SOCIETIES' PROCEEDINGS

ROYAL SOCIETY OF MEDICINE—SECTION OF OTOLOGY.

SUMMER MEETING.

June 21, 22, 1929.

President—SOMERVILLE HASTINGS, M.S.

(*Continued from* Vol. xliv., No. 12, p. 846.)

Demonstration of a Model Resonator, designed to illustrate the Mechanism of the Cochlea.

GEORGE WILKINSON, F.R.C.S.

IN considering the cochlea as a possible resonating system, I would suggest that the most direct line of approach to the problem is somewhat as follows. The basilar membrane appears to be the only possible resonating structure in the cochlea. If it does actually function by resonance, its reactions extend over some 10 octaves. Consequently, it should show a differentiation of structure in its parts corresponding to this extensive range of its reactions. Suppose, for simplicity, we take the limits of pitch perception as 20 to 20,000 d.v. per second: on the basis of the formula for vibrating

$$n = \frac{1}{2l}\sqrt{\frac{t}{m,}}$$

strings this implies that if the differentiation were by reason of the length of the basilar fibres alone, the longest would require to be one thousand times longer than the shortest, or, if it were by mass or tension alone, the proportion would be 1 to 1,000,000. We know from anatomical observation that the length of the basilar fibres varies between the limits 1 to 3. This leaves a variation of 333 units of frequency to be accounted for by variations in tension or mass, or both concurrently. If the variation were of tension alone, the tensions would have to have a range of 1 to 111,000. Have we evidence of variation in the tensions of the basilar fibres? The answer is supplied by the striking variations in density and bulk of the spiral ligament attaching the basilar fibres to the outer wall of the cochlear galleries, which was first pointed out by Dr Gray in 1900. It would be difficult to give any alternative explanation of this striking graduation of the spiral ligament other than that of a corresponding graduation of tensions of the basilar fibres, and indeed it would be difficult to imagine any other means by which such a graduation could be effected. But if tension alone is concerned, the necessary range of tensions

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seems excessive. It is hundreds of times greater than the range of tensions employed in any of our stringed instruments. The lowest tensions must be sufficient to straighten out the fibres, and to provide an appreciable resistance to deformation of the fibres by stresses acting across them, whilst the highest tensions must be sufficiently below the breaking strain to leave a margin of safety. There must be very few kinds of fibres that would stand up to such an extensive range of tensions.

Is there any indication in the cochlea of a graduation of mass such as would lower our estimate of the range of tensions required to give the full pitch range? In former writings I have suggested that the indication of graduation by mass is to be found in the fact that the basilar membrane is immersed in fluid. This would act as a load on the basilar fibres, similar to the copper wire with which the bass strings of a piano or harp are loaded. Those transverse sectors of the basilar membrane which are placed at the proximal end of the scale, nearest to the round and oval windows, would be lightly loaded, whilst those at the distal end would be heavily loaded by long columns of fluid. Note that the differentiation of the basilar membrane by all these factors—length, tension, and mass—is in the same sense so far as is required to graduate its periods of vibration. The shortest fibres are the tightest and the least heavily loaded, whilst the longest are the least tense and the most heavily loaded. I have ventured to suggest a simple transformation of the formula for vibrating strings:

$$n = \frac{1}{2l}\sqrt{\frac{t}{m}}$$

which I thought would express mathematically the relation of the various physical factors in the cochlea.

The formula I have put forward is

$$n = \frac{1}{2l}\sqrt{\frac{T}{db}}$$

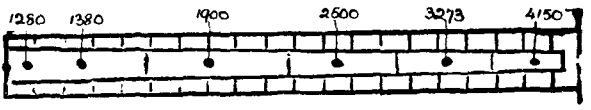
where n = number of vibrations per second, l = transverse breadth of the basilar membrane at the particular level of the scale concerned, T = the total tension on the basilar fibres comprised in the transverse sector, d = the sum of the distances of the sector from the round and oval windows, and b = the width of the sector.

I have recently been experimenting with a large-sized model 40 cm. long, which has special advantages in investigating the question of the fluid load, as theoretically this factor should be very large in comparison to the other factors in models on such a large scale. By removing the glass window from the top of the model, one converts it from a closed box into an open trough. By drawing off the fluid in the model in successive stages the amount of the fluid load can be progressively reduced, and the rise of pitch of the different transverse

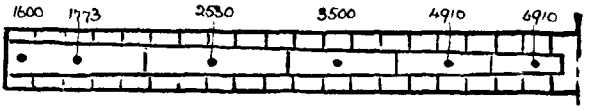
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1. Natural periods of vibration of membrane soaked in water but not immersed, as calculated according to the formula

$$n = \frac{1}{2l}\sqrt{\frac{t}{m}}$$

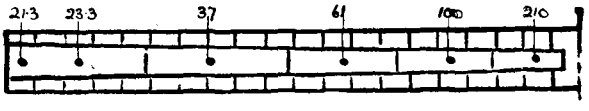


2. Ditto, with correction for stiffness of wire.

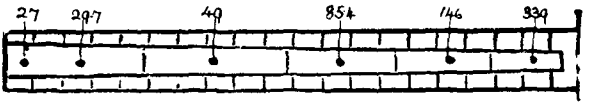


3. Natural periods of membrane in model when filled with water, as calculated according to hypothetical formula

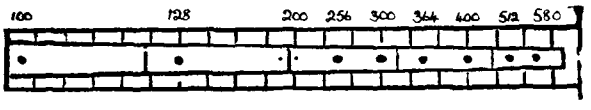
$$n = \frac{1}{2l}\sqrt{\frac{T}{db}}$$



4. Ditto, with correction for stiffness of wire.



5. Observed reactions in model when filled with fluid.



6. Plate reversed in model. Helicotrema plugged. All tuning-forks give only forced reactions starting from helicotremal end. No resonant responses.

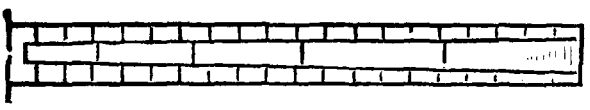
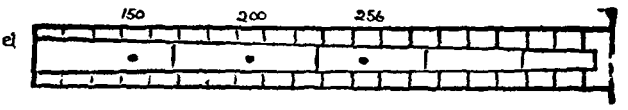


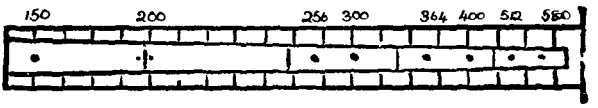
CHART I.

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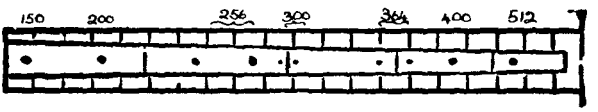
1. Reactions when glass windows removed, upper chambers filled with water to level of windows = 1·2 cm. above basilar membrane.



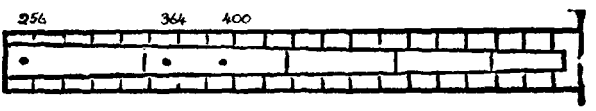
2. Ditto.
0·6 cm. of water above level of basilar membrane.



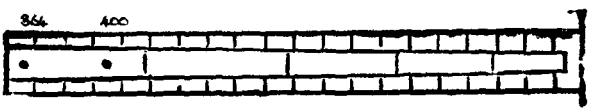
3. Ditto.
0·2 cm. of water above level of basilar membrane.



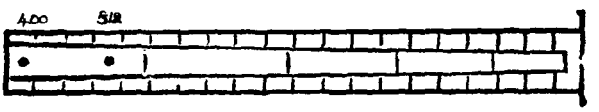
4. Lower chamber empty. Helicotrema plugged. 0·6 cm. of water above basilar membrane.



5. Ditto.
0·4 cm. of water above basilar membrane.



6. Ditto.
0·2 cm. of water above basilar membrane.



7. Ditto.
0·1 cm. of water above basilar membrane.

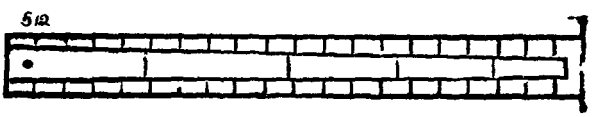


CHART 2.

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sectors resulting from the lessening of the fluid load can be observed. I have tabulated the results observed on the accompanying charts.

The conclusions I have drawn from these observations are that:—

(1) The basilar membrane of the model is thrown into localised vibration at one level, by the application of a sounding tuning-fork to the stapes. The locus of the vibration varies with the pitch of tuning-fork.

(2) There can be no question that, in the models, the immersion of the basilar membrane in fluid causes a very considerable lowering of the natural frequencies of vibration of the basilar fibres over the whole scale.

(3) This lowering of pitch is somewhat greater at the distal end of the scale than at the end nearest the windows.

(4) Neither the absolute lowering of pitch of the whole scale nor the relative lowering at the distal—as compared with the proximal — section of the membrane is as great as anticipated on the basis of the hypothetical formula

$$n = \frac{1}{2l}\sqrt{\frac{T}{db}}.$$

Consequently the formula does not actually express the relative value of the fluid load in terms of mass. Probably the relationship of the various physical factors governing the periodicity of vibration of the various sectors of the basilar membrane is much more complicated than that expressed by the formula.

The Evolution of the Sense of Hearing.

A. Lowndes Yates, M.D.

The Evolution of the Cochlea.—In the development of all animals, the sense organ which later becomes a labyrinth develops first as a thickening of the epidermis and later sinks into the mesodermal structures and becomes flask-shaped. It is probable that the portion of the epidermis so developed is originally a part of the lateral line which is well developed as a tactile organ in the fish. On the upper surface of this flask-shaped epidermal structure a narrow fold makes its appearance. The first appearance of this structure in animals is when it is elaborated into the two vertical semicircular canals and a single central chamber, a condition which is present in the labyrinth of the hag fish (Fig. 1).* The horizontal

* Figs. 2 to 7, L = Lagena; M B = Macula basilaris. The macula basilaris develops at the base of the lagena, and in the stages of evolution of the cochlea, the lagena practically disappears.

Figs. 1 to 7 are taken from Retzius' *Das Gehörorgan der Wirbelthiere* (Stockholm, 1884).

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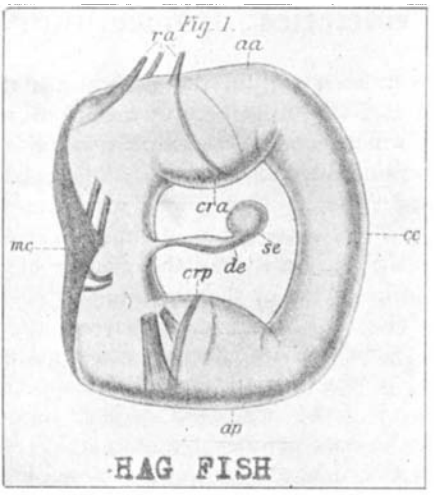


FIG. 1.

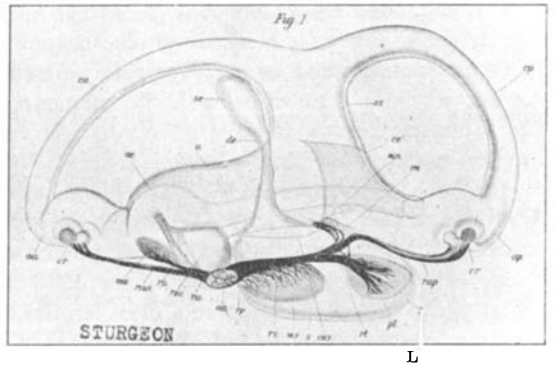


FIG. 2.

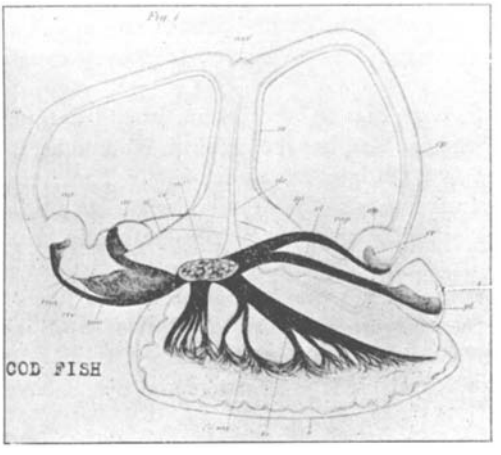


FIG. 3.

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canal is developed later, and in the bony fishes three semicircular canals are found and also three sensory areas covered by calcareous material, each of which is roughly in such a position that it can deal with movement in one direction of space. These labyrinthine organs have peculiar and intricate connections with the swim bladder of carps and herrings. Of these three otolithic organs one, the lagena, is not present in the adult man and the manner of its disappearance is the key to the evolution of the cochlea.

In amphibia (Fig. 4) Nature made several attempts at forming auditory organs. One, the macula neglecta, appears like a flash in the development of the human ear and disappears. In amphibia the first appearance of the structure that later becomes the cochlea is a dilatation at the base of one of the otolithic organs, namely, the lagena. In frogs this dilatation is quite ill-developed, but a thinning in the skull and a second thinning of the otitic capsule represent the beginning of a fossa ovalis and rotunda. Such thinnings are absent in the fish and in the urodeles, but present in all the higher amphibia, and in these the pars basilaris of the lagena has a thin circular basilar membrane framed in cartilage and beneath it a small peri-lymphatic sac in close connection with the meninges.

In reptilia, the sense organs of the pars basilaris lagenæ come to lie on the basilar membrane. Many different stages of evolution of the ear may be observed in reptiles, culminating in that of crocodiles which is very similar to that found in birds. In the crocodile is seen the first appearance of stretched diagonal fibres and the elements of the cochlear sense organ show an orderly arrangement.

In birds (Fig. 5) the lagena has become a mere terminal appendage of its pars basilaris which now is called the cochlea and in birds is straight. In spite of the primitive nature of the cochlea of birds, this sense organ is capable of very great power of discrimination. Thus the number of fibres in the parrot's cochlea is 1200, compared with 24,000 in man, but the parrot is plainly capable of accurate analysis of sound.

In monotremes (Fig. 6), the lagena is still a functional terminal appendage of the cochlea, but thereafter in mammalia, it disappears and is represented by a vestigial remainder only. The further evolution of the cochlea of mammals is one of combined elaboration of the sensory structure with simplification of the peri-lymphatic structures (Fig. 7). The work of Dr A. A. Gray has greatly clarified the views with regard to the elaboration of the human cochlea. His justly famous monographs have carried on the work of Retzius and it is from these sources and from the work of Professor Burne, the physiological curator of the Royal College of Surgeons, that I have gathered this brief review.

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As to the method of working of the cochlea, we have little more than surmise to guide us. The theory of resonators, put forward by Helmholtz, is seriously shaken, both by the efficacy of the lowly cochlea of parrots and by the fact that, in the pig, portions of the sense organ, though fully functional, rest on the bone and not upon the basilar membrane. Dr A. A. Gray has explained that it is not necessary for an individual cord to act as a single resonator, and, later, Wilkinson and Gray have brought forward the theory of the formation of sound patterns in the cochlea. This conforms with the facts met with in other sense organs, for when we touch a key we get a tactile pattern of sensation of it, and if we see the letters of the alphabet we get a visual pattern of the letters, and in no case do our educated special senses record the single point impressions of a sensation even if such single point impressions actually exist in consciousness.

Now in the evolution of the cochlea, a gradual elaboration of its microscopical structure can be demonstrated, which reaches its greatest height in man, and in the brain there is a corresponding and probably synchronous evolution of the auditory centre and of the whole of the neopallium. The sense of hearing, in fact, has been evolved as a result of the evolution of the organ of hearing, but the evolution of the upper centres in the neopallium has far outstripped the evolution of the sense organ. There is, in fact, a fair amount of evidence that the cochlea and the semicircular canals are, as a whole, in a state of involution. This involution begins in the semicircular canals, which, in man and higher animals, are noticeably less evolved than in the fish, presumably because the postural reflexes have, to a large extent, usurped their function and removed the need for the more primitive form of balancing apparatus.

In the case of the cochlea, evolution in respect of the sensitivity of the organ continued and reached its highest point in mammals. It is common knowledge that the dog hears better than man, and that therefore from the point of view of acuity the cochlea of man has undergone a certain amount of involution.

The Evidence of Embryology.—The Eustachian tube develops as a recess between the first and third visceral arches. The tympanum does not exist until the third month of fœtal life (Keith), for the Eustachian recess ends in a mass of jelly-like material containing the cartilaginous bases of the ossicles. As this jelly-like material is absorbed, the entodermal lining is pushed in and covers the ossicles and the membrane on its inner side. The mastoid antrum develops in the sixth and seventh months by an extension upwards and backwards of the Eustachian tube. The stapes develops from the hyomandibular bar of cartilage; the malleus represents the upper end

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of Meckel's cartilage, and the incus the quadrate bone of lower mammals. As a result of this, the incus in a certain stage of development is attached to the base of the skull, and this bony attachment

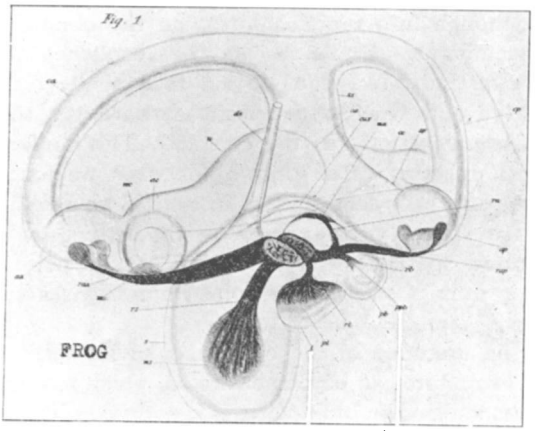


FIG. 4.

is absorbed, leaving a ligament in its place to support the incus; this resulting ligament varies considerably in thickness.

The external ear is developed as a pit derived from the first cleft

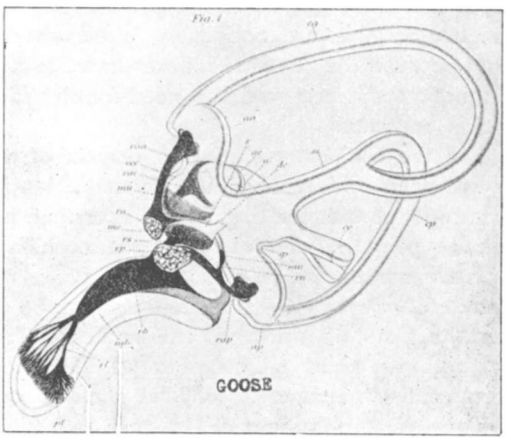


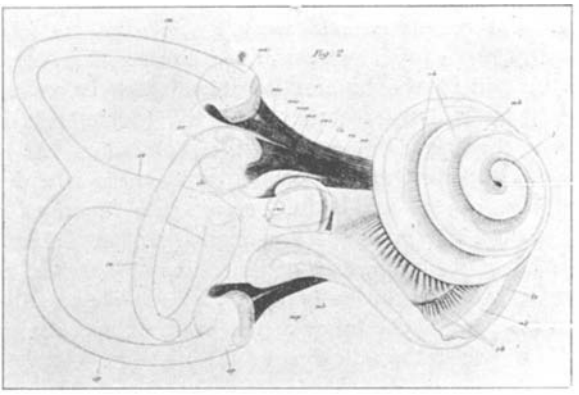
FIG. 5.

depression. The deeper part arises during the second and third months of fœtal life by a solid ingrowth of epithelium beginning at the bottom of this pit. When it reaches the future level of the

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membrane it expands, and in the seventh month its centre is absorbed, leaving a canal.

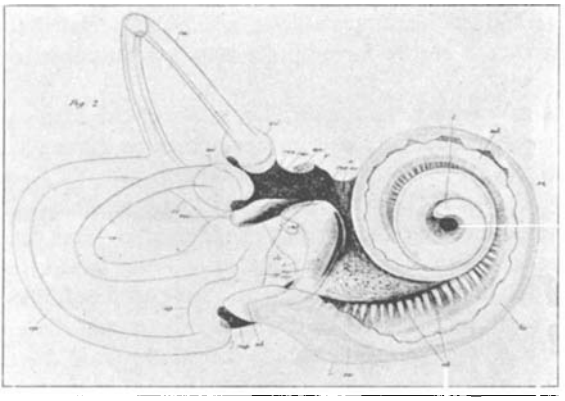
The labyrinth is developed from a thickening of the epidermis,



(PIG)

FIG. 6.

which is present in the embryo of 2.6 mm. length. This is invaginated to form the otocyst in the embryo of 3.2 mm. and is cut off from the exterior in the 4.5 mm. embryo. In the 20 mm. embryo the cochlea has three-quarters of a turn.



(MAN)

FIG. 7.

The epithelial cells lining the cochlea become flattened, excepting in the region of the sensory cells, where they develop hairs and come in contact with the ganglion spirale of uncertain origin.

In the fifth week there is a ductus endolymphaticus, a vestibular pouch and a cochlear pouch. In the sixth week, from the vestibular

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portion there develop the ductus and saccus endolymphaticus, the semicircular canals and ampullæ; the utricle, saccula and cochlea rudiment is in the form of a bent canal. In the tenth week all the parts are present almost in their adult form, and in the twelfth week the cochlea has three turns. (Howden.)

Evolution of the Auditory Areas of the Brain.—As we ascend the scale from the fish to the highest mammals there is an increase in the complexity of structure of the mid-brain, which leads ultimately in mammals to the formation of the inferior colliculus. As we ascend the scale from the lowest apes to modern man there is a decrease in the relative size of the mid-brain, because the functions of it are passed over to the cortex of the ever-increasing neopallium.

The surface of the brain and of its various lobes has undergone a great increase in the evolution of man from ape-like ancestors. The difference in the area of the lobes of the brain of man compared with that of apes is shown in the following table:—

	Man	Tarsus
Whole brain	24	1
Auditory lobe	85	1
Occipital lobe	4	1
Parietal lobe	80	1
Motor cortex	8	1
Frontal lobe excluding motor area . .	240	1

In the next figure I have attempted to show this in graphic form. It will be seen that there is a great increase in the frontal lobe, in the parietal lobe and in the temporal lobe, while the occipital lobe and the area of the motor cortex have undergone a relatively slight increase (Fig. 8).

In casts taken from the fossilised remains of the skulls of primitive men, the same gradual increase in these portions of the brain may be detected (Fig. 9).

Evolution of the Power of Auditory Interpretation.—The brilliant work of Pavlov has introduced us to the idea of reflexes, which operate only under certain definite conditions. One of his best known experiments is that in which a bell was rung at feeding time and the dogs that were under observation learned to associate this sound with the idea of food. It is common knowledge that dogs and horses will associate a certain group of words with the idea of food, or with simple movements. Horses will stop or start in response to verbal orders, and elephants will carry out most complicated orders at command. The lower monkeys do not appear to respond to orders as readily as many lower animals, but the higher apes, particularly the chimpanzees, are very quick in their response to orders. "Jack" and "Bubu," the chimpanzees at the Zoo, are particularly interesting little animals. When in their cage they are by no means polite to each

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other and are not particularly gentle. They rush at their food and snatch it noisily. Out of their cage and in the presence of their keeper they assume their party manners and are obviously shy. They do not attempt to take food in front of them until the keeper says, "Jack, take a banana," and then Jack does so. "Break it in half, and give half to Bubu." This he does. "Now give the other half to man, myself. Now, Bubu, give your half to Jack," and Bubu does so and bursts into tears and goes on sobbing just like a child, after it has been given back to her. Next Jack is told to take a bunch of

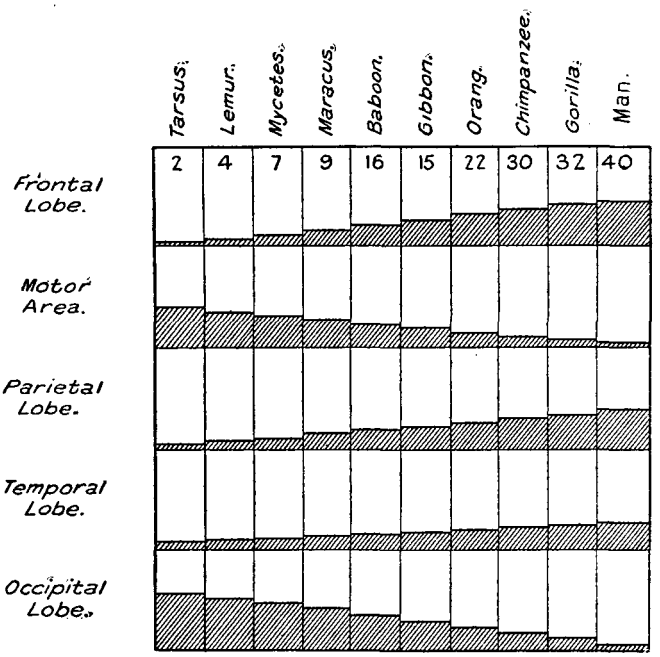


FIG. 8.

keys and from them he at once selects the key which fits the lock of his cage, lifts the cover of the keyhole and inserts the key, but, though he tries to do so, he cannot turn the key because the thumb is so small and as yet so little evolved.

This high intelligence is not, however, the natural condition of the monkey. Chimpanzees who have not been trained by men chatter, while the domesticated monkey is relatively silent. While in their chattering they seem, like the dog, to be endeavouring to express themselves, there is no evidence at all that they have any code of speech and each dog or monkey makes a noise which he thinks expresses his emotions, but is not the same as that which other monkeys or dogs employ in similar circumstances.

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When we come to study children, it is evident that in babyhood they pass through a phase similar to that met with in the lower animals. They chatter to themselves long before they have learned to understand even the most simple forms of speech. Then comes a time in which they undoubtedly hear and understand spoken words, particularly if reduplicated. Lastly there comes a time when the child imitates the sound of the words that it has heard and slowly learns to speak, that is to say, to adopt the sounds of words instead of the noises that it would naturally make as a vehicle of expression of its thoughts.

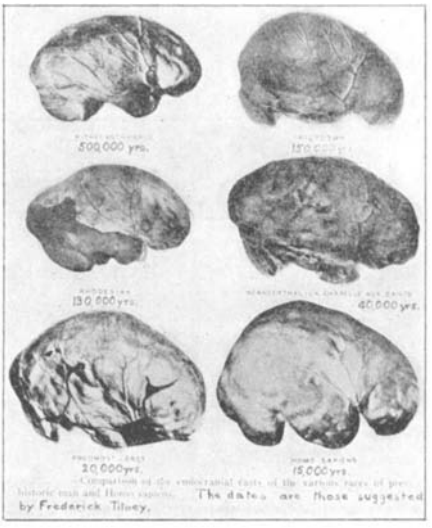


FIG. 9.—In the casts from the interior of the skulls of primitive men, shown in this figure, there is a gradual evolution of the neopallium and in particular of the frontal and parietal areas and also of the temporal lobe.

(From *The Brain from Ape to Man*, by Frederick Tilney, New York, 1928 [Hoeber].)

So far as I have spoken of the evolution of the analytical sense of hearing, it is clear that the evidence seems to be in favour of a hypothesis that the analytical sense of hearing is the main cause of development of the intellect, and this is, I think, generally true throughout the whole period of intellectual development. It is, however, necessary to consider certain factors which may modify this view.

In the lower animals the sense of hearing is a mid-brain function and is primarily connected with the need of auditory warning of the approach of enemies or of other animals which will serve as food. This sense is never wholly lost in man and it is noticeably acute in mentally

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deficient children. There is one type of mentally deficient child which is of special interest in this connection, namely, that in which the intellect develops normally, though a little slowly, until the intellectual powers are equal to those of a child of a certain age, say of ten years of age, and there the intellectual powers stick and cannot be developed further. I am informed that this is the normal mode of education in certain primitive peoples who attain a certain intellectual status and cannot be educated beyond this. Now in these children the hearing as a sense of warning is markedly developed and the failure in their further education seems to be due to lack of power to appreciate speech in its higher forms. Next, it is necessary to consider the two main types of intellect, the auditory and the visual. Some people can appreciate things far more easily when they see them, others when they hear them. In this connection we have to consider the manner in which the idea reaches our minds when we read.

I find that all normal persons, when they read, think of the sound of the word they see, before they can appreciate its meaning, and if they do not raise the idea of the sound of that word in their minds, they skim the word and do not understand it. I have said "all *normal* persons," and by the remaining abnormal persons I mean those who are congenitally deaf or become deaf in early childhood. These, when they have learned to speak, associate the word they see with sensation of movement of the tongue and lips such as will form the word.

A further investigation of the matter seemed to prove that we use our sense of sight in two quite separate ways. If we look about a room and see the objects in it, we get a mass visual impression of them. If we examine them more minutely and think of the purpose for which they are employed, we call into our minds the sound of the words which form our thoughts about these objects. A similar analytical power is found associated with the sense of touch, as a result of which we think of the sound of the words which form our thoughts on touching any object, or alternatively just touch it without thinking.

Hearing, then—that is, the analytical sense of hearing—is the prime sense of the intellect, and the more we realise this, the more important does the higher study of otology become. Viewed from this aspect, the study of deafness becomes comparable to the study of a change of auditory environment.

It seemed probable that although the external environment of sound was unaltered, the sound, when it had been translated by the ear into nerve impulses, was altered. I made an attempt to assess this alteration in the following way: I took a microphone and fitted it with a membrane and with levers to represent the auditory ossicles.

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This was connected to a loud speaker in another room. I then caused the microphone to record the sounds made by a gramophone and listened to the loud speaker. I then caused adhesions to form with glue beneath the membrane and noted the alteration in the sound emitted by the loud speaker. The sounds of the letters B, D, C, V, B, P, E, came through badly. I then perforated the membrane and found that the alteration in the sounds emitted by the loud speaker was made worse. I then removed the adhesions and found an alteration in the strength, but not in the quality, of the sounds. I then tried to damage the microphone itself, but destroyed it.

I then examined deaf persons. Those with middle-ear deafness showed a difficulty in appreciating the sounds B, D, C, V, B, P, E. Those with perforations and no apparent adhesions, had no difficulty of interpretation but had a diminished power of hearing simple sounds, but all showed a factor which was not present in the experimental model, namely, the increase of deafness due to auditory fatigue, and as this was infinitely more marked in cases with an alteration in their analytical power, I assumed that the fatigue was cerebral in origin.

Lastly, I examined patients in a search for evidence of involution. It seemed that if the deafness came on suddenly involution was often very evident and that the sufferer retraced the path of evolution; he became auditorily timorous, his power of appreciation of spoken words slowed, while the groups of words, the phase words, the power to hear which is the last evolved, was early lost. If the deafness came on slowly, particularly when people of good auditory intelligence were the sufferers, they learned to note the difference in the message going to their brain and suffered very little from deafness even when the lesion was evident on inspection of the ear.

The patients who were youthful and therefore in the days of easy education seemed, in particular, to escape the results of damage to the ear and to be educated to their different auditory environment.

The older patients and particularly those who were not accustomed to employ their hearing in the decision of important questions, showed marked involution of their powers of interpretation and when their hearing was recorded on an audiograph they proved to have a certain degree of deafness for the simple notes, say, 30 per cent. H.D., and a much greater diminution of their hearing power for the human voice, say, 90 per cent. H.D. I have attempted to express these facts in graphic form in Figs. 10 to 13.*

* Figs. 10 to 13.—The dotted line . . . . represents the power of hearing simple tones. The broken line - - - represents the use of this as a protective sense of hearing. The thick continuous line ——— represents the evolution, or the development, of the sense of interpretive hearing.

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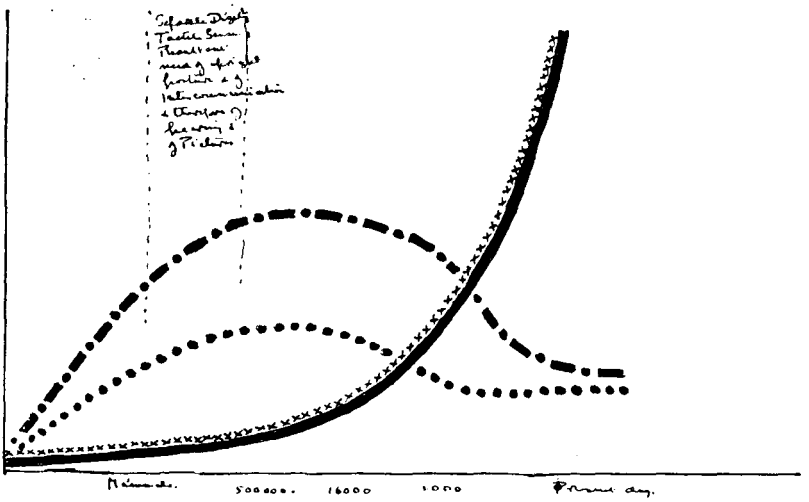


FIG. 10.—THE EVOLUTION OF THE SENSE OF HEARING.

The line × × × × represents the evolution of the auditory area of the neo-pallium. The figures indicate the approximate number of years considered in the period of evolution.

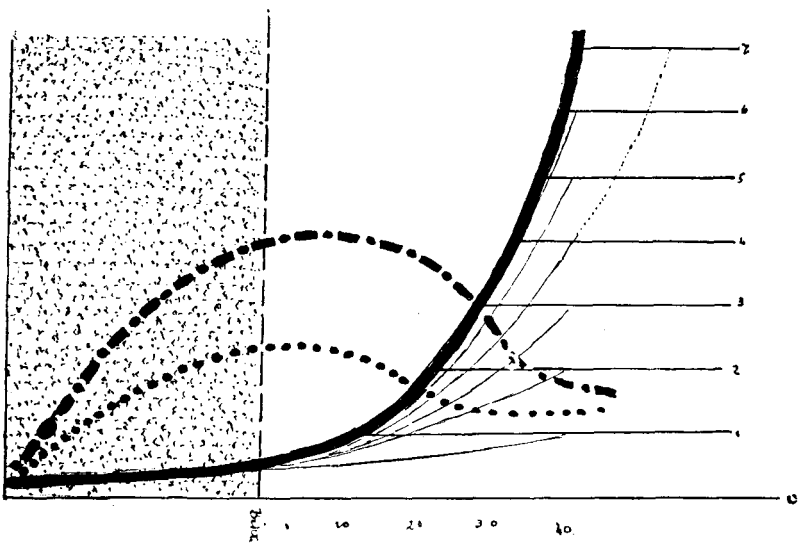


FIG. 11.—THE DEVELOPMENT OF THE SENSE OF HEARING.

The figures indicate the age of an average person. It will be seen that the stages of evolution are traced out in the development of an individual.

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Conclusions.—The cochlea originally developed from the tactile organ which is represented in fishes as the lateral line. It sank into

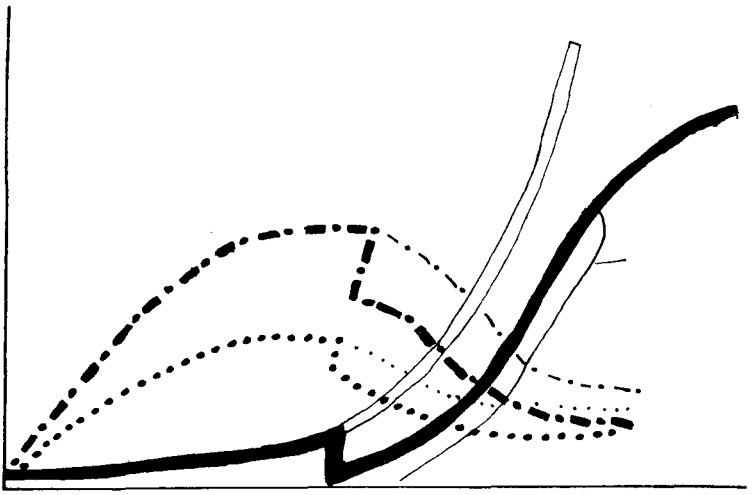


FIG. 12.—The development of the sense of hearing of an individual who suffered from damage to the middle ear in childhood. It will be noticed that in spite of a temporary damage to the middle ear the sense of hearing develops on the lines of evolution.

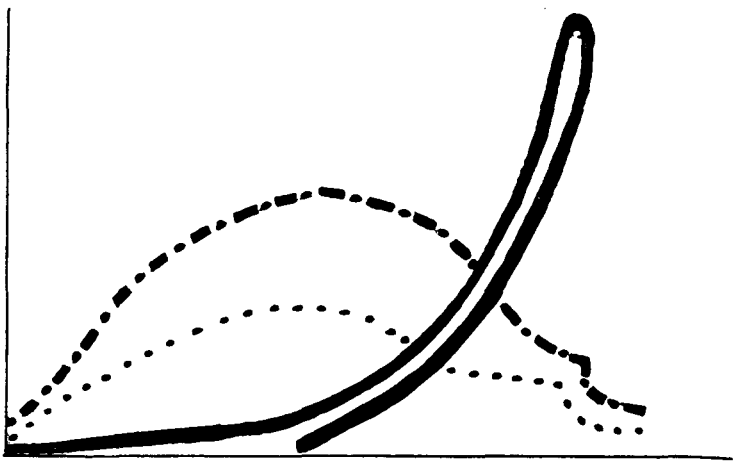


FIG. 13.—This represents a case in which deafness comes on after the age of easy education. It will be seen that the sense of hearing suffers involution.

the mesodermal structures and it was furnished with the working mechanism of a microphone, and with nerves leading to the mid-brain. In mammals it served to give auditory warning of enemies and of food.

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In apes we find this auditory protective reflex partly disappearing and becoming an intellectual sense. In men this intellectual sense has increased so greatly that it has masked to a great extent the protective sense, and the centres in the mid-brain which serve the latter have become relatively smaller and those centres which serve the intellectual auditory function have increased enormously. With this increase man, as a baby, tries to speak but has to be taught a recognised code of sounds which takes the form of words. Gradually, from single words the growing intellect learns to appreciate word groups. The power of intellectual hearing apparently has grown as a result of man's ever-increasing tactile and muscle sense, and if the ear be damaged in a person with poor tactile power, a small degree of damage will cause a great degree of deafness to conversation, but in persons either with good tactile sense or in persons who make great use of their intellect a far greater degree of damage to the ear is necessary before there is a great impairment in the power of hearing conversation. The insistence of the maintenance of intellectual powers in persons who are going deaf, and of the full use of their tactile sense, appears to be a vital factor in the prevention of some forms of deafness and a similar reasoning may be applied in the case of children who are going deaf.

A protracted search of the literature has failed to reveal any article upon the evolution of the sense of hearing.

I wish to express my gratitude for the advice of Sir Arthur Keith, Dr R. H. Burne and Professor Lloyd Morgan on points connected with this paper and for the great assistance of the librarians of the Royal Society of Medicine in the search of the literature of the subject.

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DISCUSSION.

Mr SOMERVILLE HASTINGS (President) said that he had wondered whether there was any explanation of the curious psychological fact that deaf people were very suspicious and were easily frightened. If the theory put forward by Mr Lowndes Yates was correct—*i.e.* that the sense of hearing had been evolved as a means of recognising the approach of an enemy or of food—it might afford some explanation. He had not noticed that deaf people showed particular interest in their food, though that also should be the case if Mr Yates' theory was correct.

He had also wondered, whether in dealing with the deaf, one ought for psychological and other reasons, to try to get them to develop their tactile sense to a high degree. Whether to do so would improve their psychological capacity was a point on which he would like to hear opinions.

Mr ALEX. R. TWEEDIE said he had been much interested in Mr Yates' opening remarks about the lateral line in fishes, and asked if Mr Yates had followed up the connection between this system and the development of the auditory organ.

It had usually been taught that the lateral line organ was supplied by the tenth nerve, but on inquiry he gathered from biologists that the eighth nerve might at any rate share in this service.

He would be very glad of any information as to the literature and previous investigation of this structure.

Mr WATKYN-THOMAS said there was one point about the psychology of deaf persons which he had noticed. Patients would frequently say, "It makes people so angry to talk to us." The probable explanation was that, when raising the voice so as to let them hear, it was difficult to prevent the face taking on the expression of annoyance or impatience, and this the deaf person was quick to see and to resent.

Mr NORMAN BARNETT said that when the power of hearing in people suffering from middle-ear deafness was improved by treatment, they still remained slow in the interpretation of what they heard. It was a common experience that they did not reply to words spoken to them for perhaps ten seconds afterwards, and probably intimated that they had not heard, but afterwards confessed that they had done so. Re-education of the hearing centre was a matter of great importance. The clearing away of the factors causing the deafness did not suffice in many cases, because disuse of the centre had made it dormant. This factor should never be lost sight of in the treatment of the deaf. The binaural tube which he used was a most useful form of re-educator. The matter could be demonstrated by taking some cases as controls and omitting re-education from the treatment and comparing them with those in which it was not omitted. If the hearing centres of the first group were then re-educated much improvement would be found.

He would conclude with a "fish story." Daily, in the old Roman bath at Bath one could see the attendant ring a bell and the fish come from all parts of the bath to the edge to receive their food. This probably did not mean that fish could hear, but these fish had been taught that when a bell was rung there was food to be had. It happened at whatever time in the

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day the bell was rung. He would like to know how the fish knew, as the bell was not rung in the water.

Mr C. HAMBLEN THOMAS said he had been told that there was one fish, namely, the cat fish, which had been shown anatomically and by experiment to hear, but he had not investigated the point. Seals, of course, were not fish, but during the war some seals in Plymouth had been trained to answer various bells. A man in Munich was said to have trained fish to answer to certain sounds, such as those made by a whistle and a vibrating cord, and, in response, coming to the surface of the water to be fed.

When a person who was becoming deaf first appreciated that fact, he manifested a great anxiety to hear what was being said, and this over-anxiety—this attitude of strain—rather increased the difficulty of hearing. If such persons could be persuaded not to be so anxious about it, he (the speaker) was sure that they would hear much better. He often told patients not to strain to hear, or to get into an anxious condition, and often when this advice was adopted, the hearing improved.

Dr ALBERT A. GRAY said that to one who was beginning to feel a veteran on the stage it gave a great deal of pleasure to see younger men taking an interest in these matters.

Mr Lowndes Yates—probably owing to lack of time—did not refer to hearing in winged insects. Winged insects developed "ears" on different parts of the body; flies had the function located on their anterior legs; some carried it on their abdomen. They had developed a chordotonal organ, very like the organ of Corti and basilar membrane; it was, however, not in fluid, it vibrated in the air.

Mr LOWNDES YATES (in reply to the President's remarks on the auditory protective sense) said that, no doubt, the auditory protective sense was the criterion in animals; they possessed no analytical sense at all. He thought it had been proved that hearing was a mid-brain function. It was a curious fact that binaural hearing was developed very much earlier in the scale of evolution than was binocular vision. It was only when the change of site of the nerve-centre from the mid-brain to the neo-pallium occurred, that interpretive hearing was found.

The training of the tactile sense improved the perception of deaf persons. Often people had become deaf because they had allowed their tactile sense, and hence their interest in surrounding things, to fall into desuetude. In persons who were always about and "doing things," *e.g.*, pursuing several hobbies, deafness developed only late in life, although they had sustained the same degree of aural damage as those who, with less reason for desire to hear, went deaf earlier. If one could get patients early enough, one could say to them: "If you will use your hands more you will get more interest out of life and you will hear better."

Reference had been made, in the discussion, to the "lateral line." This was a matter difficult to deal with in evolution. It would appear that the tactile sense, though specially developed at this line, was present in less degree all over the body. Regarding the fact that certain biologists stated that the lateral line was supplied by the tenth nerve and others that it was supplied by the eighth nerve, this discrepancy was surely due to the difference in the number of segments forming the head in man and in the fish, for the tenth nerve did not necessarily remain the tenth in the process

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of evolution. The auditory vesicle was almost certainly developed from the lateral line and was supplied in man by the eighth nerve.

In answer to Mr Norman Barnett, much work had been done on the hearing of fish ; rods had been immersed in tanks and tuning-forks placed on the top of those ; then the forks had been set vibrating, and observation made as to whether the fish appeared to hear the vibrations transmitted by the rods. Positive evidence was not as yet forthcoming as to whether fish could hear, or not.

He did not doubt that the auditory environment of a person going deaf was a factor of great importance, and it was necessary to consider both external and internal environment. If a person becoming deaf was placed among people who habitually shouted at him, he came to regard the shout as the normal occurrence, so it came about that he did not answer unless he was addressed in a shout. Internal auditory environment was likewise important, for damaged ear structures would not transmit the same sound to the brain as did undamaged structures. There would be a difference in the message, and that could be imitated on a mechanical model.

In answer to Mr Hamblen Thomas : With regard to seals, although the seal's cochlea was sunk beneath the surface, the cochlea had undergone no involution and it appeared to be as capable of functional activity as if the animal was using it all the time.

With regard to the psychology of the deaf person and his over-anxiety it was almost impossible to deal with that, because of the factor of auditory fatigue. Many deaf people were so easily fatigued in hearing that they became over-anxious. Fatigue had been defined as a condition in which each succeeding effort produced less and less result: it was a condition manifested by many deaf people.

The portion of this paper dealing with the evolution of the cochlea had been written largely round Dr Gray's work. He had not dealt with winged insects, as they were on an entirely different line of evolution. The same could be said of birds. Probably man sprang from the urodeles, and did not develop through the animals which led up to the bird or those which led to the insect. Possibly the parrot represented the highest point in the evolution of birds, but it had no tactile sense in its wings and a very low degree of tactile sense in its claws. Therefore, whether the tactile sense had preceded the sense of hearing in man was called in question. The parrot, though it might not understand the sounds, could repeat them, and hence had a very high analytical power, but no power of creation of auditory ideas.

With regard to Pavlov's work : it had recently been stated in correspondence that Pavlov was reviewing much of the work which he had done. He would not therefore deal with it.

Ionization in Cases of Suppuration of the Middle Ear—G. Seccombe Hett, F.R.C.S., A. G. Wells, M.B., and G. Murray Levick, L.R.C.P., M.R.C.S.

I.—Mr G. Seccombe Hett.

Ionization is a valuable adjunct to the treatment of suppuration of the middle ear, but like all other special treatments, it is likely

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to get into disrepute or to be regarded as a failure if used in unsuitable cases. I have found the method very suitable up to the present. I have not used it except after every form of local treatment has been adopted and when, in my opinion, operation was the only alternative.

In cases in which there is chronic attic infection, local treatment may, and often does, effect a cure and ionization may be tried, but in these cases it is experimental, and the prognosis should be guarded, as operative measures may still be indicated. In a tympanic mastoid where cells communicating with the antrum are involved in the suppurative process, ionization would probably prove useless and surgery is indicated. With a satisfactorily draining attic and aditus, a small antrum, and no cells, the treatment is worth a trial.

I have at present a case, under the care of Dr Levick, in which, years ago, a left radical mastoid operation was performed. The ear has continued to suppurate ever since and is deaf. On the right side the hearing is fairly good, but suppuration has taken place intermittently for about the same time, despite long-continued hospital treatment. There is a well-draining perforation, but the middle ear contains granulations. The tonsils and adenoids have been removed. We are trying ionization on both ears as an experiment; if it fails, operation on the right side will be indicated, and I cannot hope that the patient will have as good hearing as she has now—in fact, the good ear upon which she depends will probably be somewhat deaf.

Those troublesome cases in which a radical mastoid operation has been performed and in which the discharge continues, are becoming rarer, owing to improved technique, but are seen by all of us now and then. In every case of this type which has come under my observation, the ear has completely dried up after ionization, confirming my belief that we have in ionization a valuable aid in treatment.

In this connection I may quote the case of a boy, aged 9, whom I was called to see on account of an acute left mastoiditis. He also had double pneumonia and, I thought, a left acute frontal sinusitis. The physicians thought he was dying and permission to operate was refused. Later the pneumonia resolved and a local surgeon operated on the mastoid. The patient seemed, however, to have signs of intracranial pressure and a temporo-sphenoidal abscess, and a neurological surgeon was called in who trephined, but found no signs of this lesion. The mastoid healed well, but polypi appeared; the boy underwent local treatment, but there was intermittent discharge for some years. I operated on a pronounced nasal obstruction, and also performed an intranasal frontal sinus operation when the patient was 17. After this, the aural discharge stopped. I next heard of him

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when he was in India, where he had a radical mastoid operation performed on account of urgent symptoms. He subsequently returned with a discharge of pus from the cavity. The tube was patent, the discharge cleared up with local treatment, but recurred whenever he had a cold. Ionization was then tried; he was then aged 26, and the cavity became dry after the third treatment. This was three years ago. He is now married and well, and the ear is dry with a healthy mastoid cavity. This has remained so up to the present time.

Another type of case in which successful results have been obtained is that of the acute otitis in which there is a well-draining perforation, but in which—instead of the normal resolution within a week or ten days—the discharge continues unabated without impairment of hearing and with no acute symptoms, such as tenderness or temperature. In one such case recently, in which I was considering the necessity of operation for stopping the discharge and preserving the hearing, Dr Levick applied the ionization treatment. The discharge ceased and the perforation healed at once; the result was dramatic. This discharge had continued for nearly two months, and now, six months afterwards, the ear is—and has remained throughout this period—perfectly normal.

II.—Dr A. G. Wells.

Ionization in the treatment of otorrhœa has been found by some workers to be of great value. In the hands of others marked success has not been attained. It is my object firstly, to state what I have found from actual experience to be the main causes of this lack of success, and secondly, to bring to your notice some statistics which are very definite evidence of the high value of this method of treatment.

The first cause of disappointment relates to the *selection of cases.*

In deciding what cases are suitable for ionization, an accurate diagnosis must be made of the condition, not only of the ear, but also of the nose and throat, by all the means we have at our disposal.

Speaking generally, acute cases are unsuitable, but now and then a successful result is obtained. It is in certain types of chronic otorrhœa that the best results are seen. I divide all discharging ears into three classes of suitability, viz.:—

(*a*) Those suitable at the outset; (*b*) those not suitable when first seen, but which may be made suitable; (*c*) those unsuitable firstly and lastly.

In class (*a*) are cases which may be described as purely "tympanic sepsis." These show a chronically infected tympanum, and continue to discharge because no means has been adopted to sterilise the

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cavity completely or adequately remove the sepsis therein. They are cases of mixed infections, the original discharge having become infected with outside organisms, which, by their action and the action of their products, irritate the tissues, causing the secretion of more serum and leucocytes which degenerate and add to the discharge, so that a vicious circle is set up.

In class (*b*) we have such cases as those of tympanic sepsis complicated by granulations, polypi, enlarged tonsils, adenoids, other nasal conditions, and so forth. The preliminary treatment of these conditions, followed by ionization, supplies a further series of successful results.

These two classes may also be described as cases of "accessible sepsis" and "accessible sepsis + a complication," and in practically all cases of accessible sepsis ionization is indicated.

In the third group (*c*) we have cases which come under the heading of "inaccessible sepsis" or "accessible with difficulty." Examples of these are disease of the antrum or mastoid bone, many cases of attic disease, certain cases of carious conditions of the tympanic walls, etc. These will generally need a mastoid operation.

It has been stated, and the statement has been published, that in order for ionization to be of any use the perforation must be a large one. This is absolutely incorrect. The size of the perforation matters little, so long as the ionizing fluid can be made to reach the whole of the septic area. Thus, if ionization is performed in any of class (*c*) cases, or of class (*b*) before the complication has been dealt with, no success can be expected, and workers should not form an opinion of ionization on cases of this kind, as has been done.

The second cause of failure to obtain good results by ionization is *faulty technique.*

In this connection the preparation of the ear for ionization is most important. Every bit of discharge and debris must be removed by syringing, or, if necessary, washing out with pure ether. Unless this precaution be taken, a successful result will not be obtained, even in "suitable" cases. Another common error of technique results in the presence of an air bubble in the ear. This happens when the fluid is introduced into the ear in such a way that the air present and in contact with the septic area is not entirely displaced by the fluid. It can be prevented by introducing the fluid very slowly and allowing it to run down the meatal wall on one side only. Another method is by using Siegle's speculum to aspirate any air present.

Thus we see that the reasons for failure to attain good results are: (1) faulty selection of cases; (2) faulty technique. If the technique is perfect and if suitable cases are selected—particularly cases of tympanic sepsis—excellent results will always be obtained.

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There is another class of case in which I have employed ionization extensively, with much success, namely, the discharging ear after mastoid operation. Ionization produces sterilisation of the cavity and physiological rest, the two things most needed for the healing of the ear after operation. Another use to which ionization may be put is the clearing up of a diagnosis. It is not always possible, in seeing a case for the first time, to make an accurate diagnosis of the condition present. A temporary improvement is often brought about by ionization, which reduces the inflammation and swelling of the mucosa, and an obscure condition is thus revealed.

Critics have complained that though ionization may cause a cessation of the discharge, it is only temporary, and that the discharge from the ear will occur again later. Now this statement gives quite a wrong impression of the position. It is true that an ear once cleared up by ionization may, and often does, discharge again at a later date, but this is equally true of an ear which has been cleared up by any other form of treatment, or, indeed, without any treatment at all. If an ear remains well for one or two months after treatment, one is justified in assuming that the treatment has been successful. Should a fresh discharge develop after that period, it is due to a reinfection, and reinfections are not more liable to occur in ears cleared up by ionization than in ears cleared up by any other means.

The table below gives the figures of a series of cases treated in a certain clinic during the past three years.

Year.	No. of Cases Diagnosed as Tympanic Sepsis.	No. Lapsed.	No. Cured.	No. still under Treatment at end of the Year.	Percentage.
1926	611*	10	454	146	75
1927	840	27	675	138	83
1928	1201†	21	929	239	79

* One case sent to hospital. † Twelve cases sent to hospital.

Had those cases which were under treatment at the end of the year been followed to their termination, the percentage would have been found higher than these figures.

The point I want to emphasise is that in the great majority of these cases the patients had already been treated elsewhere by syringing, drops, etc., for weeks and months, and in some cases years, before they came up for ionization.

I submit that these figures may be regarded as sufficiently convincing evidence of the value of ionization in suitable cases.

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Royal Society of Medicine

III.—Dr G. Murray Levick.

In this short paper I shall confine myself chiefly to describing the technique of ionization in the treatment of suppuration of the middle ear.

For the active electrode I use a vulcanite aural speculum, with a fixed coil of zinc wire on its inner surface, the lower end extending almost to the bottom of the speculum, the upper end being attached to a rheophore. I have always ionized with zinc, and never seen any reason to use other ions.

The treatment should always be given with the patient in the reclining position; no exception should ever be made to this rule. He should lie on his side with the affected ear uppermost. A very small current affects the semicircular canals, thus causing loss of balance and giddiness. An indifferent electrode (negative) is attached to some other part of the body. The milliampere metre should be sensitive, accurate and of wide amplitude, so as to record in at least duodecimals of a milliampere.

I pass a couple of turns of rubber bandage round the patient's head just above the ears, across the forehead and below the occiput, and place the rheophore that is attached to the active electrode beneath the bandage, close to the ear. The rheophore is thus held firmly in place so that it cannot drag the electrode out of the meatus or disturb it in any way during the treatment.

The meatus, having been carefully irrigated to clear out accumulated pus, is now filled to the brim with 2 per cent. aqueous solution of zinc sulphate, and the speculum electrode above described is introduced into the meatus just far enough to secure a firm hold, but not so far as to cut off the outer half of the wall of the meatus from the ionizing current. The current must be very gently introduced, in fact so gently that the patient suffers no discomfort. It is fortunate that the anode is the pole required for the introduction of metal ions, because much less discomfort is caused with this than with the negative pole. It produces an electrotonus with consequent reduction of inflammation.

The amperage of the first treatment and of those to follow must be determined largely by the acuteness of the inflammation and the hypersensitiveness of the innervation. Not infrequently 0.2 milliampere is the maximum current supportable; and any increase on this is followed by acute discomfort. Later on this hypersensitiveness departs and larger currents may be used. I never exceed 1 milliampere, but it is much better to allow more time with a weak current than to employ a stronger current for a shorter period.

Only two sensations should be felt by the patient. The first is a tinnitus with very high-pitched note which ceases directly the current

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ceases, the second is a metallic taste due to stimulation of the gustatory nerves. This may or may not be present, as a rule the current is insufficient to excite it. "Swimming of the head," or shocks, are simply the result of too much current or of clumsiness in its application.

The first treatment, as a tentative measure, should last about five minutes, after which the current is gently turned down and the speculum removed. The turning down of the current should take place very slowly, giddiness being produced more easily when it is diminished than when it is increased. The solution is now removed from the meatus by a succession of suitably fashioned cotton-wool swabs. A good deal of discharge may have taken place into the solution. The meatus is finally cleaned up by the gentle application of swabs squeezed out in spirit, and an examination is made through a speculum, to make sure that it is thoroughly clean. Finally, a loose plug of dry wool may be introduced into the ear and the patient may be allowed to get up. When the treatment is desirable after a mastoid operation, the opening into the mastoid cells should be ionized separately from the meatus.

In skilled hands and through a shunt resistance, there is no reason why the electricity should not be taken from a direct current main supply, if the usual precautions are taken as to insulation, but accumulators form the ideal source. If a wire shunt resistance is used it should be in first-class order, otherwise the steady flow of current will be disturbed when the amperage is increased or decreased. I prefer a water resistance because there is less risk of such disturbance.

Before each subsequent treatment a careful examination should be made to ascertain whether any inflammatory reaction remains as a result of the previous application. It must be remembered that the success of the treatment largely depends upon a fine discrimination as to the amount of zinc to be introduced into the tissues, and overdosage is the most likely mistake to be made. The zinc ions, as soon as they enter the tissues, surrender their electrical charge to hydrogen ions, remaining *in situ* as atoms of zinc. These atoms are deposited in a beautifully even manner upon and just beneath the surface of the tissues in the manner of electro-plating. Their effect is to sterilise the part and to stimulate leucocytosis and the processes of repair. The advantage of ionization over mere irrigation with a solution depends upon the penetration of the ions *into* the tissues, so that fissures and small cavities are ionized through the exudates that fill them.

Should an over-reaction be noted as the result of the previous treatment, it is my practice to ionize for one or two treatments with boiled tap water only and I have obtained excellent results by this method, with subsidence of the inflammation.

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We must remember that an electrical current of suitable strength, in its passage through chronically inflamed tissues, has a therapeutic effect apart from ionic medication. How this effect is obtained we do not know, but I am inclined to think that it may be through stimulation of the sympathetic nerves, on which nutrition so much depends, or through stimulation of metabolism in the cell nuclei, or stimulation of phagocytosis, or possibly through all these factors. Again, while the current is flowing, anion bacteria leave the surfaces and migrate to the zinc electrode, leaving only kation bacteria behind. These will in turn be detached by reversing the current, but I prefer to leave them for destruction by the ionized zinc rather than to reverse the current, as in my experience the kathodal current is inadvisable for the middle ear. In any case such simple ionization is a valuable accompaniment at certain times during a course of ionic medication with zinc.

The treatment of the ear by electricity is a process requiring a nicety of technique, sound judgment, especially as to dosage, and experience in this particular branch of electro-therapeutics. It is only really advisable when in the hands of a qualified man who has made it a special study, and he should, in every case, work in co-operation with an aural surgeon when dealing with any case of sepsis. It must not for a moment be thought that this treatment is safe in the hands of the average masseuse. No difficulty arises in private practice, but one sees the difficulty that may arise in hospital practice if this treatment is adopted as a routine in an aural department dealing with a large number of patients. The best procedure in this case would be for an electro-therapist to be specially attached to the department so as to be one of the team. He might then train a specially selected qualified masseuse, with a certificate in electro-therapy, who should also be a trained nurse, to work with him under his supervision. Such an organisation would, I believe, be very successful, and a definite advance in therapeutics.

This form of electro-therapeutics is an example of the advisability for special hospital departments to have their own electro-therapeutic organisation.

DR A. R. FRIEL said that his remarks would deal with his experience at some of the school clinics opened for the treatment of chronic otorrhœa and would also indicate the place of zinc ionization in aural practice. The economic importance of simple and efficient methods of treatment was evident. In January, 1924, a weekly session lasting two and a half hours, began to be held during term time at Bruce Castle, Tottenham. The school population in Tottenham was over 25,000. When the clinic began there was an accumulation of cases of otorrhœa and it took two years to work through these and to deal with some of the fresh cases which occurred. During those two years only six ears were seen in the stage of acute suppuration. In 1926 twenty-seven ears were treated in the acute stage,

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but in the following year ninety-two ears were seen during the acute stage, as it had become possible to see every case of otorrhœa within a week after it had been notified to the organising clerk. There was now no waiting list. In 1928 it was believed that untreated otorrhœa did not exist in the schools. To test this a circular was sent by the Medical Officer of Health to all the head teachers instructing them to discover—and send in the names of—any children who were found with ear discharge, and who might have escaped the net of medical inspections, etc. Three only were discovered. It is necessary to be explicit about these cases. There were the patients who came during the stage of acute inflammation with discharge, which had lasted for less than a fortnight. It was reasonable to suppose that within ten days of the onset of the discharge the anti-bacterial powers of the body would have developed, and that if stagnation of the discharge in the meatus and tympanum was not permitted, and there was no mastoid disease, recovery should follow quickly. This has proved to be the case. These cases were treated at home with drops of undiluted glycerine containing 1 per cent. of carbolic acid, a teaspoonful being poured into the ear and allowed to remain for a quarter of an hour. When the discharge diminished the glycerine was discontinued, and boracic powder was insufflated at the clinic.

If, however, the child did not come during this early stage, but in the third week, when infection of the discharge in the ear with saprophytes, rather than infection of the tissues, might be expected, he would be considered as entering on the chronic stage. In this early chronic stage it was not often necessary to resort to zinc ionization. The ear was carefully cleansed and boracic powder was blown in on one, two, or three occasions.

It was now only occasionally that a patient was seen attending for the first time with a discharge that had lasted for weeks or for months. These were the cases for which zinc ionization was of such great importance, and of which the numbers in 1924 and 1925 had been so large. If the area of sepsis was accessible, and if polypi or large granulations were not present, they yielded as rapidly to treatment by zinc ionization as did the cases first mentioned to simpler treatment. Finally, there were the cases in which the area of sepsis was inaccessible—the attic and mastoid cases, most of which needed operation. Zinc irrigation played the essential part in getting rid of the incubus of severe chronic cases due to accessible sepsis, and made it possible, later on, to devote the time of the Session to treating cases during the acute and early chronic stages, and so preventing the conditions and complications which were prevalent when the clinic started. Although during the year there were a good many cases of otorrhœa treated, the incidence at any one time in the schools was small, since the duration of treatment was short. The experiences at the school clinics in Hornsey and Walthamstow were similar.

Dr PAVEY SMITH said there was one important point in the ionization treatment of the middle ear which was liable to be lost sight of, namely, the toilet carried out before ionization was begun. If this was performed instead of syringing or instilling drops into the ear, he thought the results would be almost as startling as those which followed the ionization. There were two factors for success in this treatment, electricity and a careful and thorough toilet. By carefully washing out the ear beforehand, and

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repeatedly using the vacuum tube to extract discharges, and to ensure the proper introduction of the antiseptic, very good results were obtained. He had used flavine, and metaphen, a mercury-cresol compound. If an ear was treated with this, and by suction with a Siegle's speculum, a sufficient penetration of the antiseptic was ensured, and this should be left in contact with the area for five to ten minutes, with the patient lying on the couch. Three or four applications in this way would often clear up the trouble without the use of electricity.

Dr J. ACOMB said he had not personally carried out ionization, but among his patients there had been some successful results from its employment. Often, however, he had noted that in cases treated by this method, some dermatitis of the meatus had developed as a sequel, and he wondered whether that was a common experience.

Mr A. D. SHARP (Leeds) said he had tried ionization in a series of cases on three separate occasions, and he had come to the conclusion that the value of ionization for middle-ear suppuration was over-rated.

In his third series he had treated an equal number of controls, and the results had not been definitely in favour of ionization. He had not found ionization successful in refractory cases which resisted the usual methods of treatment.

Any method of treatment superadded to the preliminary conditions demanded by the advocates of ionization, namely, thorough overhauling of the nose, nasopharynx and tonsils, careful and efficient cleansing of the middle ear and meatus, and removal of granulations and polypi, was bound to give reasonably good results.

Mr T. B. JOBSON said that he had been carrying out ionization for ten years, and he regarded it as the greatest advance made during this century in the therapeutics of the discharging ear. Yet in the London teaching hospitals very little ionization was employed. He had tried to open a small clinic for this treatment at the Central London Ear and Throat Hospital, and the results had been very good, the cures being about 80 per cent. The cases for treatment had, however, been carefully selected. By ionizing cases in which the sepsis was inaccessible, one was asking for failure.

He joined issue with Mr Hett and one or two others who suggested the allocation of the treatment of these cases of discharging ears to the electro-therapeutical department. He felt strongly that the treatment of these cases by ionization should be carried out by the aural surgeon; an electrician would not have the skill to select the cases which were suitable for ionization or to carry out intra-tympanic toilet. Diagnosis of the case was a first essential, though, of course, the technique was equally important.

With regard to the clearing out of the accessory factors, the underlying principle of ionization was sterilisation of a septic cavity, and that could be achieved whether septic tonsils or rhinitis were present or not. But if those conditions were present, the case was very likely to relapse, whatever method of treatment was carried out. If there was an infected area surrounding it, relapse was almost certain. That was one reason for insisting on enucleation of septic tonsils, cleansing of the nose, and so on.

The results of ionization in suitable cases of mastoid cavities or tympanic sepsis were simply dramatic. The case was dealt with on the accepted

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plan and the patient came, perhaps a week later, with a dry ear, and did not seem to comprehend that he was cured until the passage of time without discharge assured him of the fact. It was a great satisfaction to a surgeon to get cases of that kind repeatedly.

He would quote the following case: A boy, aged 10, had consulted him in 1924. The mother said that the right ear was perforated when he was 6 weeks old, and an abscess had burst in the nose. He had further trouble when 4 years old, and had repeated attacks of the same nature, until early in 1920, when an operation was performed for adenoids, as a possible preventive. In December 1920, a mastoid operation was carried out, considerable bone being removed, as the condition was believed to be tuberculous. The wound had healed up within a month and afterwards there was much improvement in health. In September 1921, the boy caught a cold and the ear again became affected. He underwent a radical mastoid operation in France in December 1921, and in April 1922, came to Bournemouth, and was treated there by a specialist. For six months he was at Lausanne, under Rollier, and then had sun treatment under Sir Henry Gauvain at Alton. The mastoid was re-opened for closure of the Eustachian tube, and he was to have another operation, as there was some swelling in the pinna. The patient had consulted him (the speaker), as the condition had been described as tuberculous, though there was no obvious sign of tuberculosis. He (Mr Jobson) thought it was a case which might clear up with ionization. Granulations were present in the tympanic cavity. It seemed like a case of pure tympanic sepsis. After two ionizations, *i.e.*, within a month, the cavity had become quite dry, and it was still dry, five years after the treatment. Such dramatic results, frequently occurring, made one a firm believer in this method which was apparently coming to be more generally accepted by otologists.

Mr SECCOMBE HETT (in reply) said that in this matter he had begun as a sceptic but had become a disciple. It had been said in the discussion that if careful asepsis were employed and the nose and throat were made right and local treatment was efficiently employed, ionization would not be needed. In private cases he had been struck by the frequency with which those treatments had been carried out and yet the discharge continued. Then ionization was applied, and, dramatically, the discharge stopped.

Dr Jobson had joined issue with him in his advocacy of the treatment of these patients in the electro-therapeutical department of hospitals. Perhaps he (the speaker) had not made his point clearly. In his hospital was an assistant, a trained aural surgeon, who had obtained a travelling scholarship in order to study all electro-therapeutical work in connection with the specialty. On his return he (the speaker) hoped he would be appointed. He agreed that electro-therapeutic work of this kind should be under the supervision of those who were trained aurists.

Dr WELLS (in reply) said that in the course of thousands of administrations of the treatment which he had carried out he could remember only two in which any form of irritation of the skin of the meatus or the neighbourhood ensued; and in both of these the patients had an unusually sensitive skin, which reacted abnormally to any form of stimulus.

Dr Sharp had remarked that if all the preliminary conditions required before ionization were fulfilled, there would remain little to treat. His

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reply was that his own results, obtained during a period of over three years, had been solely in cases of tympanic sepsis, in which those other conditions were not present at all. Further, in all the cases in which the condition had cleared up under ionization the patients had, almost without exception, had weeks, sometimes months, of other treatment previously. If it was not ionization which had cured them, what was it? Again, in the case of a man who had had this trouble for forty-two years, during which long time he had had all kinds of treatment, the condition had cleared up under treatment by ionization. If that was not a cure by ionization, what was it?

Dr JOBSON (in further comment) said that a paper on the subject, by Dr Maclagan, of the Central London Throat and Ear Hospital, had appeared a few months ago in the *Lancet*. In that paper the results of 100 cases, treated with ionization, were given, also the results in 100 cases treated with the preliminary technique, but stopping short of the passing of the electric current. There was practically no comparison between the two series, the results in the cases treated by ionization were so far superior to those in the others.

Dr MURRAY LEVICK (in reply) said it was conceivable that dermatitis might ensue from allowing the solution to leak out and spread over the margins. This could be avoided by keeping the edge of the meatus dry during ionization.

It was difficult to reply to criticism recording failures when no particulars as to the cases treated, and no details of the technique followed, were supplied.

The Chorda Tympani Nerve in Otology.

M. VLASTO, F.R.C.S.

This short paper owes its inception to a conversation with Dr Logan Turner some five or six years ago. I asked him if any patients upon whom he had performed a radical mastoid operation had ever spontaneously reported a loss of taste on the affected side of the tongue. His reply was, I believe, in the negative. We then discussed the effect of this operation on the trans-tympanic course of this nerve, and Dr Logan Turner suggested that an investigation of the subject might be of interest.

There is no need for a detailed account of the anatomy of the chorda tympani, but perhaps I may be allowed to recapitulate very briefly the main accepted anatomical and physiological facts as they affect this paper.

The chorda tympani is a mixed nerve containing afferent taste fibres from roughly the anterior two-thirds of the tongue, and efferent secreto-trophic and vasodilator fibres to the sublingual and submaxillary glands. The nerve begins to interest us as it parts company with the facial nerve in its vertical course, about 6 mm. above the stylomastoid

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foramen, and *just* below the slender branch to the stapedius muscle. It makes its appearance in the tympanic cavity, immediately to the outer side of the pyramid, and henceforth, until its exit from the tympanic cavity, hugs the tympanic membrane in the sulcus tympanicus, between the mucous and the fibrous layers. The precise relationship of the chorda tympani to the tympanic membrane is not easy to make out in the formed being, but becomes evident when studying sections of the fœtal ear.

Invested by mucous membrane, the nerve is stuck down, so to speak, to the lateral aspect of the upper part of the incus, and then to the mesial aspect of the neck of the malleus just above the insertion of the tensor tympani muscle. The relationship of the chorda tympani to the malleus and incus is so intimate that it would appear that the removal of either of these bones must sever the nerve. The nerve hugs the lower margin of the notch of Rivinus, and crosses the upper part of Shrapnell's membrane. It is therefore in a vulnerable position in cases of attic disease.

The nerve leaves the middle ear through the "iter chordæ anterius," or, as pointed out by Gray, through a small passage immediately to the inner side of the Glaserian fissure. Further on, it joins the lingual nerve on the deep surface of the external pterygoid muscle.

The purpose of this investigation is to study the effect on this nerve of injury and disease of the middle ear.

The accepted criterion of a functioning chorda tympani is the ability to perceive taste on the anterior part—roughly anterior two-thirds—of the tongue on the corresponding side. Whilst this statement is perfectly correct, the converse is not true. It has been shown by many observers that loss of taste on the anterior part of the tongue has followed complete fifth nerve palsy, as, for instance, in cases of extirpation of the Gasserian ganglion. Wilfred Harris[1] found total loss of taste on one side of the tongue in eighty-six cases of injection into the foramen ovale, though taste was at once recognised on the other side. Indeed, the precise rôle played by the chorda tympani, the fifth and the glosso-pharyngeal nerves is still under discussion.

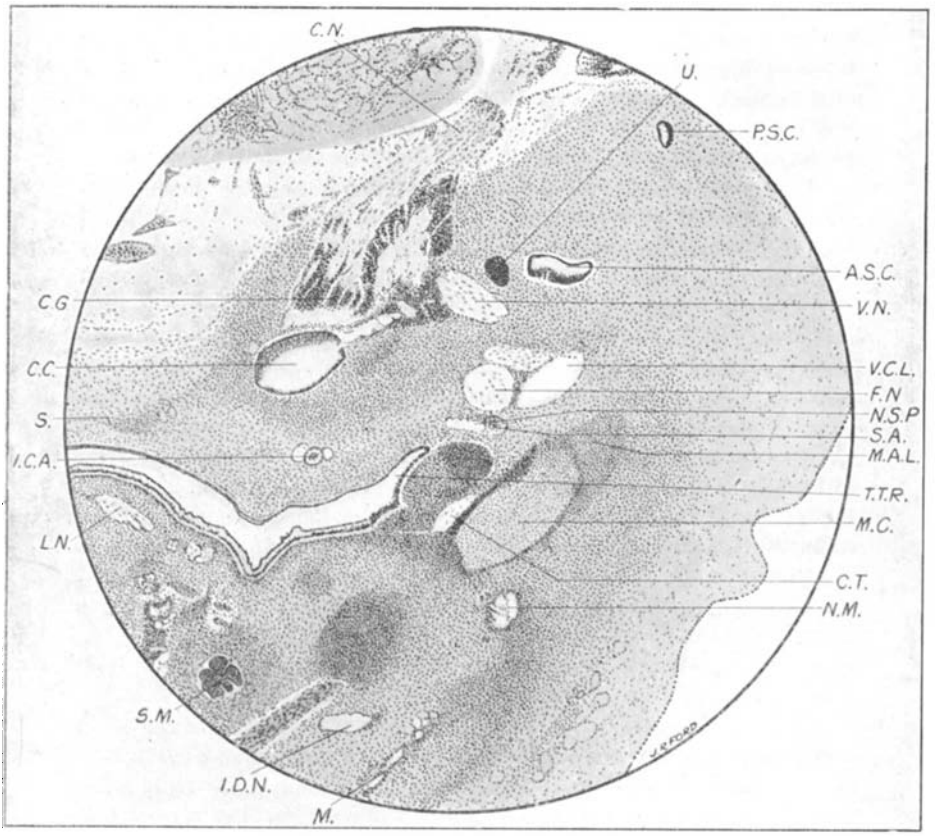
My feeling on this point is that the lingual nerve does not contain specific taste fibres, but that when common sensibility over an area of the tongue is completely abolished, the patient's higher centres are not in tune to receive and analyse taste impressions to which he may be subjected.

Observations on the sense of taste are tedious and frequently unreliable. Moreover results based purely on subjective evidence must be accepted with caution.

The method I have employed for testing taste is much the same as that used by other observers and is as follows:—

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The subject is first informed what his duties are to be, namely, that he will have to put out his tongue and keep it out until told to put



CORONAL SECTION THROUGH THE ACUSTICO-FACIAL GANGLION AND INTERNAL EAR OF A 20-MM. HUMAN EMBRYO.

C.N. = Cochlear nerve. *C.G.* = Ganglion spirale. *C.C.* = Canal of cochlea. *I.C.A.* = Internal carotid artery. *T.I.R.* = Tubotympanic recess of primitive pharyngeal cavity. *L.N.* = Lingual nerve. *S.M.* = Submaxillary gland. *I.D.N.* = Inferior dental nerve. *M.* = Ossification of mandible. *M.C.* = Meckel's cartilage. *C.T.* = Chorda tympani. *S.A.* = Stapedial artery. *N.S.P.* = Great superficial petrosal nerve. *F.N.* = Facial nerve. *V.C.L.* = Vena cerebri lateralis. *A.S.C.* = Anterior semicircular canal. *P.S.C.* = Posterior semicircular canal. *V.N.* = Vestibular nerve. *U.* = Utricle.

(For the loan of this section the author is indebted to Dr R. J. Gladstone, of King's College, London.)

it in again. He is then told that his tongue will be smeared with some solution that is either sweet, salt, bitter, or that has no taste. He is told to point his reply on the board [shown].

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When I first started my inquiries, I used for my testing reagents relatively dilute solutions, and timed with a stop-watch the interval elapsing between application and response. I soon came to the conclusion that uncontrollable factors came into play, and that no useful deductions could be drawn from these refinements. I therefore contented myself with the testing of taste with maximal stimuli, and with the elimination, as far as possible, of unreliable witnesses.

Aqueous solutions of salt, sugar and quinine sulphate are used.

After each application the mouth is washed out with plain water. My first application in every case is one of ordinary water. Should the patient ascribe a taste to this—and it is surprising how many subjects do ascribe a taste to plain water—he is rejected as an unreliable witness.

One of the factors which made observations tedious and difficult to interpret was the variation in the threshold of tastability in normal subjects. One person with a minimal stimulus over quite a limited area of the tongue will respond correctly and quickly, whereas another will require a maximal stimulus applied over a relatively large area. Indeed, from a large number of observations on normal subjects, one cannot help coming to the conclusion that the discrepancy in the results obtained is due to a definite anatomico-physiological cause. Is there a predominance in individual cases of specific fibres for one kind of taste, or, as Maier[2] thinks, is the distribution of specific fibres shared by the glosso-pharyngeal and chorda tympani nerves? In other words, is it not correct to say that the capacity for judging taste is inborn in individuals in varying degrees?

I will now pass on to the consideration of the question of the effect on the chorda tympani of injury and disease of the middle ear.

(*a*) *Injury to the Chorda Tympani after Paracentesis.*—Only a few cases of such injury have been recorded in medical literature. This may be due to the following facts: (1) That the nerve is situated normally at the periphery of the ear-drum. From my own dissections, I would say that some text-book illustrations tend to show the nerve lying at rather a lower level than it normally occupies. The chorda tympani is almost a structure of the attic rather than of the lower part of the tympanic cavity. (2) That, patients having made no complaint of an alteration in the sense of taste, no tests were carried out, and the damage to the nerve passed undetected.

No case of ageusia after paracentesis has come under my personal notice. Of those mentioned by others I will refer to two only.

Sobotky[3] reported a case in which ageusia followed paracentesis on one side, and he noted that on the opposite side the healthy drum showed a faint white line which he interpreted as being the chorda tympani taking an abnormally low course across the tympanic membrane.

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The second case was brought to my notice in a personal communication by Dr Douglas Guthrie four years ago.

It is interesting to note in this connection that very exceptionally a facial paralysis has been known to follow the operation of paracentesis. Lermoyez suggested the explanation that the paresis might be due to an effect on the facial nerve consecutive to disruption of the chorda tympani.

(*b*) *Injury to the Chorda Tympani after Ossiculectomy.*—Never having performed the operation of ossiculectomy, I cannot quote my personal experience in this respect. It is obvious, however, from the intimate anatomical relationship between the chorda tympani, the malleus and the incus, that in the extraction of either of these ossicles, the disruption of the nerve is inevitable. In clinical support of this assumption is the statement of Ludwig Känder that "the removal of the hammer and anvil always leads to the ageusia on the side of the operation."

(*c*) *Injury to the Chorda Tympani after the Radical Mastoid Operation.*—As a corollary to what has just been stated, it follows that the performance of the radical mastoid operation must also be followed by ageusia over the area supplied by the chorda tympani nerve. A large number of observations has proved this to be the case. Moreover, this loss of taste is permanent so far as such a statement can be made.

(*d*) *Injury to the Chorda Tympani in Suppurative Affections of the Middle Ear.*—A considerable amount of attention has been given to this subject abroad. I would particularly quote in this respect the names of Känder,[4] Schultz,[5] Schlechting,[6] and Maier.

Certain facts can be laid down as proved: Firstly, that a considerable number of cases of middle-ear suppurations show a lesion of the chorda tympani. Secondly, that, as one might expect, the chorda tympani is most frequently lesioned where the middle-ear disease is of long standing, affects the attic and is attended by cholesteatoma. Thirdly, that in many advanced cases of middle-ear disease the integrity of the chorda tympani is completely preserved. No useful deduction as to the extent of the disease can therefore be drawn from the integrity or destruction of the chorda tympani nerve.

The results hitherto described have all been based on subjective evidence. German observers, in particular, have published the results of series of cases in which delayed taste perceptions and perversions of taste—such as sweet being called salt, salt bitter, and so on—are noted as positive indication of a lesion of the chorda tympani nerve. Without denying the truth of their contention, I am inclined to think, from results obtained in a large number of cases in normal persons, that the tendency has been to ascribe too positive a value to the results obtained.

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It occurred to me that it might be interesting to try to obtain *objective* evidence of the destruction of the chorda tympani nerve in cases in which the nerve might be supposed to have been damaged.

So far as I am aware, these observations have not been made before in their application to otology.

The submaxillary gland has a double nerve supply, from the sympathetic and from the cranial nerves. The cranial fibres are derived from the chorda tympani nerve. After a short course from the lingual nerve, the fibres of the chorda tympani leave it as a slender nerve which runs along the duct of Wharton to the submaxillary gland.

If the chorda tympani of the dog is experimentally cut on one side, the submaxillary gland enters into a condition which is termed "overflow activity" or "paralytic secretion." The condition is attended by a gradual atrophy of the gland, and sections of the gland present typical appearances.

The object of my inquiry was to ascertain whether or not changes occurred in the submaxillary gland as a result of interference with the continuity of the chorda tympani in the tympanic cavity.

Case I.—A male, aged 36, with otorrhœa of fifteen years' duration and extensive attic disease on the left side. The right ear was normal.

Taste testing gave the following results: *Right ear:* Positive for sweet, salt and bitter. *Left ear:* Negative for sweet and bitter; (?) slight reaction for salt.

The patient died from intracranial complications ten days after the above tests were made.

I am indebted to Dr Elworthy for the following report on the submaxillary glands:—

Both glands were removed post-mortem, cleansed of extraneous fat and weighed. The right gland weighed 7·94 grams, the left 6·91 grams. No calculi were present, and there was no gross evidence of obstruction of the ducts.

Sections were made through about the centres of both glands after an identical preparation.

The *right* gland sections are those of an average normal gland.

The *left* shows marked changes of an inflammatory and degenerative character as follows:—

Vessels.—Very prominent, engorged and presenting many more leucocytes, mainly polymorphonuclears.

Ducts.—Generally more distended and full of mucin. Some few of them show polymorphonuclears.

Parenchyma.—Cells of alveoli suggest hypersecretion with lack of restoration to normal and with ultimate necrosis in places.

Stroma.—Early diffuse fibrosis with round and polymorphonuclear cell infiltration.

The above changes tend to be lobular in distribution. The gland is not equally damaged throughout.

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CASE II.—The second case is that of a boy, aged 9, who, seven years before, had had a radical mastoid operation performed on the right ear. Owing to the boy not being a reliable witness, no taste experiments are noted.

I had occasion to perform some small operation on the right ear, and the opportunity was seized for removing a small piece of the submaxillary gland on both sides.

Sections of these glands were mounted, after identical preparation, and sent to Mr Lawrence, of the Royal College of Surgeons, who kindly examined them for me and reported as follows:—

There is a distinct difference in the two slides when examined under a high power. The protoplasm of the cells of the serous acini in the slide marked "right" is in many places vacuolated, and, in consequence, the granules are less evenly distributed than they are in the other slide, and tend to run in lines and networks. I do not think that the vacuoles can be mistaken for lumina of the acini because there are often several in the same acinus. I will not attempt to decide what the change means—whether it is pathological (liquefactive degeneration) or whether it is some purely physiological change.

These two cases, taken in conjunction with taste experiments, establish, I submit, that the chorda tympani may be lesioned in suppurative disease of the tympanic cavity and after a radical mastoid operation. In the latter case, I submit that the nerve is always destroyed and the effect is permanent.

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DISCUSSION.

The PRESIDENT said he would like to know why Mr Vlasto used only three tests, and why he did not include a sour tasting substance also. He (the President) had tried to do something of the same kind, but had given up the attempt, as it was very difficult to get patients to give consistent replies. Did Mr Vlasto repeat the tests, and, if so, did he get the same kind of replies from the patients on another day?

Mr T. B. JOBSON said it had occurred to many otologists to find a distortion of the taste sense after the radical mastoid operation. On more than one occasion patients had complained of "a foul taste" and others had spoken of having a "metallic" taste. Could Mr Vlasto assign any cause for such changes in taste?

Mr G. J. JENKINS said that sometimes there was evidence of affection of the chorda tympani in chronic suppurations. On two occasions he had had patients sent to him to account for a burning taste on the anterior part

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of the tongue on one side. On examining these patients there was found to be chronic suppuration of the middle ear on the same side as the abnormality of taste. Tumours in the neighbourhood of the ear sometimes caused pain and aberration of taste in the tongue. It was usually a taste of ink, or a metallic taste, occasionally with a burning pain.

Mr VLASTO (in reply) said that the President had really given his own reply to his questions. Examinations in taste-testing were very tedious, and introducing the factor "sour" in the examinations made them more so. Some German observers had tested all areas of the tongue, the soft palate and the gums. He (the speaker) had begun work on these extended lines, but had given it up because the results obtained did not appear to justify the labour they entailed.

A certain number of patients complained of a salty or metallic taste in the mouth after a radical mastoid operation. He attributed this taste to an overflow activity of the submaxillary gland on the affected side.

Some Observations on Bone Conduction—C. S. HALLPIKE, M.B., M.R.C.P.—The paper is published in the *Journal of Laryngology and Otology*, vol. xlv., p. 1, January 1930.

DISCUSSION.

The PRESIDENT said the paper had indicated that the work on which Mr Hallpike was engaged would really help otologists, if not in prognosis and treatment, at any rate in the recognition of the different types of ear disease.

Mr WATKYN-THOMAS said that some years ago Mr Jenkins had collected a number of figures which absolutely bore out Mr Hallpike's conclusions.

Mr G. J. JENKINS said that this subject had interested him for some years, and in a paper on "Otosclerosis," read at the International Congress of Medicine in 1913, he had given a short account of his studies on the Weber and Rinné tests in which he had mentioned some of the facts discussed by Mr Hallpike.

In that paper he had referred to the "vibrations in an ordinary room which we had learned to eliminate psychologically": "These vibrations cause confusion, and so we do not hear a tuning-fork so well by air. conduction in a somewhat noisy room as when in a quiet room." . . . "It is more difficult to see the details of a tympanic membrane with reflected light in a room with much diffused daylight." "There are physical laws governing this confusion." At that time he had made some experiments with regard to the Weber and Rinné tests. He made these tests on students in whom he had produced obstruction deafness in one ear, under different conditions: in a noisy street (Thames Embankment), ordinary room, and in an underground room with steel walls (strong room of offices). In this imperfect silent room it was just possible to obtain a positive Weber, though it had been very definitely positive in the room above and in the street.

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In two cases he enclosed the head in a more or less sound-proof box, leaving the face exposed—and here again the Weber test was indefinite.

A further experiment on the effect of noise was made by carrying sound by means of a large rubber tube from a noise apparatus, in one room, to one ear of a normal person, and then employing the Weber test. The sound of the fork was referred to the other ear.

He objected to the term "increased bone-conduction," as he thought there was no evidence that this occurred. When the bone-conduction was apparently increased, it was very probable that if the normal observer could have the advantage of the same degree of obstruction to the confusing sounds by air-conduction, then he would hear the fork by bone-conduction as well and as long as the patient. He thought it would be shown that bone-conduction did not increase in any case, even in otosclerosis, and that the factor in the apparent increase was always the increasing diminution of confusing sounds by air-conduction.

Also, in the paper referred to he had described bone-conduction as a molecular movement affecting the labyrinthine fluid directly. He knew of cases in which the stapes had disappeared and yet the patient had heard well by bone-conduction.

Mr A. LOWNDES YATES, speaking of the term "screening," said that there were possibly other views which had to be considered in a discussion of the cause of hearing by bone-conduction.

There was, for example, the question of resonance. The older writers considered that the hearing by bone-conduction was produced because the fork imparted resonance to the bone and thus to the air-containing cavities of the mastoid antrum, middle ear, and external auditory meatus. The tympanic membrane was very thin and easily movable in health. In health the resonating cavities therefore fell into the class of tubes open at one end. If the finger was placed in the meatus, resonance in the cavities was increased because these at once fall into the class of tubes closed at both ends, in which the degree of resonance was admittedly greater than in the first class. If the tympanic membrane became thickened or partially fixed, this also increased the efficacy of the resonator afforded by the middle-ear and mastoid cavity.

By the theory of screening, he understood a theory that the ear rendered deaf by a thickening of the membrane, etc., was *silence*-adapted while the normal ear was *sound*-adapted. This was true, but he did not think that it would account for more than a part of the phenomena of bone-conduction.

It seemed to him inconceivable that the sound could stimulate the cells of the cochlea directly, for if a fork was placed upon the mastoid, the rays of sound passed out in all directions through the bone: such rays must pass through the cochlear at very many points, and thus if at each of these points a stimulus resulted, a chord and not a single note would be heard.

He did not think that one could view the internal ear as a whole without considering the stapes as functionally a part of it. In bone-conduction the stapes was moved by the sound in resonance and this led to the stimulation of the cells of Corti and the hearing of the note by bone-conduction.

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Societies' Proceedings

Apparatus for Control of Conversation Test—ALEX. R. TWEEDIE, F.R.C.S.—Magneto microphone "A" (Fig. 1) is connected in simple series with receiver "B," which is exactly similar in characteristics to "A." The like is shunted by a non-inductive variable

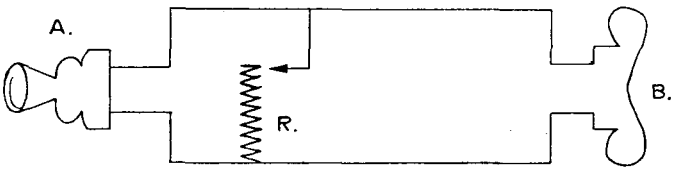
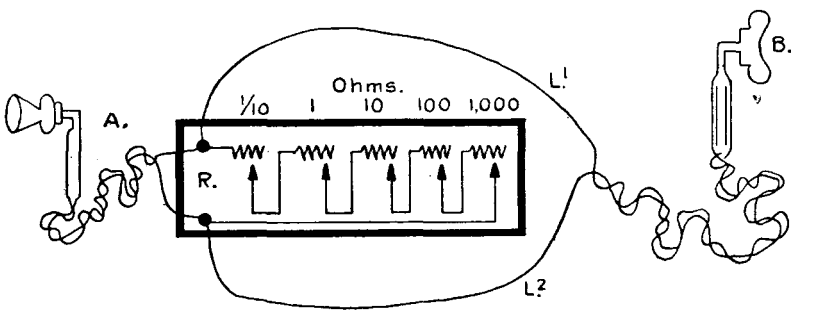


FIG. 1.



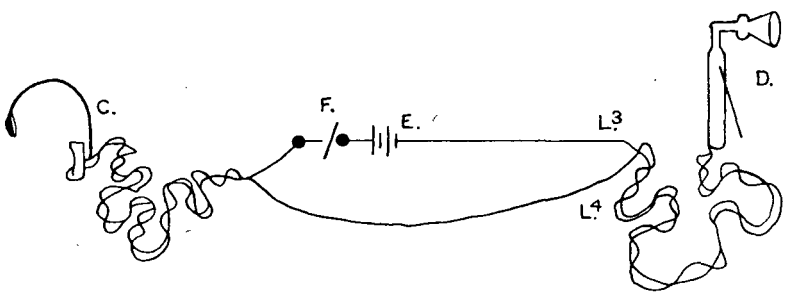


FIG. 2.

A. Magneto microphone.
B. Receiver.
C. Current polarised receiver.
D. Transmitter. (Carbon microphone.)
E. Battery.
F. Switch.
L^1, L^2, L^3, L^4, 4-wire cable.

resistance "R," which is calibrated and variable from 0 to 9999.9 ohms in steps of 0.1 ohm.

The act of speaking into the microphone "A" generates a definite electro-motive force which passes along the line, and by reverse action causes an emission of sound from the receiver "B."

The effect of the shunt "R" is to vary the intensity of the energy

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passed to receiver "B," and this energy will be proportional to the amount of resistance in the shunt.

That is, with no resistance at all in the shunt no sound will be heard in the receiver "B"; inversely when the maximum resistance is across the line maximum intensity of sound will be heard in "B."

It follows, therefore, that a person speaking at "A" will be able to note the exact point at which a person ceases to hear; such notation being made in a standard unit, that is the "ohm," which is the international unit of resistance.

The actual circuit of the apparatus is as shown in Fig. 2.

The circuit comprised by C, D, E, F, L^3 and L^4 is the return speaking circuit, so that the person under test can, if required, repeat back words spoken by the individual carrying out the tests. This circuit is controlled by two switches, one at "F," the other in the handle of the carbon microphone "D." The receiver "C" is of the current-polarised type to avoid any possibility of inductive action of the speech currents in L^1, L^2, L^3 and L^4 in any way interfering with the test. This receiver is absolutely inactive unless both switches are closed.

The apparatus has been elaborated on the idea that the most important standard of hearing is the range for recognising the human voice.

Into such test three variable factors enter: (1) Strength of voice used. (2) Conducting medium. (3) Environment.

It is suggested that, with this method of test, the conducting medium can be accurately controlled by the international circuit of resistance, the "ohm," and that the variation of environment can be reduced to a negligible minimum.

The variation of the strength of voice of course remains unaffected, as in any other "conversation" test.

It is also suggested that by this method the range of hearing for conversation of normal children can be approximately estimated—which is too great for assessment by any other practicable test.

The wires L^1, L^2, L^3 and L^4 are insulated and bound together in one cable, 30 feet long, which can thus be carried, preferably, under two doors across a passage to another room, so as to avoid the possibility of ærial conduction.

The observer (whilst operating resistance "R" so as to control intensity of sound) speaks at "A" and listens with headphone "C" for the repetition of test words by the patient, who listens at "B" and repeats by "D."

The apparatus is all contained, when not in use, in a portable box 18 by 12 by 6 in. and weighing 14 lb.

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