, but it must be borne in mind that other affections of the labyrinth not infrequently manifest themselves in this way. Even when the onset is not sudden, the deafness usually proceeds rapidly, the condition being in this respect different from that of most chronic affections of the inner ear. The eye should always be examined with the ophthalmoscope, and sometimes pigmentary disturbances in the fundus will reveal the nature of the case when other evidences of the constitutional disorder are not present.

Prognosis.—The prognosis is unfavourable on the whole, but, judging from the author's experience, it depends upon the degree of deafness, and not upon the severity of the vestibular symptoms.

Treatment.—The first and most important measure is to put the patient at once upon large doses of mercury and iodide of potassium. Those who believe in the greater efficacy of mercurial inunction or injection may employ these methods, but the administration of iodides at the same time must not be omitted.

It is also desirable to employ at the earliest stage hypodermic injections of pilocarpine, beginning with a dose of 5 to 8 minims of a 2 per cent. solution, and increasing it according to tolerance. The injections may be made daily or three times weekly for a period of about ten days, and if no improvement results by that time they should be discontinued. It is true that the pilocarpine treatment only succeeds in a minority of cases, but every case should have a trial. After the labyrinthine symptoms have been in existence for months or years, no benefit will result from the use of this powerful drug. A purge at the beginning and rest in bed for the first few days are important, and if Menière's symptoms are present the head should be steadied by sandbags.

In *inherited syphilis* the affection of the inner ear manifests itself in a way rather different from that seen in the acquired type of the disease. The importance of the subject was first demonstrated by Jonathan Hutchinson and Hinton, and owing to the investigations of these writers the subject has been properly recognized.

In respect to age, the labyrinth may be affected at any period within the first half of life, and possibly later. It may occur so early as to produce deaf-mutism and, according to some writers, is the commonest cause of that condition. But the most usual period for the onset of the disease is between the eighth and sixteenth years, and in this respect it is curiously similar to interstitial keratitis. Indeed, the coexistence of the two conditions at that period of life may be considered as proof of inherited syphilis, even when the teeth are perfectly normal as in the case cited below. As regards sex, girls are said to be rather more frequently affected than boys.

The pathology of the affection is not very certainly known, but, according to Mayer,[1] it is of the nature of a meningitis, with possible extension to the labyrinth.

As in the acquired so also in the inherited form, the deafness may come on suddenly or begin gradually, but in any case its progress is rapid. Giddiness is not uncommon, and may precede the deafness. In the inherited type the middle ear is very frequently affected coincidently, the disease in this respect differing markedly from the acquired form. In the inherited form the disease is almost always bilateral. As a result of the investigation of a large number of cases, Fraser[2] found that ozæna was frequently an associated condition.

The *diagnosis* is made from the results of the tests for disease of the inner ear, from the history of the case, and from other evidence of syphilis, especially those in the eye, the teeth and the palate.

The following case is a pathetic example of inherited syphilis affecting the ear, eye and palate. The report is epitomized from my case-book.

C. S., aged seventeen, presented herself on account of deafness, but she also suffered from blindness and pain in the roof of the mouth on swallowing.

At the age of eleven she became blind in the left eye, and five months later lost the power of the right eye also. Both eyes at that time were clouded with a 'white coating' (keratitis).

At the age of twelve she became deaf, first in one ear, and

[1] Mayer, *Arch. f. Ohrenh.*, Bd. lxxvii., Hft. 3 and 4.

[2] Fraser, *Journal of Laryngology, Rhinology, and Otology*, August, 1909.

a few weeks later in the other. On both occasions the deafness came on in a single night and was accompanied by severe tinnitus, vomiting and staggering gait, but no discharge occurred. As a result of treatment the keratitis disappeared entirely from the right eye, but a white patch still remained in the middle of the left cornea. With the disappearance of the keratitis a little improvement occurred in vision, but it was not very great.

Present Condition.—On inspection, atrophic patches are seen in both tympanic membranes, but there is no sign of indrawing. On inflation through the catheter, air enters both tympana freely but no improvement results. Noises in close proximity to the ear are heard, but the voice spoken in loud tones cannot be understood.

On testing with a deep-toned tuning-fork, it is found that air-conduction is better than bone-conduction, and both are very much diminished. On examining the right eye, it is seen that, although the keratitis has passed away, the iris is adherent, so that after the application of atropine it assumes the shape of a clover-leaf. In the fundus irregular patches of pigment are seen surrounding whitish areas from which the pigment has been removed, indicating the previous existence of choroiditis. There is marked atrophy of the optic nerve. In the left eye the leukoma of the cornea does not permit of examination of the fundus. On the left side of the hard palate, and within ½ inch of the second molar tooth, there is a narrow cicatrix ¾ inch in length. The teeth are in perfect condition, there being no trace of the peg-shaped or other deformity; in fact, all the teeth are remarkably well shaped and well preserved.

On account of the extreme deafness and the very serious defect of vision, the patient's life is rendered almost useless. Antisyphilitic treatment proved of no avail.

Prognosis.—The prognosis is even worse in the deafness of inherited than in that of acquired syphilis. Furthermore, in the inherited disease both ears are almost always affected, whereas in the case of acquired syphilis it is not at all uncommon for one ear to escape.

In all the cases observed by the writer, both in the inherited and acquired form, one interesting feature presented itself. Whenever one ear was affected in such a way that

Menière's symptoms were present, the attack of giddiness, vomiting, etc., was never repeated in consequence of the disease again affecting that ear. The poison appears to strike once and no more, though, of course, the opposite ear may be affected later in the same way, as in the case of the inherited affection recorded above. This apparent immunity of one ear after an attack of Menière's symptoms is in striking contrast with those non-syphilitic conditions in which the attacks may be more or less frequently repeated over months or years (p. 351).

The treatment of disease of the labyrinth due to inherited syphilis is, naturally, the same as that of the acquired type. The result of treatment, however, in the former is, in the author's experience, negative, but it may be that in rare exceptions some benefit may be obtained.

Leukæmia.—In 10 per cent. of all cases of leukæmia the labyrinth is affected. The investigations of Steinbrügge, Mott and others have shown, as might be expected, that the symptoms are due to effusion of blood into the organ and into the auditory nerve. Alexander has further shown that inflammatory action is sometimes present, and it is not uncommon for the middle ear to be involved along with the labyrinth.

The symptoms may occur quite suddenly, in which circumstance they consist of almost total deafness, tinnitus, giddiness, nausea and frequently vomiting. In some cases the affection is more gradual in its onset, and then the giddiness and nausea may be absent, the only symptom being progressive deafness, usually associated with tinnitus, though the latter is by no means always severe.

Prognosis.—The prognosis is always bad. If improvement occur, it is due to the fact that coincident middle-ear disease is present, and with the absorption of the effusion in the tympanum the deafness becomes less marked.

Treatment.—The general treatment of leukæmia must, naturally, be carried out. The symptoms due to the effusion into the labyrinth are treated in the usual way, by rest in bed and steadying the head between sand-pillows.

Pernicious Anæmia, etc.—Pernicious anæmia and diabetes have been recorded as causes of disease of the labyrinth. Indeed, it may be said that any general condition which entails great weakness may bring about deafness in this way.

That medical scapegoat chronic rheumatism has, of course, been held responsible for causing disease of the labyrinth or auditory nerve. The relationship between the two will acquire more interest when any two authorities come to agree upon the meaning of the term 'chronic rheumatism.' At present it may apparently mean any diseased condition which cannot be called by some other name. And nothing is to be gained by discussing the relationship existing between a local disturbance in the labyrinth and a general affection which varies according to the imagination of the observer.

Before leaving the consideration of this subject, there remains to be described a certain type of cases in which the labyrinth is undoubtedly diseased, but at the same time where the symptoms are markedly exaggerated by temporary disturbances in the body. The following is a very abbreviated description of such a condition studied over a period of seven years.

In the year 1903 a highly educated and intelligent man was referred to me on account of attacks of giddiness, nausea with vomiting, and tinnitus. The first attack occurred in December of 1902, and between that date and May 5, 1903, he had six more. The attacks were sudden, the giddiness being almost instantly followed by a fall to the right side, and a few seconds later by nausea and vomiting. Rigors occurred in some attacks, and each was followed by considerable shock. Consciousness was never lost. The patient was not aware of any trouble in the ear until the fourth attack, which occurred on April 16, 1903, when he noticed a deep booming noise in the right ear. Since then he has also felt sightly deaf in the same ear.

At my first examination on May 5, 1903, it was found that in the right ear the whispered voice was heard at a distance of only 3½ yards, and a watch, heard normally at 2 yards distance, was just perceptible when held 1 inch away. On testing with notes of different pitch, the hearing for the low notes was found to be quite unaffected, but that for the high notes was lost to a moderate extent. Bone-conduction was markedly diminished.

The nature of the patient's profession entailed hard intellectual work and considerable worry, and for the same reason his meals were irregular.

He was advised to diminish the amount of his work and take his meals more regularly; and although this advice could only be followed to a limited extent, there was considerable improvement, and he had no more attacks for a period of seven months. During that time, however, the hearing did not improve. From this time onwards the attacks only occurred at intervals of several months. The patient noticed that surrounding objects usually appeared to move in the horizontal plane, but on rare occasions the movement appeared to be in the vertical sagittal plane. The hearing became slowly but steadily worse. In the year 1907 he was able to change the nature of his work to a considerable extent, so that it entailed less mental strain and much less worry. The result was again beneficial; the attacks became gradually less frequent, and at the time of writing (1910) he has had no attack for two and a half years. The deafness, however, has become so bad in the right ear that a loud conversational voice cannot be heard at a distance of more than a foot. The left ear is healthy.

Cases similar to this are not uncommon, but are frequently mistaken for attacks of indigestion. This mistake is a very natural one, since the deafness is frequently slight and usually unilateral. Moreover, an indiscretion in diet is a common exciting cause of an attack.

The *prognosis* varies considerably in different cases and under different circumstances. In respect to the hearing, the outlook is very unfavourable but the progress may be, and usually is, slow. Tinnitus is not generally very distressing, save during, and for a short time after, an attack, but there are exceptions to this rule. The attacks of giddiness, with or without vomiting, usually recur, but the intervals between vary in every case. Fortunately, however, in the very great majority they ultimately disappear, though in some individuals years may elapse before this comes about.

The *pathology and pathogenesis* of the condition are not at all well known. The seat of the lesion is probably in the labyrinth or in the terminal portions of the auditory nerve as they run through their bony channels. In some examples crystalline deposits of calcareous salts are found in the labyrinth, as in the case cited on p. 337, which was a mild type of the affection. The labyrinth of this individual is shown in Fig. 114, but it cannot be definitely stated whether the crystal actually caused the attacks, or was merely a result of earlier pathological changes.

Whatever may be the true nature of the lesion in the organ of hearing, there is no doubt that disturbances in the vasomotor system are effective in precipitating the attacks of giddiness, vomiting and tinnitus. This is no doubt the reason why indiscretions of diet, indigestion and fasting, appear to cause the trouble, the vasomotor system being readily affected by disturbances in the alimentary tract. Similarly, overwork and worry tend to bring about an unstable condition of the same system, and therefore render the patient more liable to an attack.

The *treatment* consists for the most part in removing any condition tending to disturb the stability of the vasomotor system. The physician must therefore direct his attention to ascertaining the habits of life of the patient and the condition of the other organs of the body, especially those of digestion and the central nervous system. In practice it will generally be found that prolonged rest, associated with an open-air life and freedom from work and worry, will greatly diminish the frequency and severity of the attacks, and ultimately cause them to disappear. A long sea-voyage is one of the best forms of treatment, but the tendency to constipation under these conditions must be guarded against.

Under certain rare circumstances it is justifiable to destroy the labyrinth on the affected side by operation. For example, when the attacks succeed one another at short intervals, and render the patient unable to work, and make life almost intolerable in spite of careful medical treatment, then ablation of the labyrinth is permissible. If in addition to these symptoms there is severe tinnitus and very marked deafness, the indications in favour of operation are still more obvious. The method of operating is described on p. 302.

AFFECTIONS OF THE LABYRINTH ASSOCIATED WITH DISEASES OF THE NERVOUS SYSTEM.

The auditory nerve occasionally suffers in various diseases of the central nervous system. It is, however, a rather curious fact that in this respect the auditory suffers much less frequently than does the optic nerve.

Locomotor Ataxia.—The functions of the inner ear are rarely disturbed by tabes. Voigt found that in only 2 per cent. of the patients was there any symptom referable to disordered functions of either the cochlear or vestibular nerve, and Friedrich and Treitel found these disturbances present in only about 7 to 10 per cent. It should be mentioned, however, that Morpurgo, Marina, Marie and Walton found disturbances of hearing in about 70 per cent. These discrepancies are remarkable, and it is quite possible that some mistake may have arisen in assuming that deafness occurring in a tabetic patient must of necessity be due to disease of the auditory nerve resulting from tabes, when it may frequently be merely a middle-ear condition independent of that.

But a further explanation of these discrepancies is possible. All victims of tabes have suffered from syphilis, and it follows that all these individuals are liable to disease of the labyrinth apart altogether from the tabes from which they are suffering. If, therefore, we exclude cases of tabes in which the disturbance in the labyrinth and auditory nerve is due to the syphilitic poison directly, and not to the coincident disease of the central nervous system, the percentage in which the deafness is really due to the tabes might be very much reduced. This is not merely a question of nomenclature, for the two conditions are pathologically quite different. The anatomical changes in the labyrinth and nerve due to syphilis have already been described (p. 346).

Pathology.—When deafness is due to locomotor ataxia, it has been found that the organ of Corti and the maculæ and cristæ in the vestibule and ampullæ are normal. The cells of the ganglion spirale undergo degeneration, as also do the medullated fibres in Rosenthal's canal and in the modiolus and auditory nerve. The auditory nuclei in the brain are unaffected.[1] In some cases, however, Friedrich is of the opinion that the symptoms arise from disease of the nuclei in the medulla.[2]

Symptoms.—Clinically the affection manifests itself as a slowly progressive deafness accompanied by tinnitus. According to some authorities, the onset may be sudden, in which case giddiness, vomiting and very severe tinnitus accompany the deafness. It must be remembered, however, that there is the other possible explanation of such cases already given.

Prognosis.—The prognosis appears to be uniformly bad, and the deafness is almost always bilateral.

Treatment.—Treatment is of no avail.

Deafness has also been recorded as being due to general paralysis[3] and to hydrocephalus.[4]

[1] Brühl, *Zeitschr. f. Ohrenh.*, Bd. lii., 3, S. 232, 1906.

[2] Friedrich, "Deutsch. Otolog. Gesellsch. Verhandl.," 1897.

[3] Mayer, *Arch. f. Ohrenh.*, lxxii., 1, 2, S. 94, 1907.

[4] Fuchs., *Ab. f. Anal. u. Physiolog. d. Centralnervensyst. an. d. Wien. Univers.*, 1904.

CHAPTER XVI

DISEASES OF THE LABYRINTH AND AUDITORY NERVE (*Continued*)

AFFECTIONS OF THE LABYRINTH AND AUDITORY NERVE DUE TO TOXIC CAUSES.

MANY poisons act deleteriously upon the labyrinth and auditory nerve. Of these, the most common are quinine, the salicylates, tobacco and alcohol.

Quinine.—The anatomical changes in the labyrinth and auditory nerve due to overdoses of quinine have been carefully investigated by Wittmaack.[1] He has found that the hæmorrhages in the labyrinth, which were formerly supposed to be due directly to the drug, are in reality due to the respiratory embarrassment which accompanies the death-agony of the animal when the drug is given in large doses. The real effect of quinine upon the labyrinth is the production of ischæmia, not hyperæmia. The cause of the deafness, however, is the direct effect of the drug upon the cells of the spiral ganglion.

Symptoms.—The symptoms produced by the action of quinine upon the ear are deafness and tinnitus. Giddiness is occasionally felt, but is usually slight.

Prognosis.—When the symptoms arise from one large dose, they usually disappear rapidly; but if the drug be taken for some time in large doses in spite of the deafness, the latter will generally remain as a memento of therapeutic mischief to the end of the patient's life.

Salicylates.—Salicin and the salicylates produce a form of deafness analogous to that following overdoses of quinine, and the pathological changes, also, are like those produced by

[1] Wittmaack, *Arch. f. Physiolog.*, Bd. xcv., S. 209, 234, 1903.

the latter. Aspirin and salipyrin have also been known to cause deafness of a similar character, and due to analogous pathological changes in the cells of the spiral ganglion.

Tobacco.—Deafness is a well-recognized symptom of excessive smoking. In view, however, of the enormous number of smokers it is comparatively rare. The subject has been carefully investigated by Wingrave,[1] Alt, and Delie.[2] Apart from its effect upon the middle ear, owing to the naso-pharyngeal catarrh that tobacco may cause, is its direct toxic effect upon the auditory nerve. According to Delie, the nerve suffers because it does not receive a due supply of blood, on account of the contraction of the arteries resulting from irritation of the ganglia of the sympathetic nerves.

Some years ago it was supposed that the symptoms produced by excessive smoking were due to the products of combustion such as pyridin as much as to the nicotine. This view has been definitely shown to be incorrect, and it is now known that the nicotine is almost entirely the cause of the symptoms. Apart from other sources, the truth of this was made manifest to the author several years ago, when he saw a case of deafness associated with the other symptoms of excessive smoking in a young ploughman who never smoked, because, when he tried to do so, it 'burnt his tongue.' But he constantly chewed tobacco and renewed the 'plug' very frequently. The deafness and other symptoms disappeared in the course of a few weeks by merely giving up the habit.

The only treatment of any value is entire abstinence from tobacco. If the case is seen and diagnosed early, recovery may be complete. In the majority of cases, however, the pathological changes have gone too far, and the hearing, although improved by giving up smoking, does not return to the normal. It is possible that the administration of strychnine may hasten recovery.

When deafness is suspected as being due to excessive smoking, the surgeon is warned against accepting the patient's statements as to 'moderate smoking.' In this regard, pathetically humorous revelations sometimes occur. Thus, a young man of thirty described himself as being a 'moderate smoker,' but, on pressing for a definition of the term, the patient ad-

[1] Wingrave, *Journ. of Laryngolog., Rhinolog., and Otolog.*, p. 172, 1903.

[2] Delie, *Arch. f. Ohrenh.*, Bd. lxiv., S. 75, 1904.

mitted that for ten years or so he had smoked on an average 9 ounces of heavy tobacco per week. Another 'moderate smoker' consumed ten cigars in the day and a few cigarettes, but was of opinion that these could have nothing to do with his symptoms, because the cigars were very good ones! One of the most remarkable cases was that of a woman, aged thirty-five, who smoked 4 ounces of 'thick black twist' per week! In this patient the deafness was almost absolute, and was associated with very severe amaurosis.

Alcohol.—Continued immoderate use of alcohol occasionally produces deafness. This is due to a neuritis, which may be solitary, but is more frequently associated with a similar condition in other nerves, such as the optic, the trigeminal, etc.

Other toxic agents which more rarely produce deafness through their effects upon the auditory nerve or labyrinth are mercury, phosphorus, lead, arsenic, silver nitrate, iodide of potassium and Indian hemp. No doubt other noxious substances may bring about a similar condition. The effect of all these substances falls far more severely upon the cochlear than upon the vestibular portion of the nerve; hence deafness, alone or associated with slight tinnitus, is the outstanding symptom, and only rarely do giddiness and vomiting occur.

Treatment.—The obvious and only successful treatment is to remove the cause. If seen early, complete recovery may ensue, but in very many patients only a certain degree of improvement can be looked for. The administration of strychnine may hasten recovery.

AFFECTIONS OF THE LABYRINTH ASSOCIATED WITH CERTAIN OCCUPATIONS.

Workers in various trades may suffer from diseases of the labyrinth or auditory nerve. In some of these the affection is due to absorption of poisons, such as arsenic, lead, mercury, etc., but these have just been described (p. 356).

There are other occupations, however, in which the auditory organ is affected in quite a different way.

Boiler-Makers' Deafness.—By far the most common of the latter is boiler-making and similar trades in which the worker is constantly in the presence of loud noises—firemen, engine-drivers, tinsmiths, gunners and those sailors who are constantly in near proximity to large guns which are being fired on warships.[1] But boiler-makers are by far the most commonly affected. The author has frequently the opportunity of conversing at the dispensary with boiler-makers working in the Clyde shipbuilding yards. It seems to be a universal impression among the workers that all those who remain at boiler-making ultimately become deaf. The period at which the deafness first appears seems to vary within wide limits, in some cases occurring in the course of a few weeks, in others not until several years have elapsed. There is little doubt that any tendency to Eustachian catarrh or middle-ear disease increases the susceptibility to the pathological changes in the labyrinth from which these workers suffer. At first sight this may appear remarkable, since a middle-ear trouble would diminish the loudness of the sounds ; but it must be remembered that the noises may be conveyed by the bones, and in middle-ear affections the bone-conduction is increased. Furthermore, it is quite possible that the coarser but inaudible vibrations may play a part in injuring the delicate structures of the inner ear, and these would certainly produce their effect by the conduction afforded them by the bones.

Pathology.—The pathogenesis of the condition is obscure. Spira,[2] who investigated very carefully the whole subject of boiler-maker's deafness, is of opinion that the constant vibration loosens the contact of the neurones. The anatomical changes which are found are atrophy of the organ of Corti, especially in the lower whorl of the cochlea, and atrophy of the cells of the ganglion spirale in the corresponding area of the organ.[3]

Symptoms and Course.—The only symptom, usually, is gradually progressing deafness. Tinnitus is present in about half the cases, but is insignificant in character. Giddiness, nystagmus, and the other evidences of disorder of the vestibular nerves are not present. The prognosis is distinctly unfavourable, and, curiously, the deafness sometimes pro-

[1] Cheatle, Transactions of the Otological Society, vol. vii., p. 3.

[2] Spira, *Wien. Klin. Rundsch.*, Bd. xv., S. 601, 1901.

[3] Habermann, *Arch. f. Ohrenh.*, Bd. lxix.; Brühl, *Arch. f. Ohrenh.*, Bd. lii.

gresses even when the worker gives up his occupation and takes to some other in which his auditory nerves are not subjected to constant stimulation (Kahn).

On examination it is found that, in addition to the deafness, the bone-conduction is very markedly diminished, so that Rinne's test gives a pronounced positive result. The notes in the upper parts of the scale are not heard, while there is less diminution of hearing for notes of low pitch. The membrane presents a normal appearance, except of course in those cases in which there is coincident affection of the middle ear.

Treatment.—Treatment is entirely prophylactic, and consists in protecting the deeper structures by plugging the meatus carefully with a piece of cotton-wool soaked in vaseline or lanoline. Even by this means, however, it is not certain that boiler-maker's deafness can always be avoided.

Deafness in Telephone-Workers.—Workers in the telephone departments of large cities occasionally suffer from affections of the ear which are—for the most part, at least—to be attributed to disorders of the auditory nerve or inner ear. The condition, however, is quite different from that which occurs in boiler-makers, etc. The symptoms are progressive deafness, hyperæsthesia acustica, tinnitus and a sense of fulness in the ears. Considering the large number of workers in the telephone departments of the various countries, it is rather remarkable that aural troubles are so comparatively rare, for the condition described is not common.

Deafness in Caisson-Workers.—Those whose work compels them to be under the influence of compressed air occasionally suffer from deafness, along with the other well-known symptoms which occur in 'caisson' disease. Certain middle-ear symptoms arise from entering the compressed-air chamber, but these are due entirely to the increased pressure of the air upon the tympanic membrane, and can be avoided by swallowing frequently or performing Valsalva's experiment until the pressure of the air in the middle ear is equal to that in the caisson.

But there is another and much more serious form of ear trouble which may occur along with the other nerve symptoms, on passing from the increased pressure within the caisson to the ordinary atmospheric pressure outside.

'Caisson disease' has been studied with particular care by Leonard Hill, and he has shown that no trouble occurs, however great the pressure may be, until leaving the caisson. Furthermore, the disorders can all be easily avoided if decompression be sufficiently slow. The pathogenesis of the affection is highly interesting, and worth referring to in detail. Upon entering the compressed-air chamber, the blood at once begins to dissolve more air than it can hold in solution under ordinary pressure. This increase in the amount of air absorbed refers both to the nitrogen and oxygen. Now, so long as the pressure is maintained no harm occurs, but on leaving the compressed-air chamber the oxygen and, more particularly, the nitrogen tend again to assume the gaseous state. If the change be too rapid, the gases become small emboli in the form of bubbles, which, on reaching the minute arterioles of the body, obstruct the passage of the blood, and cause the symptoms of the disease by depriving the tissues of their nourishment for a time. Now, so far as most of the cells of the body are concerned, the deprivation of nourishment or of oxygen for some considerable time does not matter, but, unfortunately, nerve cells are an exception to this rule, and when they lose their supply of oxygen they die rapidly. Hence arise the various paralyses which are characteristic of the affection, and sometimes cause death.

If the air emboli are arrested in the arterioles supplying the auditory nerve or labyrinth, the corresponding symptoms, such as deafness, giddiness, vomiting and nystagmus will occur. These symptoms will also appear if the fibres and nuclei of the nerve in the pons or medulla are affected.

It will of course be understood that the same symptoms may occur in all those whose calling necessitates work in compressed air. Hence pearl-divers and sponge-divers not uncommonly suffer.

Prophylaxis.—Hill has shown that this disorder may always be prevented by sufficiently slow decompression. The time occupied for decompression should be twenty minutes for each atmospheric pressure to which the worker has been subjected, and if care be taken in this matter no accident will occur. The late Sir Benjamin Baker pointed out that when the worker is in the compressed-air chamber for a very short time, some seconds or even a minute, there is no danger, however rapid the decompression.

Treatment.—When the symptoms of caisson disease occur, the patient must be put back in the compressed-air chamber instantly, and kept there for a little while, after which slow decompression may be allowed. If this be done, the symptoms will pass off, and death or subsequent paralysis will be avoided. But if the minutes be allowed to pass before returning the patient to the compressed-air chamber, the nerve cells die, and the paralysis, of whatever nerve or nerves it may be, becomes permanent, and death may ensue. If more than any considerable time has elapsed since the symptoms appeared, no good will accrue from returning the patient to the compressed-air chamber, or from any other form of treatment.

TUMOURS OF THE AUDITORY NERVE AND LABYRINTH.

Various tumours may extend from the surrounding tissues into the labyrinth, or involve the nerve in their growth. Among such are sarcomata of the base of the skull or carcinoma of the middle ear. It is doubtful whether a case of primary malignant disease of the labyrinth has ever been recorded, but there is no reason why such should not occur.

Tumours of the auditory nerve in its course from the medulla to the labyrinth have been recorded by Sternberg,[1] Yearsley[2] and others. The growth may be fibroma, neuroma, glioma or sarcoma, and they may be of a mixed type.

It is hardly possible to see how a correct diagnosis could be made of these conditions during life, for the obvious reason that all the functions which are disturbed could also be affected by anatomical changes in the labyrinth itself, or at the root of the nerve where it passes into the medulla. Hence any growth arising in the labyrinth or in the stem of the auditory nerve may produce such symptoms as deafness, tinnitus, nystagmus, giddiness, vomiting, etc. But all these symptoms might equally well be produced by syphilitic or other disease of these structures. If the growth extends

[1] Sternberg, *Zeitsch. f. Heilk.*, 1900.

[2] Yearsley, Transactions of the Royal Society of Medicine, 1908.

so as to encroach upon the cranial cavity, symptoms indicative of intracranial pressure may arise, such as headache, 'choked disc,' and vomiting, along with various pareses according to the nerves involved. The very early occurrence of facial paralysis along with deafness and Menière's symptoms might lead to the suspicion of tumour of the auditory nerve when suppurative disease could be excluded. In general, however, the nearest approach to diagnosis which can be reasonably made is the existence of a growth in the neighbourhood of, and involving, the labyrinth or trunk of the nerve.

CHAPTER XVII

DISEASES OF THE LABYRINTH AND AUDITORY NERVE (*Continued*)—DEAF-MUTISM, ETC.

INJURIES TO THE LABYRINTH.

By far the commonest injury to the labyrinth or auditory nerve is that incurred in fracture of the base of the skull. The immediate symptoms and signs of this serious injury are well known—discharge of cerebrospinal fluid and blood from the ear, associated usually, though not always, with loss of consciousness. Facial paralysis should always be looked for, and is recognized on comparing the two alæ nasi during respiration, when the slight rhythmic movements may be found to have disappeared on one side, or the cheeks or lip may be blown outward during expiration. Symptoms indicating injury to the labyrinth itself are not, of course, present while the patient is unconscious, but when he becomes convalescent he may find that he is deaf on one side, and suffering from giddiness, tinnitus perhaps and facial paralysis.

Prognosis.—If the deafness is complete and has lasted for two or three months, there is practically no hope of any improvement; and even when the patient has still the power of hearing to a limited extent, the amount of improvement will probably not be very great, and there may be none at all. A similar prognosis holds good in respect to the facial paralysis. If it is complete and has lasted for several weeks after the accident, the hope of recovery is not bright. But if the paralysis is incomplete, restoration of function will probably take place in the course of time. Tinnitus and giddiness, though they may persist for a long time, almost invariably disappear ultimately.

Treatment.—No treatment is of any avail as regards the deafness, and the same is probably true of the tinnitus and giddiness. With respect to the facial paralysis, however, the matter is different, for by the methods of modern surgery this distressing condition can now be alleviated by suturing the distal portion of the facial to the hypoglossal or spinal accessory nerves. It will natually be understood that the operation is not to be performed until all hope of spontaneous recovery has passed—that is to say, for a number of weeks after the injury. If the operation be successful, it must still be borne in mind that rather grotesque associated movements occur between the facial and lingual muscles, or between the facial and trapezius, etc., according to the nerve selected for suturing. These contortions, however, tend to diminish with time, and in any case the patient is in better condition than before.

Concussion.—The labyrinth sometimes suffers from a blow on the side of the head, or from a very loud explosion, such as the firing of a large gun, the condition being one of concussion of the organ. Deafness and tinnitus occur, and in rarer cases giddiness may be present. The degree of deafness varies, and it may be complete.

Diagnosis.—It is of great importance to ascertain whether the deafness is due to injury to the middle ear or to the labyrinth. If it be the latter, the deafness is usually more severe, bone-conduction is diminished, the hearing for the high notes is lost to a relatively great extent, tinnitus is more lasting and severe than in middle-ear injury alone, and giddiness may be a more noticeable feature of the case. Inspection of the membrane helps in the diagnosis, for in some cases the middle ear is not injured.

Prognosis.—Unless the deafness is very great in degree, a certain amount of improvement usually occurs, and the recovery may be complete.

Treatment.—Rest in bed, gentle laxatives and quietness, are the only treatment for this condition.

Other Injuries.—In very rare cases the labyrinth has been injured by the point of a hairpin, a match, pencil or pen being driven through the oval window. The symptoms which result are of the usual Menière's type—deafness, giddiness, tinnitus, sometimes vomiting, and occasionally facial palsy.

The prognosis is bad as regards the hearing, and it must be remembered that, as a result of the coincident injury to the middle ear, acute inflammation of that cavity is likely to supervene.

Lightning stroke has been recorded by Macnaughton Jones[1] as a cause of injury to the hearing.

Treatment.—At first the treatment is directed towards the injury to the tympanum. When this has healed and the perforation closed, the extent of the deafness resulting from the injury to the labyrinth may be discovered, and the condition treated. Unfortunately, treatment has usually but little effect. Perhaps a succession of blisters applied over the mastoid process at intervals of a few days may do good in relieving the tinnitus, and hypodermic injections of pilocarpine or the application of the galvanic current may be tried; but improvement is not to be expected from any form of treatment. The giddiness and vomiting pass off before long; then the tinnitus usually disappears, but the deafness remains.

DISTURBANCE OF THE FUNCTIONS OF THE AUDITORY NERVE AND LABYRINTH DUE TO LESIONS IN THE BRAIN.

In certain comparatively rare cases the senses of hearing and equilibration may be affected by lesions in the central nervous system. So far as disturbances of equilibration are concerned, any lesion interfering with the nuclei or fibres between the medulla and the cerebellum may bring these about. Hence a growth on the surface of the latter may produce symptoms akin to, but of course not identical with, those which result from diseased conditions in the semicircular canals or vestibule.

A more remarkable series of symptoms occurs if the lesion be situated between the point at which the auditory nerve enters the medulla and the point at which the final decussation of the cochlear fibres of the nerve takes place. The peculiar interest which attaches to lesions in this region is due to the fact that many nuclei and fibres involved in the motor, sensory, thermic and other vital processes are affected.

[1] Macnaughton Jones, Trans. Otolog. Soc., 1902, p. 116.

Hence it comes about that disease in this region is protean in its manifestations. In respect to motor disturbances, almost any muscle may become paralyzed, and, on the other hand, sensation may be paralyzed in almost any region of the body, and this in respect either to tactile sensation or to the perception of heat and cold. The cardiac, respiratory and digestive functions may be seriously disturbed, owing to involvement of the nuclei associated with these functions. The body temperature also may be affected through involvement of the heat-regulating centre. The functions of the bladder and rectum, however, are among the very few that remain unimpaired.

The following case, already reported in full by the author,[1] illustrates the points mentioned above, and he is indebted to Professor Samson Gemmell for permission to record it.

J. K., aged twenty-two, a butcher, was admitted to the Western Infirmary, Glasgow, on account of difficulty in swallowing and giddiness of a month's duration, and 'paralysis of the face' and deafness in the left ear of a fortnight's duration.

Present Condition.—There is no headache and no mental disturbance, but articulation is somewhat impaired owing to paralysis of the lips and tongue.

The condition of the *ear and throat* is reported upon by Dr. Albert Gray. Simultaneously with the onset of the deafness, tinnitus of a singing nature was perceived. There has been no pain in the head or ears, nor has there at any time been discharge from the ear. In the left ear the whisper is only heard at a distance of 2 inches. In this ear air-conduction is affected much more seriously than bone-conduction, Rinne's test giving a result of -7. On the right side the tympanic membrane is normal, but on the left it is indrawn. The palate is paralyzed on the left side, and the left vocal cord is also paralyzed and remains fixed in the middle line during phonation, expiration and inspiration.

On examination of the *eye*, it is found that the left pupil is more contracted than the right, and ptosis is noticed on the left side. The right pupil responds to light, but not to accommodation, and the left gives no reaction to either. No optic neuritis is discoverable.

[1] Gray, Transactions of the Sixth International Otological Congress London, 1899.

The sense of *taste* is lost on the left side of the tongue.

The knee-jerk and plantar reflexes are stronger on the left than on the right side.

On the left side of the body, face and limbs, the *heat sense* is not affected, while on the right he can tell no difference between hot and cold tubes. With respect to *common sensation*, it is found that the left side of the body and the left limbs are unaffected; but on the left side of the face, and on the right side of the body and right limbs, the sensation of touch is seriously affected, and he cannot tell the difference between the touch of a finger and that of a pin. These results are confirmed by testing the sense of touch with a pair of compasses.

The thoracic and abdominal organs all appear to be healthy, and the urine contains no albumin, sugar or blood.

A few days after admission the symptoms above mentioned became worse, and others began to make their appearance. The temperature rose to 100° F., and subsequently oscillated irregularly between that and 104° F. Continuous and very distressing hiccough was present and seriously affected sleep. Paresis of the left side of the body became pronounced. Perspiration became profuse, but no rigor or sense of chilliness was felt. The bladder and rectum were unaffected.

On the seventeenth day after admission he became much worse; convulsions set in, and he died the following night, thirty-one days after the first symptoms of illness.

The *treatment* adopted was palliative. Iodide of potassium was administered, but was found to be of no avail.

The *post-mortem* examination was conducted by Dr. Lewis Sutherland. 'There is a lesion occupying the left half of the medulla and floor of the fourth ventricle. This portion is swollen, and softer than that of the opposite side. The lesion involves an area measuring 4 by 1·3 centimetres, and touches the middle line, but does not cross it. On transverse section the affected area presents a mottled appearance, irregular patches of hæmorrhage alternating with others of an opaque yellow colour. There is no disease of the inner or middle ear, nor is there anything noteworthy in the other organs of the body.'

The cord, medulla, and pons, were hardened in Müller's fluid, and a series of sections was prepared by Dr. McKenzie Anderson.

'The lower limit of the lesion corresponds with the decussation of the pyramids, and the upper with the middle of the floor of the fourth ventricle. In transverse section the lesion appears most extensive in the posterior portion of the pons, where it measures 1·7 centimetres in diameter. It presents the appearance of a gliosarcoma, with hæmorrhages into its substance' (Fig. 116).

Such a case, with the accompanying post-mortem examination, indicates better than a detailed list the remarkable symptoms which arise from lesions in this portion of the brain. There is no need, therefore, to enumerate these, but it should be pointed out that in the case above related the lesion was strictly unilateral. Had it crossed the middle line, death would have occurred at a much earlier date, and the comparatively complete sequence of disturbed functions would not have been evolved so far. Where the corpora quadrigemina are involved in the lesion, the muscles of the eye in particular are affected.

Cerebral Lesions.—Cerebral lesions rarely disturb the function of hearing, this being due to the fact that the cochlear fibres of each auditory nerve are represented on both sides of the brain cortex. In a remarkable case recorded by Wernicke and Friedländer, both temporal lobes were the seat of gummatous deposit, which resulted in deafness in both ears. Similar cases have been recorded by Pick and Mott, and a very complete description by the last-named writer will be found in the *Archives of Neurology*, vol. iii., p. 401. Cases have even been recorded in which unilateral disease in the temporal lobe has caused true deafness, but such must be extremely rare, except in the limited sense described below as word-deafness and tone-deafness. Deafness has been recorded several times as the result of cerebellar tumour, but it is obvious that this is not due to the local disturbance in the cerebellum itself, but to pressure upon, or extension into those regions through which the fibres of the cochlear division of the auditory nerve pass. In the same way intracranial aneurism may cause deafness, if it be situated in these regions.

It is a rather curious fact that tumours involving the fibres or nuclei in the central course of the auditory nerve are not usually productive of severe tinnitus, even when the hearing is affected. Siebenmann found that the symptom was only present in a small minority of these cases, and even then was not marked in character, and usually passed off comparatively soon. It is important to remember this, since it is a common mistake to assume that tinnitus is a pronounced symptom in lesions of this region.

Word-Deafness and Tone-Deafness, or *Sensory Aphasia*.—Although unilateral lesions of the temporal lobe very rarely cause deafness in the proper acceptation of the word, yet they sometimes produce the curious conditions known as word-deafness and tone-deafness. The patient *hears* the words said to him, but they suggest no meaning. From post-mortem examinations made in these cases, it has been found that the lesion was situated in the cortical portion of the left temporal lobe, and it appears that its position may be located with even more accuracy in the posterior third of the superior and middle temporal convolutions. By means of careful histological examinations Campbell[1] has found two distinct areas in this neighbourhood, both of which are concerned in audition. The first is the audito-sensory area, which receives the stimuli from the fibres of the auditory nerve, while the second is the audito-psychic area, which 'deals with the interpretation and further elaboration of these stimuli.' Now, the audito-sensory area is equally present in both right and left hemispheres, and therefore a lesion on the left side does not make the patient deaf to sound. On the other hand, the audito-psychic area is presumably much more highly developed in the left hemisphere than in the right. Hence a lesion on the left side affecting this area prevents the patient from understanding the significance of the word which he hears. In unilateral cases the disability is never complete; hence it would appear that elsewhere in the brain (probably in the corresponding area of the opposite side) there are cells capable of taking up the function of those destroyed upon the left side.

FUNCTIONAL NERVOUS DISTURBANCES OF THE ORGAN OF HEARING.

The ear is sometimes affected by disturbances in the nervous system which, for want of a fuller knowledge, may be included under the term 'functional.' These disturbances

[1] Campbell, Transactions of the Otological Society, vol. iv., p. 95.

may affect the inner, the middle, or, more rarely, the outer ear.

Neuralgia.—Neuralgia affecting the auricle, the meatus or the middle ear, is not a common affection, but there is no doubt that it does occasionally occur. It is frequently reflex in character, and, when there is no associated deafness, the diagnosis is not difficult, since practically all other painful diseases of this region either cause dulness of hearing or manifest themselves by accompanying visible changes in the part affected. The exciting cause of the neuralgia is not always discoverable, but in many cases it can be found if looked for carefully. Carious teeth are a frequent cause, but others less obvious may be found, such as spurs and deflections of the nasal septum. Particular emphasis must be laid on the importance of making a very careful examination of the nose, pharynx and larynx, in cases of 'neuralgia' of the ear. The reason of this is that the symptom may be the first indication to the patient of malignant disease in those regions. The author has seen two such cases, one of epithelioma of the posterior and upper portion of the larynx, and the other of epithelioma of the buccal surface of the soft palate. Both were in a very early stage, and neither patient had felt any noticeable trouble in the throat. These examples are no doubt exceptional, as the otalgia is usually complained of after the throat affection has become obvious to the patient.

Tubercular disease of the larynx is also a cause of otalgia, but I have never seen this symptom occur as a first indication of the laryngeal affection. Granular pharyngitis may occasionally cause otalgia.

Treatment.—Any possible cause, such as those mentioned above, must be removed if present. If there be any reason to suspect rheumatism, gout, anæmia or other constitutional condition, these must be treated on appropriate lines. To relieve the attacks of pain, aspirin or phenacetin may be used, but morphia should never be employed. Blisters applied over the mastoid process are frequently helpful.

Tic Convulsif.—In that curious condition of spasmodic contractions of the facial muscles known as 'tic convulsif' the hearing-power is sometimes affected. Usually it is slightly increased during the contractions, but in some cases it appears to be diminished. The effect upon the hearing is supposed, and probably correctly, to depend upon simultaneous contractions of the stapedius muscle, which, it will be remembered, is supplied by the facial nerve.

Spasmodic contractions of the muscles of the Eustachian tube and of the tensor tympani, apart from any actual disease in the ear, have been recorded. These produce sounds usually described by the patient as 'clicking,' and they are sometimes audible to anyone who is sufficiently near the patient.

Hysterical Deafness.—Hysterical deafness is, on the whole, a rare condition. Its diagnosis is sometimes easy, but occasionally very difficult, and it must be carefully distinguished from simulated deafness.

The affection is usually associated with other stigmata, such as limitation of the field of vision, diminished sensitiveness or anæsthesia of the auricle, the external meatus or other regions of the skin, etc. Hysterical deafness is usually, but by no means always, unilateral. Its onset is more often sudden than gradual, and it is usually severe in degree. It is not associated with tinnitus or giddiness, and these are important points in the diagnosis. A rare but very characteristic feature of hysterical deafness is the transference of the symptom from one ear to the other, and sudden alterations in the intensity of the deafness without apparent cause are also of value in framing the diagnosis. Hammerschlag[1] has made the observation that in hysterical deafness the auditory nerve is easily exhausted. Thus, if a tuning-fork be struck and held in front of the ear, the patient hears it only for a short time, but soon hears it again, even although the fork has not been struck in the interval.

Treatment.—The treatment of hysterical deafness is not satisfactory from the physician's point of view. That is to say, he rarely effects a cure by his own treatment, though the hearing usually returns sooner or later, either without known cause, or as the result of a shock, a journey to some holy well, or under the brazen-faced ministrations of a quack. To those who appear to have most experience of hysterical deafness, treatment by hypnotism seems to have given the best results, but the application of the galvanic current is warmly recommended by many. The exhibition of asafœtida, valerian and the like, belongs to an age of simpler

[1] Hammerschlag, *Wien. Allgem. Zeit.*, 1904.

medical faith than the present, but these may be prescribed if the patient is determined to swallow some drug. Though nauseous, they are harmless. For an excellent description of hysterical affections of the ear, the reader is referred to the paper by Holmes in the *Laryngoscope*, August, 1907.

SIMULATED DEAFNESS.

It occasionally happens that an individual is led to simulate deafness in order to escape work or some prescribed duty, or to gain compensation under the Employers' Liability Act, or for some other reason.

It is rarely difficult to detect these malingerers, but occasionally they are sufficiently clever to mimic real deafness in a remarkable way. The methods employed for the detection of these individuals are various, and it is frequently necessary to employ several tests. The suspect should be made to relate the history of his case several times at intervals, and it may then be noticed that the different stories do not agree.

When the hearing is tested the malingerer is apt to overdo the case, ignorant of the fact that absolute deafness to all sounds is a very rare condition. During the tests, if the subject is really trying to hear, slight movements of the auricle usually occur, whereas, unless the malingerer is skilful, he will probably neglect this precaution against detection. In cases of simulated deafness in both ears the suggestion, within the hearing of the malingerer, of painful operative procedures will sometimes reveal the nature of the case.

When the subject only claims to be deaf in one ear, various tests may be employed. Thus, a vibrating tuning-fork is placed on the forehead or teeth and the patient will say that he hears it in the good ear. The good ear is then closed with the finger, and the subject is again asked if he hears it. He will then usually say that he does not hear it, being ignorant of the fact that the closing of the good ear actually increases the hearing by bone-conduction.

A more complicated but also a more conclusive test is as follows. The ends of two indiarubber tubes are inserted into the two meatuses, and are led behind him to the physician. The two free ends of the tubes are then held alongside one another, and the physician speaks into the free openings and the subject is asked to repeat the words. By pinching the tubes alternately, the sound can be directed to either ear according to the intention of the physician and without the knowledge of the patient. In this way the deception is almost sure to be revealed before long, by the malingerer repeating words which can only have reached the deaf ear, or by stating that he does not hear words which have reached the good ear.

DEAF-MUTISM.

Deaf-mutism is the result of defective hearing, either congenital or acquired in early life, so marked that the patient either does not learn to speak or else loses what faculty of speech he or she has acquired.

Deaf-mutism is usually spoken of as 'inherited' or 'acquired,' but Hammerschlag has rightly pointed out that this is not a desirable terminology, since a child may be born deaf, and yet not have inherited it in the proper sense of the term, the lesion having been 'acquired' *in utero*. Such cases are apt to be incorrectly described as 'inherited.' He therefore divides deaf-mutes into two classes: (1) *Acquired*, those which owe their defect to local disease of the ear or nerve, and which may be congenital or may occur within the first few years of life; and (2) *constitutional*, which may be sporadic or endemic, resulting from cretinism or from true inheritance from deaf parents or ancestors.

True Inherited.—In the case of true inheritance other defects than deaf-mutism are sometimes present in the relatives of the sufferer, such as epilepsy, mental disorders, etc. It is a curious fact, as observed by Liebreich and Bezold, that retinitis pigmentosa is relatively common among the sufferers of inherited deaf-mutism. In view of the attention which the scientific world has recently directed to Mendel's laws of heredity, it would be interesting to ascertain the extent to which inherited deaf-mutism obeys these laws. So far as the writer is aware, however, the subject has not yet been studied in this light.

Acquired.—Acquired deaf-mutism, using the term in the sense above defined, may result from lesions occurring *in utero*, the cause of which is not properly known. After birth, however, the disorders which produce the aural lesions are

FIG. 117.—FIBROUS ANKYLOSIS OF THE MALLEO-INCUDAL ARTICULATION FROM THE CASE OF A DEAF-MUTE. ×4.

(Prepared and photographed by the Author.)

a, processus gracilis. *b*, processus brevis.

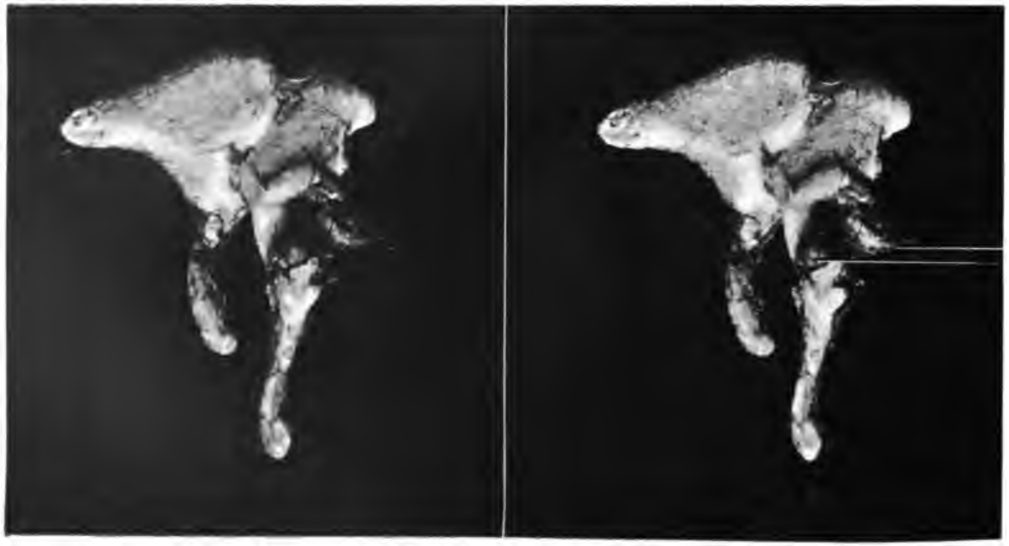


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FIG. 118.—SECTION OF A PORTION OF THE TENSOR TYMPANI MUSCLE FROM A DEAF-MUTE, SHOWING THE NORMAL HEALTHY CONDITION OF THE MUSCULAR FIBRES. × 300.

(Prepared by the Author; photographed by Dr. Leslie Buchanan.)

[To face p. 375.

well recognized. Scarlet fever, cerebrospinal meningitis, cretinism, measles and congenital syphilis, are the commonest causes, but almost any of the acute infectious diseases may destroy the hearing sufficiently to produce deaf-mutism. It is doubtful if suppurative disease entirely confined to the middle ear can be held responsible for deaf-mutism, but if the labyrinth on both sides be involved in the process deaf-mutism will result if the child be sufficiently young. A few rare cases have been recorded in which the removal of adenoids has cured the deaf-mutism. But, with the rarest of exceptions, the deafness caused by the presence of these growths is not sufficient to cause mutism.

About 15 per cent. of deaf-mutes are mentally deficient, and it is a common error to suppose that the percentage is higher. As a rule the deaf-mute is particularly bright.

Pathology.—Although the pathology of deaf-mutism remains to a certain extent obscure, improved methods of investigation and careful observation have in recent times revealed the most important anatomical changes.

In very rare examples the whole organ of hearing—outer, middle and inner ear—has been arrested in development. The middle and inner are coincidently affected in a rather larger percentage of cases, and this may either be of the nature of bilateral inflammatory changes extending from the tympanum into the labyrinth, or it may consist of bilateral arrest of development in both structures. Thus, ankylosis of the stapes in the oval window associated with changes in the labyrinth has been recorded, and fibrous ankylosis of the malleo-incudal joint, also associated with labyrinthine changes, has been described by the author (Fig. 117). Defective formation of the round window has been found by Politzer. So far as is known, however, changes in the middle ear alone are not sufficient to cause deaf-mutism.

In regard to the condition of the *intratympanic muscles*, Denker[1] found the tensor tympani atrophied in one case. In the temporal bones of four deaf-mutes examined by the author,[2] the tensor tympani presented a normal appearance, as is shown in Fig. 118.

[1] Denker, *Aufl. d. Deutsch. Otolog. Gesellsch.*, Lief. iv., Wiesbaden, 1907, J. F. Bergmann.

[2] Gray, *Journal of Laryngology, Rhinology, and Otology*, May, 1910.

In the majority of deaf-mutes, however, the middle ear is quite normal, and the interest centres chiefly in the changes found in the labyrinth.

The changes may be conveniently divided into those which are macroscopic and those which are microscopic.

Among the *macroscopic* changes may be mentioned arrests of development, such as complete absence of the whole or parts of the organ. Siebenmann[1] found complete bilateral absence of both labyrinths in one case out of seventeen, but the actual percentage of such abnormalities is, of course, very much smaller, and, indeed, such a defect is amongst the rare causes of deaf-mutism. Portions of the semicircular canals and cochlea are sometimes absent, but taken altogether these conditions are not common in the deaf-mute.

Deposits of calcareous salts in the vestibule have been found by the author,[2] but they are probably of secondary importance (Fig. 119).

The most interesting of the macroscopic features of the deaf-mute labyrinth relates to its size. This subject has been investigated by the author, and the results were found to be in striking contrast with those which would naturally have been looked for. In the case of an organ whose function has been entirely or almost entirely abrogated either from birth or from within five or six years thereafter, it would be expected that the structure would retain its infantile measurement. But out of three cases examined exactly the reverse was found, the labyrinth in all being noticeably larger than in the normal human adult. These findings were the more remarkable in view of the fact that only one of the subjects had reached adult life, the other two being nine and eleven years old respectively. This increase in the size of the labyrinth was true of the individual parts as well as of the organ as a whole, as the table on p. 377 demonstrates.

Limits of space prevent the further discussion of these peculiar facts. It may be said, however, that they appear to indicate the occurrence of increased intralabyrinthine pressure either during intra-uterine life or very shortly thereafter, when the walls of the labyrinth have not acquired the rigidity which

[1] Siebenmann, *Archives of Otology*, vol. xxxiii., p. 504.
[2] Gray, *loc. cit.*

FIG. 119.—MEMBRANOUS LABYRINTH FROM A DEAF-MUTE. × 3½.

(Prepared and photographed by the Author.)

The outline of the organ is normal. Deposits of calcareous salts are seen in the utricle, saccule, and horizontal canal.

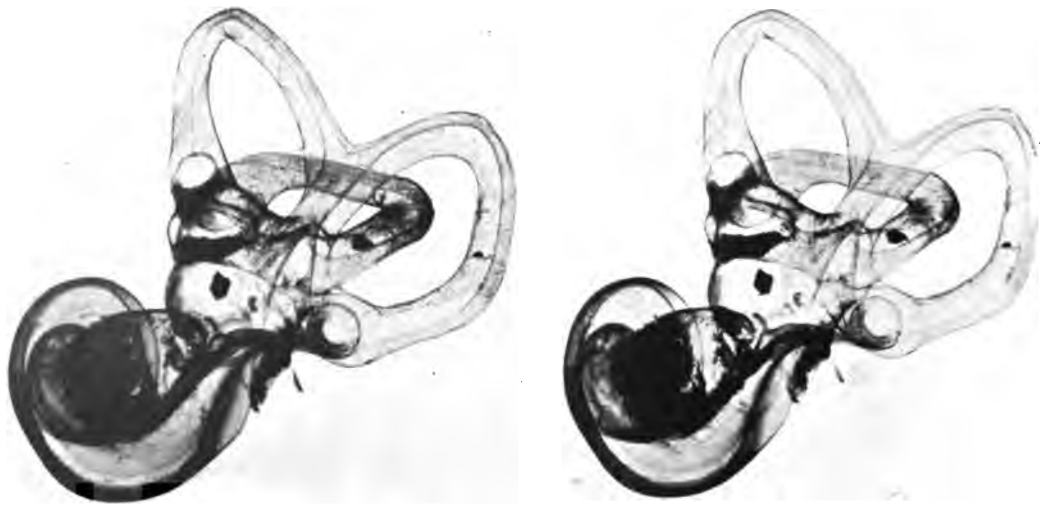

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FIG. 120.—SCALA MEDIA OF THE COCHLEA FROM A DEAF-MUTE. × 100.

(Prepared by the Author; photomicrographed by Dr. Leslie Buchanan.)

There is little if any departure from the normal.

[*To face p.* 377.

TABLE OF MEASUREMENTS OF THE LABYRINTH.

	Newly-born Child.	*Average Human Adult.*	*Deaf-mute aged 32. Case I. (Right).*	*Deaf-mute aged 9. Case II. (Left).*	*Deaf-mute aged 11. Case III. (Right).*
	Millimetres.	Millimetres.	Millimetres.	Millimetres.	Millimetres.
Length of labyrinth from vertex of the posterior canal to innermost point on cochlea	16·20*	17·25	19·25	19·00	19·00
Diameter of lowest whorl of cochlea at its widest	—	8·25	9·75	9·50	8·50
Diameter of second whorl of cochlea at its widest	—	4·62	5·75	5·50	5·25
Diameter of tube of cochlea just in front of round window	—	2·06	2·75	2·50	2·25
Diameter of vestibule above the oval window ..	—	3·50	5·50	5·50	5·50
Transverse diameter of superior canal from limb to limb (internal)	—	4·30	6·00	6·00	6·00
Transverse diameter of superior canal from limb to limb (external)	—	8·00	9·00	9·00	8·50
Height of vertex of superior canal above vestibule	—	4·30	6·00	6·00	5·75
Transverse diameter of posterior canal from limb to limb (internal)	—	4·02	5·00	5·00	5·00
Transverse diameter of posterior canal from limb to limb (external)	—	7·68	8·25	8·50	8·00
Height of vertex of posterior canal above vestibule	—	3·07	6·00	6·50	5·50
Transverse diameter of horizontal canal from limb to limb (internal)	—	2·56	3·25	3·25	3·00
Transverse diameter of horizontal canal from limb to limb (external)	—	6·87	8·50	8·00	6·00
Height of vertex of horizontal canal above vestibule	—	2·75	4·50	4·50	4·00
Length of major axis of oval window	—	2·25	2·75	2·75	2·25

* This measurement is taken from Alexander's paper, ***Arbeit. aus. d. Anatom. Institut.***, Bd. xix., S. 571. The other measurements by Alexander were taken at different points from those of the writer and cannot, therefore, be compared with the latter.

they subsequently do, and when, therefore, they can yield before the pressure within. Such increased pressure may be caused by inflammatory activity within the labyrinth itself, or may be transmitted from the cranial cavity by way of the aqueduct of the cochlea.

Microscopic Changes.—The microscopic changes in the labyrinth of the deaf-mute have been investigated in recent times by Siebenmann, Denker, Alexander, Görke, Schwabach, the author, and others. In a few rare cases there may be no departure from the normal sufficient to be termed pathological. In Fig. 120 may be seen the scala media and organ of Corti prepared from one of such subjects. The nerve fibres in the lamina spiralis and in the auditory nerve also appeared to be quite normal, and the cells of the ganglion spirale were healthy.

In the great majority of deaf-mutes, however, very definite changes are found in the labyrinth. The commonest of these are complete disorganization of the organ of Corti, depression and thickening of the membrane of Reissner, and sometimes adhesion of that structure to the organ of Corti. The tectorial membrane is frequently absent. These conditions may be seen in Fig. 121. The nerve fibres in the lamina spiralis are degenerated, as also are those in the cochlear branch of the auditory nerve (Fig. 122). The nerves to the ampullæ of the canals and the cristæ in the vestibule are frequently quite healthy, but sometimes degenerated.

A curious feature of the cochlea in some subjects of deaf-mutism is a remarkable development of the stria vascularis. This consists of a striking enlargement of that structure, so that it projects into the scala media and, becoming pedunculated, may reach almost as far as the organ of Corti. As will be seen from Fig. 123, the growth is of the nature of a true hypertrophy, the differentiation of the cellular elements being far more complete than that found as the ordinary result of inflammatory activity in post-natal life. It consists of a core of connective tissue covered by a layer of cubical epithelial cells almost identical in appearance with those of the normal stria vascularis. The bloodvessel which lies at the base of the structure is very much enlarged. This excessive development of the stria vascularis appears to the writer to indicate the occurrence of a process of repair in fœtal life—a time at

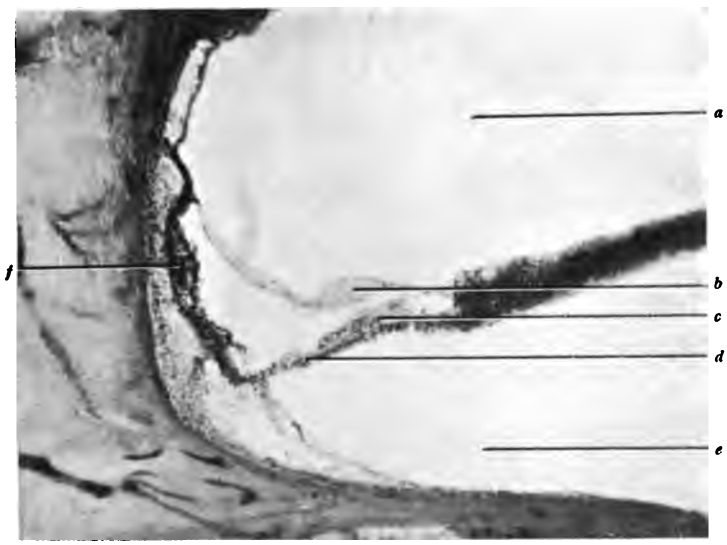

FIG. 121.—SCALA MEDIA OF THE COCHLEA FROM A DEAF-MUTE. × 100.

(Prepared by the Author; photomicrographed by Dr. Leslie Buchanan.)

The membrane of Reissner is depressed and thickened, the organ of Corti is disorganized, and the stria vascularis shows pathological changes.

a, scala tympani.
b, membrane of Reissner.
c, organ of Corti.
d basilar membrane.
e, scala vestibuli.
f, stria vascularis.

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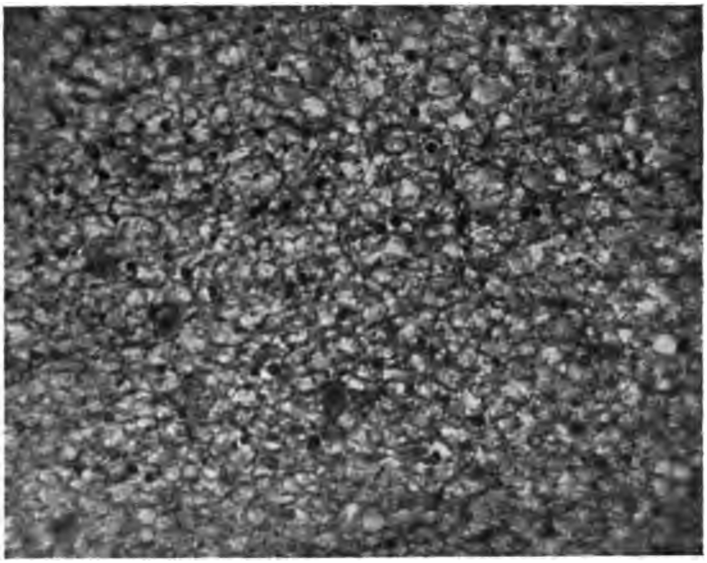

FIG. 122.—SECTION OF COCHLEAR BRANCH OF AUDITORY NERVE OF A DEAF-MUTE. × 300.

(Prepared by the Author; photomicrographed by Dr. Leslie Buchanan.)

There is almost complete degeneration of the nerve fibres. A few normal fibres are seen in the figure.

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which cell differentiation can be carried out far more completely than is possible later.

Bony, calcareous and connective-tissue formations encroaching upon the cavity of the labyrinth are, according to Mygind,[1] frequently found in deaf-mutes.

As regards changes in the brain, it should be stated that arrested development of the third left frontal convolution and of the Island of Reil have been recorded several times, and in one case atrophy of the first temporal convolution has been found.

Consanguinity.—It is a popular belief that the offspring of a marriage between near relations is a cause of deaf-mutism. It is very doubtful if consanguinity of the parents, *per se*, could ever be held responsible for any defect such as deaf-mutism. But it is not difficult to understand why such a belief has come into existence. For if two individuals have as a common ancestor a constitutional deaf-mute, it is obvious that, in accordance with the laws of heredity, there is very considerable possibility of some of the offspring being deaf-mutes, even when the parents themselves manifest no trouble of hearing. Now, it is to be noticed that even in this case the deaf-mutism must be, in the strict sense of the term, of the inherited type. Acquired deaf-mutism, whether it be acquired after birth or *in utero*, could not be transmitted under any circumstances if the modern view of the non-transmissibility of acquired characteristics be correct.

Examination of Deaf-mutes.—In proceeding to make a clinical examination of a suspected deaf-mute, it is of the utmost importance to see that the child does not observe the movements concerned in producing the sound. The patient should either be blindfolded, or the sound should be produced behind his back. The hearing must be tested throughout the whole length of the scale, and if the face of the child be studied during the tests, it will at once be seen to light up if the sound is heard. These tests may be carried out with tuning-forks, organ-pipes and Galton's whistle, and, should 'islands of hearing' occur in any part of the scale, they should be noted. The bone-conduction should also be tested. If there is no response to these tests, then a loud bell should be tried and finally, of course, the voice must be employed.

[1] Mygind, *Arch. f. Ohrenh.*, Bd. xxx.

The condition of the vestibular apparatus in deaf-mutes may be tested by Barany's method. In this respect the number of deaf-mutes in which the functions of this portion of the labyrinth is effected is smaller than would be expected.

Prognosis and Treatment.—The outlook for the deaf-mute is unfavourable. Cases have been recorded in medical literature in which the patient acquired sufficient hearing-power to enable him to develop the faculty of speech, but they are so rare that they may be considered as having no weight in giving a prognosis. Adenoids, if present, should be removed if they are interfering in any other way with the development of the child, but their removal cannot be expected to improve the hearing perceptibly. It is doubtless true that in rare circumstances the removal of the growths has been followed by the acquisition of speech,[1] but, as stated above, these are so unusual that they may almost be considered negligible in the prognosis.

Treatment.—Any diseased middle-ear condition, such as suppuration, must be attended to, but beyond this the treatment is purely educational. Two systems are in vogue, the French and German, as they are sometimes termed, or the manual and oral respectively. One of the earliest pioneers of the former was the Abbé Sicard, whose miraculous escapes by the aid of the brave watchmaker, in the September massacres of the French Revolution, form one of the most fascinating pages in Carlyle's history of that time. In the manual system signs are substituted for speech, while in the oral system the patient is taught to speak, though articulation is frequently very imperfect.

In deciding upon which method to employ each case must be studied individually. The factors to be considered are the amount of hearing-power which may still be present and the intelligence of the patient. If the child is bright and has a certain amount of hearing left, the oral method is to be preferred, but in mentally defective children the manual system should be employed. After having decided on the method to be adopted, the child should be sent to a suitable instructor.

For further information on the educational aspects of deaf-mutism, the reader is referred to Love's work.[2]

[1] Yearsley, 'Diseases of the Ear,' p. 421, 1908.

[2] Love, 'The Study of the Deaf Child.' Glasgow, 1907.

FIG. 123.—SECTION OF THE SCALA MEDIA IN THE UPPERMOST WHORL OF THE COCHLEA OF A DEAF-MUTE. × 300.

(Prepared by the Author; photomicrographed by Dr. Leslie Buchanan.)

The organ of Corti is completely degenerated. The stria vascularis has undergone a remarkable process of development (*cf.* Figs. 36 and 38).

a, stria vascularis. *b*, organ of Corti. *c*, membrane of Reissner.

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THE BEARING OF EAR DISEASE UPON LIFE INSURANCE.

Applicants for life insurance are sometimes sent to the surgeon on account of some ear condition which may affect the granting of a policy, and a few words therefore may be said in this connection.

Deafness alone does not add sufficient risk to demand an increased premium. Individuals who are hard of hearing learn to take care of themselves so well by the training of the other senses that the defect has no perceptible influence in shortening life.

When, however, the applicant is the subject of otorrhœa, the question is quite otherwise. This condition is dangerous to life, and the applicant should be refused until, and for some time after the discharge has ceased.

The presence of an old perforation in an ear which has long since ceased to discharge is hardly a sufficient cause for rejection, or even for an increased premium. But if the discharge has only recently ceased, the application should be suspended for a year, and if during that period the ear remains dry the case may be accepted. Similarly, if after operation the suppurative process is brought to a termination, and the ear is found to be dry at the end of a year, there is no cause for rejection.

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THE END

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