THE EAR AND ITS DISEASES

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The Prevention of Deafness and its Alleviation by Modern Means

BY

DR. EDGAR WHITAKER

Late Aural Surgeon to the Palmerston North General Hospital, New Zealand

ILLUSTRATED

And with a chapter on Electrical Apparatus and Principles by

BARNARD WAY

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ILLUSTRATIONS

AUTHOR'S NOTE.

Owing to the proofs of this book being passed under office-evacuation circumstances three small errors have crept into the pages uncorrected :—

In page 45, *line* 9, the text should read : " The stapes is embedded in the *oval* window " ; not the " round " window. It is shown correctly in diagram, page 33, and described correctly on page 35.

In the footnote on page 31 : The original composition of the B.I.P. paste is incorrectly given. It should be Bismuth, Iodoform, and Parolin. We, in our ear hospital, found it unsuitable. It was unstable, as the iodine content was set free and irritated the ear passages. It was also objectionable as an ear dressing from its smell, etc. We modified it in the manner shown. But it should have been correctly printed.

On pages 14, 45, 46 *and* 55 : The position of the Otoliths (the little bodies having to do with balancing) are purposely mentioned with the semi-circular canals. Actually of course they are anatomically situated in the *utricle* and *saccule* at the entrance to the semi-circular canals, ¼" away, but if they are associated in the reader's mind *with* the canals their purpose will be better realised. The *utricle* is shown in the illustration on page 44.

INTRODUCTION

THIS small book on the Ear and its Diseases is not meant to instruct the medical profession, whose experience and practice is already formed about them, but is undertaken for a rather different purpose.

The ear is a special sense-organ and is necessarily, therefore, something of a mystery. It does not admit of examination by the patient himself nor by his wife or friend, and it is seldom examined in any professional scientific detail (in the ordinary way) by the general practitioner, nursing profession or student.

Yet the disorders and diseases of it arrive without much notice and proceed insidiously. They may vitally affect the earning of a living, even the health and lives of sufferers and their children.

I have therefore taken the unusual standpoint that there should be a low-price textbook from which all those interested should have an opportunity of understanding about their ears, their hearing and possible troubles, and what the doctor is doing and thinking about when he is dealing with them, so that they do not regard them lightly, nor shirk the responsibility individually upon them, as patient or parent, to consult a properly qualified medical practitioner ; or an aural surgeon, on the subject ; which I show them how to do.

It is sometimes the case that in attending a hospital Out-patient Department for the ears nothing is told the patient about the disorder from which he or his child is suffering. In a case complaining of distressing head noises from ear trouble nothing, as the patient often says, is " done ".

As an aural surgeon retired from practice it seemed to me possible to fill a gap, which may enable the student to realize the importance of early diseases of the ear and

to look at them rather differently, with sympathy and encouragement—how to form their opinion and to advise with wisdom.

In the medical portion of the volume I have, of course, relied on the textbooks upon which I was " brought up " —Politzer's, Ballenger's and other *Diseases of the Ear* in revised editions, etc., and upon recent experiences of out-patient and specialist practice where I could see modern improvements, so far as they have arrived. But mainly this work is practical experience, with the hope that it will be helpful all round.

In the Hearing-Aid portion of the book, I have had the co-operation of Mr. Barnard Way, himself an engineer and a wireless expert as well as having great experience in illustrating technical books. We have visited together the works of one of the makers of the best hearing-devices and seen for ourselves everything used. This visit satisfied us that in the latest instruments illustrated they are as explained and their use as stated. Where in the text there appears to be some repetition and insistence the observant reader will understand that there are so many who know nothing of electric principles and apparatus. Repetition, in some small degree, fixes the principles in their minds.

I personally have examined hearing aid appliances for twenty-five years and written articles upon them for the benefit of the deaf, so that the readers, here, should benefit from this survey and trust what is said. I have no pecuniary interest in appliances of any sort.

Where the argument is my own and not strictly relevant to the text footnotes have been used. The reader will excuse any egotism it may suggest. I have nothing to gain by it, except the ambition to be of use.

EDGAR WHITAKER.

NOTE.—For the purposes of this investigation Mr. A. Edwin Stevens, B.Sc., Managing Director of Amplivox Ltd., placed his instruments and aids for hearing entirely at our disposal and this service is hereby acknowledged.

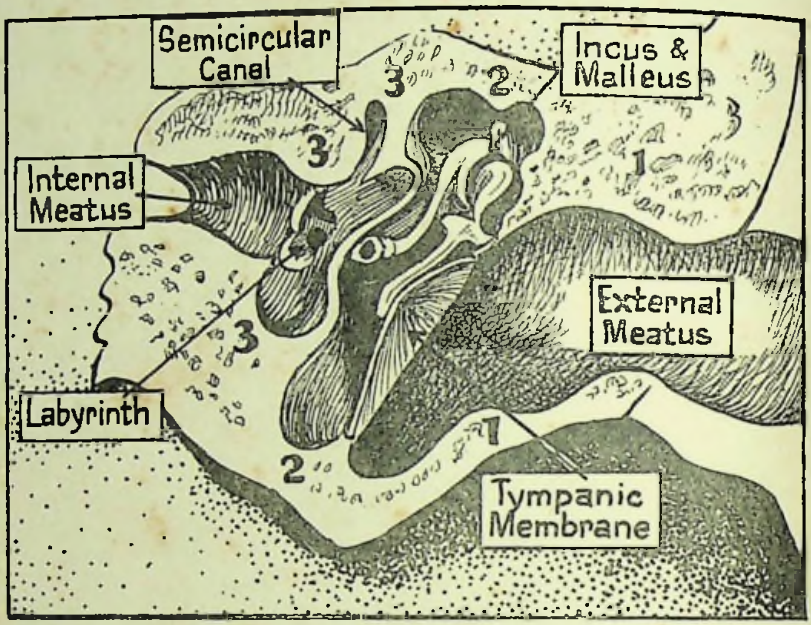


FIG. 1.

Cross-section through the temporal bone, showing: 1. The external meatus of the ear, ending at the Tympanum; 2. The Middle Ear with the chain of bones, malleus, incus and stapes between the two membranes; 3. The Inner Ear, showing the Cochlea and semi-circular canals (cut across) with opening for the nerve of hearing, 7th cranial nerve. (Semi-diagrammatic.)

WHAT IS THE HUMAN EAR?

THE ordinary person carrying on the duties of the day is hardly aware that he possesses anything wonderful or miraculous in having an ear each side of his head or that the despised donkey has much better ones.

Still less is he aware that as a child in the womb he was the possessor of five branchial clefts or gills in his embryo neck and that behind the second of these gills a bony plate formed and as it slowly invaginated (turned) itself inwards, it developed an " otic vesicle ". By the time he was born it appeared in the right position as an ear, just like those of other children. If he hears well as an adult and carries himself upright, even when bumping into anything or riding a bicyle, he is generally unaware that both these functions, so easily and automatically accomplished, are due to the shape of the ears, the various tympana or drum-parchments in it, and a miraculous chain of bones which communicate pressure to fine hair vesicles with nerve endings in the hearing part of the ear, and to the otoliths (balancing " governors " much like those drops in a spirit level if they were solid and yet acted) which are part and parcel of what are called man's Ear.

All mammals have similar hearing devices, most fishes and insects too, but some of the latter carry them on their legs or stomachs and caterpillars on their hairs.

If you wish to see a good ear tympanum lift up the first free feathers at the head just behind the eye in a chicken or a hawk (especially). There is the tympanic membrane—very much easier to examine and about the same size as your own.

It has no " external ear " like the cartilaginous flesh-covered auricle of your own but in other essentials, behind the drum that you see, it is very similar.

In your own auricle, or outer ear, there is an aperture which leads to the drum. The length of this opening, the external meatus, is about an inch and a quarter by half an inch wide, narrowing down to three-eighths, but it does not lead straight inwards. It rises to a slight elevation and then narrows and turns inwards and a little down. That is why neither you, your wife nor friends; can look into it and observe the drum. Which is fortunate, as will be later observed, for children and the heavy handed. This channel in the Outer Ear is termed the *external meatus* (marked " 1 " in the illustration) which is a passage ending at the tympanum, or drum, which contains between its layers a central prominent structure, the " handle " of the malleus or hammer-bone. On the other side of the drum, as you can see in the illustration (marked " 2 ") is another cavity, about a quarter of an inch wide, called *The Middle Ear.*

It contains the other side of the drum, the top and back of the little *malleus* bone, to which are joined the *incus* bone, and to this the stirrup bone or *stapes*. The flat foot of this stirrup is attached to another membrane on the far side covering a hole ; but the cavity of the Middle Ear is not entirely enclosed. The front of it, towards the nose, is attached to the Eustachian tube which (unfortunately in some respects) not only continues into the back of the upper throat and nose but is lined with similar epithelial and mucous covering.

Behind this *Middle Ear* is bone, but very peculiar bone, in which is shaped out three semi-circular canals placed exactly at right angles to each other and (marked " 3 ") joined through a *vestibule*, a canal curled exactly like that of a snail's shell. This is the *Cochlea* or hearing organ. In the semi-circular canals are little bodies called otoliths suspended on nerve-threads which govern the balance of the body. In the curled cochlear canal are the very fine ciliary hairs attaching to fibres of the VIIth or auditory nerve which goes thence to (but actually derives from) nerve substances in the temporal (auditory centre

region of the brain. This little box of devices is called the *Inner Ear*.

The drum is kept moist by wax on the outside and by lymph and air circulating on the other.

Each ear is in communication with the opposite one by cross-fibres from the nerve substance in the brain.

THE AURICLE AND ITS DISEASES

ALL that the human hearing apparatus presents to the outside world is the auricle on each side, a few hairs in each of them, and the indications of a cavity.

It must have been quite a long time in anthropological history before these head-appendages became generally associated with hearing. The first person who said to another, pointing to the ear, " I am certain you hear sounds with *that* ! " was a scientist and investigator who took his life in his hands. One of the beneficent acts of the Creator is that in the ordinary way it may be years before there is any necessity to have the ear looked into and examined, but that carries the drawback that when it is examined there is a certain tenderness and anxiety associated with having it done. Most people (wisely or other wisely !) have screwed up the corner of a handkerchief or towel to dry their meatal canal and, if there is a collection of wax in it accomplished a certain amount of harm to it for future prospects ; but at the same time they have " felt " it to be unwise to penetrate too far.

It is not easy to penetrate too far in a straight line because there is a raised portion of the floor of the canal preventing it, just before the narrowed part turns inwards and a little down.

By pulling the ears gently back against the head the meatal canal is straightened but in order to see properly into it even then there are still one or two things wanted.

They are shown in the illustration (Fig. 2).

A good illuminating lamp which will reflect a bright band of light from a mirror into the speculum, when it is gently insinuated into the meatal canal, is essential. Several *sizes* of blunt-ended silver specula also, since the size of the meatal canal is so variable, particularly in children. A pair of thin and delicate ear-forceps

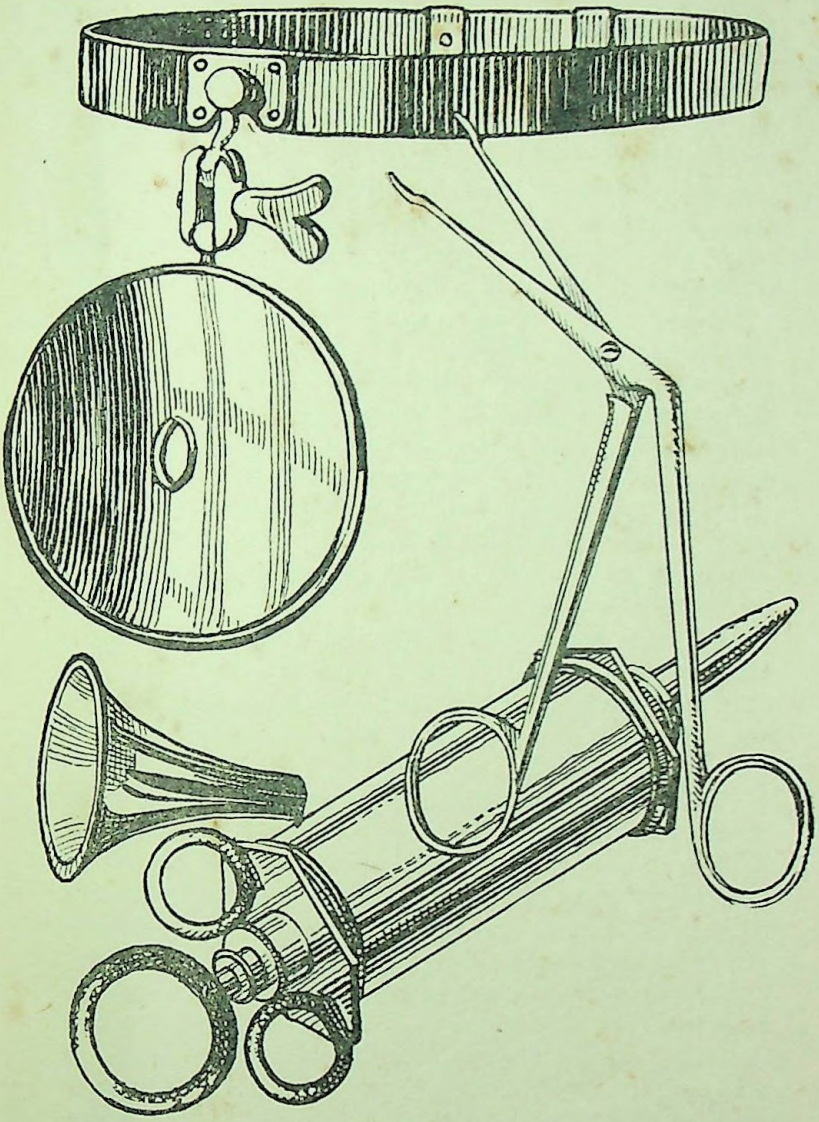


FIG. 2.

Forehead headband with adjustable mirror. Ear speculum. Ear forceps. Ear syringe.

which will enter the speculum and carry cotton wool and medicaments, and a full-sized 6 oz. metal syringe with a hexagonal screw-top (to prevent it rolling off the glass table). These instruments complete the simple outfit at the moment (except for the mirror they can all be sterilized !) for examination of the ear.

A proportion of those who consult a doctor about some discomfort in their ears do so conscious that their hearing is affected. If they are not conscious of it the necessity for diagnosing it is greater.

Having been brought up among general medical practitioners (there were five of us in the family either in or married to general practice) the last thing I should do would be to write anything but praise of their capabilities and services, but in diseases of the ear, the testing and preservation of the hearing, some practitioners do not take any special interest in them as part of their work. Their business is to deal with the matter upon which the patient comes to consult them, to cure it, and there their duty ends.

If you are cured, it may be a long time before you see them again and if it is about your ears it is unlikely, save in exceptional cases, that they have been able to keep anything but the barest record of your previous visit.

The aural surgeon regards your ears differently. His primary duty is to cure your disorder, safeguard your hearing if he can and, since he knows the dangers of ear trouble, to think about your future life so far as it depends upon it—and above all to make and preserve your ear-records, which are an essential guide.

If he cannot refer instantly to them, it is merely a statement to say your " hearing is worse ". But if you say so on your second visit, he can refer to his notes and estimate how far it is true. If it is not true how grateful you will be to him for the *proof*. If you are only a tiny mite worse, how relieved. If you are really worse, how sensible of you to undergo further treatment !

For various reasons based on practice, travel and experience of American surgical methods (which were at one time twice as good as those in England) there is no question that the old aural specialist with his tail-coated university-professor-company-promoter aspect in a thousand-pound room crammed with luxury dust-gathering lounges and expensive bric-à-brac is entirely out of date. Aural specialists in this country are so highly qualified and capable that they would be successful under any conditions, though they depended entirely on the aseptic surgical perfection of an outside nursing home.

The actual testing of hearing can be done in any room, the larger the better because of the walls echoing sound, but there is no doubt that in the examination and treatment of the ear proper, the patient and surgeon should be in such positions and chairs that the ears can be approached with comfort; and that every instrument, boilers and remedies should be within instant reach of the surgeon. The examination room should not only be sterilizable but everything in it should be sterilized regularly. In short the closer the ear-surgery approximates to the operating theatre the better outlook *for the sudden emergency case* brought in. And in general an examination is less tedious to the patient where everything is designed so that no movement is wasted.

But you have come to consult the surgeon about your ear and he is taking your " history " down.

At present you have only your auricles within his view, yet even these may be subject, just as the inner parts of the ear, to congenital malformation, injury and disease.

The external ear should normally appear as in the illustration (Fig. 3), but the auricle may be deficient in some part or have additional " nodules " from some error in development of the branchial clefts. If these are complained of something in the way of surgical rectification can be done. Similarly with prominent and protruding ears; but if the patient is a child the surgeon

will let it alone. The *entrance* to the ear may be blocked or non-existent and it is in these rare and strange cases that the experience of the aural surgeon is so valuable. He will know whether anything surgical can wisely be undertaken.

In the matter of injury to the auricle, the commonest is that caused by a blow or tear. In "*Cauliflower*" *ear*, blood coming from the extraordinarily good blood supply

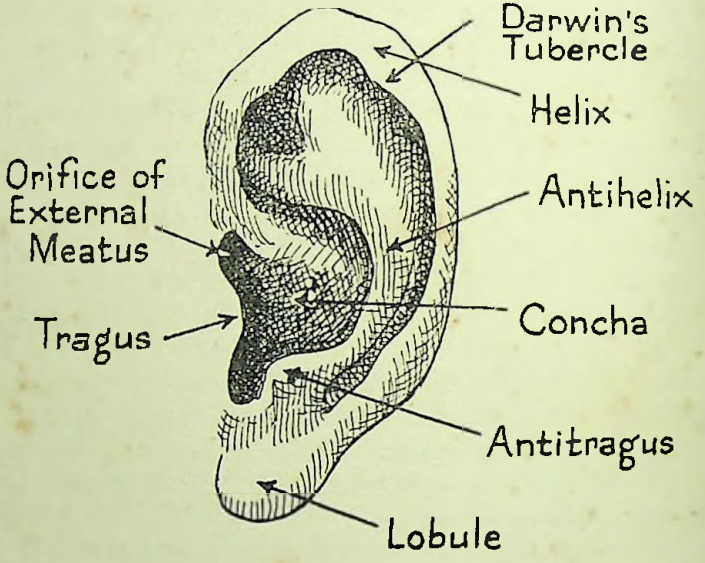


Fig. 3.

is extravasated into resistant cartilaginous substances and may cause great malformation. The clots of it can be turned out by surgical methods but it is odd how "thick ears" of this kind avoid the aural surgeon at the only time he could do much good, which is at once!

The inflammatory conditions to which the external ear or auricle is subject range from skin troubles to very severe general involvement of the tissue and even of the cartilage. As the patient with these will already have

tried several ointments and applications they will, in each degree, involve experienced new treatment. Undoubtedly, the basis of it lies in cleansing away any hard scabs and exudations which prevent the proper application of medicinal remedies and this can be done by careful fomentations, softening them away so that the layer of healing can be favoured to good result.

It is well to bear in mind that in all surface injuries and inflammations of the ear there are three layers to be considered, just as, but not quite the same, as are caused by a burn of the skin. The epithelial skin layer only may be involved, next the sub-epithelial layer of tissue, and lastly the deeper layer of fibrous, muscular or connective tissue and fat which contains the main battery of blood vessels, lymphatics and nerve fibres and upon which you must depend for your renovation. It is dangerous to harm these but rather from them to encourage growth. The cartilage of the auricle, like cartilage anywhere, is a great aid in elasticity and moulding of form, but not a great help in inflammation cure.

But returning to yourself, unless you are complaining of bad hearing, you are giving the aural surgeon certain definite *subjective* symptoms, those " things " which have brought you to the consultation and you feel for yourself. Possibly you are saying that you have an " irritation " inside the ear, that you are constantly putting in your finger to ease the itching and discomfort of heat, pricking or noise sensations in the head, which prevent you feeling normal and comfortable. We are not suggesting, yet, that you are complaining of great deafness or, say, a discharge from the ear, for that comes later and is serious.

THE recording finished, it brings you to the examination chair and the surgeon to his mirror-headband and reflecting light which he throws into the ear so that his eye, the hole in the mirror, and the illuminating band of light into the ear, will be in the same plane. He can see everything, but he is looking into a bent and narrow

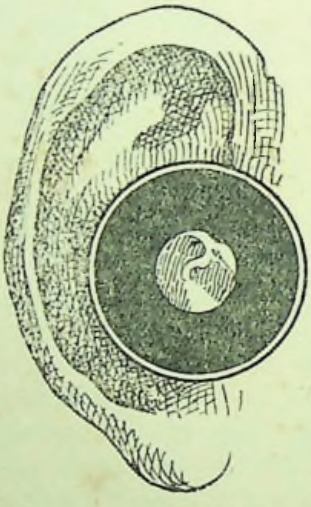


FIG. 4.
The Speculum in the right ear with the tympanic membrane as it is seen through it.

channel. By pulling the ear lobe gently back and upwards he can manipulate and make the channel straight, until with the help of a warmed silver speculum, which fits the size of the canal, he can see the whole passage of the meatus and *perhaps* the drum at the end of it. If he cannot see that then you have an obstruction—which is generally wax derived from the wax glands and sebaceous glands lining the canal. Sometimes

it has gathered so long and become so hard that it must be softened by warmed drops of bicarbonate of soda, say, 10 grains, and glycerine half a dram to an ounce of water before it is wise to move it. It lies tight on the skin-layer all round, and because this has therefore been damaged it is irritating you. If water has got behind the block of wax and caused an airlock, or swollen it up when you were bathing, it has made you temporarily deaf. Syringing with either warm water or some containing half a teaspoonful of disinfectant, Sanitas, Lysol, etc., carefully done from the back of the canal passage will in time "deliver" the wax-block out. The aural surgeon will remove it anyway for it is A B C to him, but he may have a fancy for using hydrogen peroxide drops before doing so.

If wax has been there some time it will always bring away some of the lining epithelium and leave a temporary white lining to the meatal canal. If the other ear has similarly to be treated you have had enough for the day; but the aural surgeon will not have finished until he has dried the canals out with cotton-wool and perhaps instilled some weak disinfecting fluid, ointment or salve to the injured walls (every surgeon has his own preference) and perhaps gently used inflation, afterwards placing a cotton-wool plug in each ear to protect you from cold.

The aural surgeon knows now roughly the extent of your hearing and the condition of your *meatus* in the ear on either side, the state of your ear-drums and in a measure the course of your future hearing and ear history.

What has he seen through his ear-speculum, which, despite your apprehension and because of his experience, has not hurt you at all though he has put an instrument literally inside your head?

He has seen the whole of the three-eighths to half an inch wide inner canal of mixed cartilage and bone basis, covered with skin and epithelium, as it goes downward and inward for about three quarters of an inch into the

head. It ends with what you see in the illustration as the tympanum or drum (Fig. 5).

This is of a varying yellowish-grey colour marked by the almost central bony handle of the malleus which inclining at an angle backwards is enclosed in the skin of the drum, and, leading from the point of it, generally as indicated, is the " cone of light " as shown. The drum seems drawn inwards by the bony prominence and

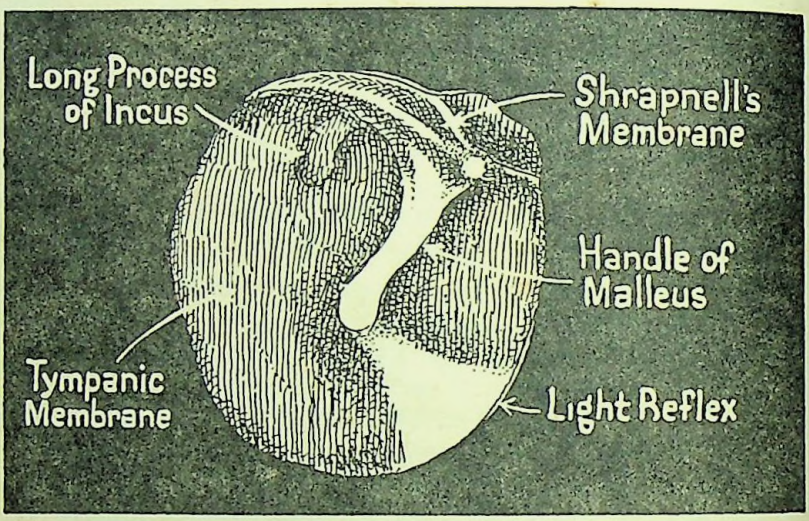


FIG. 5.
The Tympanic Membrane.

stretched tight. The aural surgeon has divided it in his mind, subconsciously, into four quarters and examined them, for they each have significance if only in his notes. He looks at the top and sees the horizontal bony-ridge of the *malleus* and *incus* and the other (Shrapnell's) membrane at its top. This is sometimes little more than a thin line.

There is a little artery in the main tympanum running down the bone. The drum can blush, and it can bleed. The meatus has three blood supplies, from the posterior

auricular and superficial temporal and deep auricular arteries. Which brings us back to the business of why we prefer to sit ready in surgical garb in the consulting room, just because of this meatus ; with every instrument and convenience at hand. You will see the reason below.

You can hear because of the drum but you can also hear without it. The aural surgeon knows that all sorts of things can happen because of it, and because of the narrowness and bending in the meatus canal. The things won't happen to you but (one day) each of them must have happened to someone who is brought to the aural surgeon.

You yourself have had one kind of " foreign body " in the ear, wax which is past use (we will return to this later), but lots of other things can get in, or be pushed in, the meatal canal of the ear.

A child may have pushed anything into his ear, from a pencil end to a plumstone, and be brought howling and frantic and promptly be sick on examination.

The child or woman (it is generally a woman because of her hair) may have " got " an insect, twig, earwig, bee or wasp fast stuck in the ear canal. If it is small enough to climb over the drum surface it is exquisitely painful and on the way to drive the patient frantic. The hairs in the canal point outwards and the insect has to work its way in and is held more or less fast.

There is not the least need to worry. It can be dealt with at once. The stone or pencil can be got away, the drum made insensitive if necessary, the insect killed in a second and removed. The first by skill with instruments, such as delicate forceps, loops or snares. The second with installation of drops of cocaine and adrenalin—five drops of 5 per cent of each, or a hollow pad of ether or chloroform placed over the ear, with subsequent removal of any dead insect which is instantly killed.

Though I have seen many wasps and bees stuck fast in the ear and the patient horribly afraid of being stung to death, they can all be quieted in a second and dealt

with. You have everything handy and you *know* you can do what is wanted. They know it.

Wasps or bees may not sting when they are feeding on the wax, for I have never seen them do so, but it is best not to give them a chance! If the sting-part can be freely seized, seize it and take the animal out, but on the other hand to vapourize it to death and then seize it or syringe it out takes only a moment or so longer. A foreign body in the ear can *generally* be syringed out, if not, it can always be removed by operation without pain.

On the other hand, the patient may be hysterical, sick or faint while you are doing it, as an urgent first aid, and it is necessary to be ready for anything of the sort.

A patient will often faint if the drum is touched for the pain is excruciating. The drops (above) prevent that but it is the adrenalin used with the cocaine which localizes the effect of the latter's otherwise dangerous general action. As domestic first-aid I have known wine glasses of warm water poured into the auricle to make a wasp come out, and it does. A pair of kitchen scissors and a steady hand will do the job also, and I have known a lighted match held behind it be successful; in the home!

An aural surgeon will always get surprises at what can come out of the meatus of the ear. Obstructions can take many forms. Bony exostoses pressing up and narrowing the canal. Moulds which form in the ear, like the *aspergillus*, of which I have had two specimens. They are removed and the spores easily killed by spirit. They are rare.

The shapes taken by accretions in slow-discharging ears are extraordinary. They cause little pain, or notice, yet when removed they may be half as long as a cigarette, riddled with holes like a sponge and made of a substance very like that of a wasps' nest, hard or inspissated by the heat and fluid.

Discharging conditions in the meatus itself come only

from infection in the meatal wall. The wax- and sebaceous-glands can both get stopped up, and be infected. But the real danger associated with a careless assumption that wax is the sole cause of discomfort and that syringing it out will cure it lies in failure to diagnose the source of the discharge.

Never syringe a painful ear. Find out the reason for the pain, by gentle examination.

Perforations of the Drum. The drum may be perforated, that is it may have a hole in it caused by infectious discharges that are present, or that have occurred previously, and that have found their way out in drainage *through* the drum. Promiscuous syringing of the ear can therefore force the water into the Middle Ear (which is dealt with in the next chapter) and it is possible to do great damage.

At the best syringing of a perforated tympanum makes the patient go giddy and perhaps faint away. At the worst it may tear off a part of the drum causing intense pain, damage, bleeding and possible infection. All aural surgeons have had such cases brought to them, caused by forcibly syringing in the wrong case. Inspection of the tympanum through the speculum shows the hole in the drum and very often, in chronic long-standing discharges of the ear, there is a polypus protruding through it. *Polypi*, like stalagmites in a cave, are prolongations of the original substance, in this case, the swollen infected epithelial layers are producing " granulations " and are the chief factors in the discharge. Skilled examination of the meatal canal will reveal whether there is a healthy or infected condition even though perforation is present. A perforation does not prevent the patient hearing but a polypus is a sign of great danger, since the middle ear is in fault.

In such a case the polypus must be removed and it is in these chronic " slow " cases, after removal, that I have found bismuth and lead applications act as a charm. They can all be cleared up.

The hole in the drum heals and the discharge ceases without further spread of trouble inside. The question of treatment by mastoid operation must, in these cases, be left to the aural surgeon to decide, since by skilled experience alone can the necessity be judged.

An old perforation from infantile febrile conditions (measles and scarlet fever), if seen in an adult, seldom heals. The ear *is generally dry* and the hole in the drum is unnoticed by the patient and, very often, he has heard well.

Furuncles or little pimple-boils caused by the infection of the small glands along the meatus may be very troublesome and most painful. The skin of the canal is so tight, it resists expansion and that causes intense pain. They are dealt with on antiseptic lines, by opening the heads of them if you can or carbolizing them by a pin's-head application. The cavity is very small but soon yields to cleanliness, cooling applications and application of your favourite mild antiseptic ointment or drops. It is a very painful condition, but local, and with antiseptic precaution is not going to cause permanent damage. The intense pain and the obvious blocking of the meatus, which may swell right up, with normal hearing, makes the surgeon sure it is not a dangerous internal ear trouble.

The *parotid gland* lying as it does exactly below and fitting into the bone of the floor of the meatus sometimes gives pain to and may suppurate upwards into the meatal canal. The glands behind the ear are also easily involved in these streptococcal complaints. Your doctor may therefore deal with the former by giving (perhaps) one of the sulphanilamide remedies; and afterwards taking care of your debilitated condition, building your system up with tonics and change of air. Mumps, which involves the parotid gland, is not reckoned an aural surgeon's business but nevertheless it may cause suppuration.

There is also a serious condition of deeper skin ulceration which may go on in the meatal canal, refusing cure and suggesting (at least) malignant trouble. In a recent

case of fissure, long standing, I was asked as a friend to give advice. It was chance, of course, but I was struck by the glassy appearance of the fissure. I had what the homœopaths calculate as *4x* of *Silicea* (colloidal, i.e. not triturated with the usual milk sugar) *potentized* by electrical succussion—which means violently, persistently, and irregularly shaken by an electrical atomiser—to make one millionth of the substance in solution. This was regularly applied and healed the crack in ten days. Forming the opinion that the crack had worn away its third layer of healing vessels I thought to glaze it over in order to give it protection while recovering. At least I suppose so. If you have read modern physics you won't need to be told that electrons can "jump over" more easily if there are not too many of them and they are violently stimulated. I never used it in my own practice but I understand that *Silicea* is a well-known internal homœopathic remedy for fissures.

One can learn all one's life and *know* nothing, possibly blundering into a cure. After a hard-working surgical life one can best leave "cures" to the unqualified and optimists, satisfied if you have restored the organ to a state of health.

That relates the ordinary evils that can come to the meatal canal, considered alone and as the first part of the ear proper, though it is only too often involved in "middle-ear" disease.

THE TYMPANUM AND ITS DISEASES

THE actual tympanum or drum may however be itself (on the *external* surface, as you have seen it described in the previous chapter) the seat of sudden and violently painful inflammation. The surgeon can diagnose that by observing it through the speculum, but the sufferer calls it earache, with good reason. *Acute Myringitis*, as it is named, *is sudden; the hearing is still present* and the local signs are seen—inflamed altered surface and blood vessels covering the drum which perhaps shows yellow blebs; possibly a bulging serum-filled sac in one quarter of it. This is the one condition which calls for puncture if the pain is excruciating. To pass a very narrow-bladed knife through a narrow speculum, along which the light must be accurately directed so as to guide the hand, calls for exact skill. Textbooks sometimes say that it can be done when the patient has the drum under anæsthesia by cocaine, so it can, but in many cases of this acute myringitis the inflammation of the whole meatus is very intense. Cocaine has little effect on many. If the drum is actually bulging and the surgeon feels sure it is the cause of the pain and if unrelieved will burst the drum he is justified in using a general anæsthetic. Since the bulging bleb *only* must be opened, and the drum must not be perforated by the knife, it is a business requiring great care.

Generally these acute earaches react well to warmth and care in bed, purges, and hot drinks, steam inhalations; and cooling applications to the drum, of which Lotio Plumbi Subacetatis is most useful.

The *external* surface of the drum *may* alone be involved in this infection or inflammation. The drum appears to be that way affected on inspection, but this myringitis is what the surgeon does *not* see when the child is at last

brought to him with a discharging ear. There is a first stage in every inflammation and under treatment with warmth, etc., these acute earaches disappear without bad effect. One can only *see* the external surface so that the condition of the inner surface is a matter of doubt.

If the hearing is not affected one is justified in diagnosing simple myringitis with no implication of the middle ear.

As regards the good effect of lead and bismuth applications for ear trouble, particularly with discharge, see footnote.*

Myringitis or inflammation of the drum can arise also from concussion. High-explosive can tear the substance of the tympanum and do great damage but most of us have seen the natural repair of it without infection. It is this quality of natural repair which, from experience, inclines one to let the drum alone unless special reasons

* When one is retired from surgical practice it is not proper to "push" a remedy forward. Therefore I can only say that those practitioners to whom I recommended it on return home have found bismuth and lead applications wonderfully reliable for discharging conditions in the ear. Surgeons will recall that suppurating war wounds in 1914 were packed with B.I.P., which is Bismuth, Lead and Iodine. They used it also for "packing" after mastoid operations.

I found this pasty substance was irritating to the skin of the ear because the Iodine, if it was not closely incorporated in the mixture by mulching, made it so to ear tissue. But by using Bismuth Subnitrate ℥i, Liq. Plumbi Subacetatis fort. ℥i and mulching it into an ounce of Parolin it was non-irritating. The longer it was mixed and mulched the better, and more effective in clearing up old discharging surfaces.

The idea behind its efficiency and use is logically sound. Bismuth and Lead are the heaviest metals and each of them is in the highest class of those elements which have incomplete electronic shells (as shown in modern physics). Bismuth has 29 and Lead 28 free electrons in its sixth shell. There is only one element higher, Polonium, which has yet to be isolated, but it contains (or should contain) 30 free electrons.

Whether you come to regard the hearing-interchange, from energy of vibration to interpretation of its impulses simultaneously as sound, as "electrical" in nature, or not, it is better to have a logical backing for your treatment than always to be empirical in it. The two best substances to insure conduction of vibrations and currents are insulation by lead and glass (silica).

It is equally true that mixtures, medicines and substances which one may find miraculous in the way of cure in one epidemic have, or seem to have, lost their power in the next similar one. The bacillus, chemical or electrical interchange, which ever it may be, gets a little too clever or too used to it to be overpowered.

call for surgical measures. Very humbly, I am of opinion, that the operation of *paracentesis* is too often suggested and too lightly regarded in aural textbooks.

Watching a case of myringitis through its twenty-four hours I have seen serous bullae appear on the external drum-surface and *disappear* by resolution and cure within that period. Let well alone is often a wise decision, if you are standing by watching all reactions.

THE MIDDLE EAR

In the illustration on page 12, the three divisions of the human ear are plainly shown but in the illustration on this page (the clever diagram, Fig. 6, being adapted from Dr. Beatty's *Hearing in Man and Animals*) all the essentials are exposed.

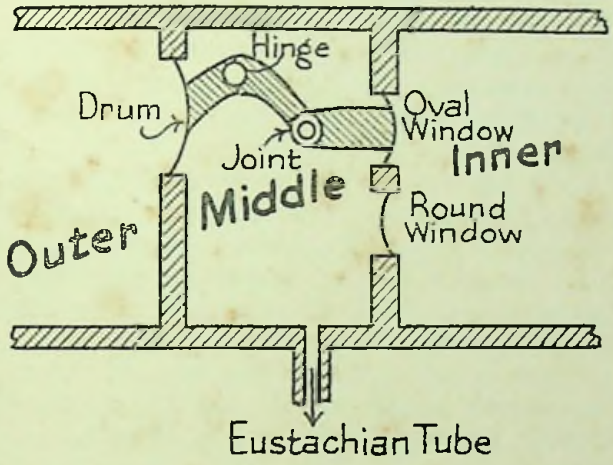


Fig. 6.

The Middle Ear (diagrammatic), showing how it acts as interpreter of signals between the external and inner ears by means of a chain of little bones.

For a moment, just regard it as representing three rooms in a flat which are called the Outer, the Middle, and the Inner. The essential room, in which the whole of the *service* of the flat is conducted, being the Inner. Everything done by this "Inner" room is, however, conducted through small membrane-covered doors (because of the intolerable noise otherwise). By a system of telephonic messages by pressure of membranes;

between the outer room-door and a chain responding to variable signals communicated to the two membranes in its own inner door—all the service can be done. Messages in reply to " knocks " are flashed to the various nerve-ganglions and all the functions and necessary muscular movements are instantly put in motion by the hearing staff in the " Inner room ".

For another moment, figure to yourself what happens when there are muffled messages and knocks coming from the membrane-door in the Outer room ; because the entrance has become blocked or the membrane and the little bone-joints thickened. The Middle and Inner rooms are both still ready to function the moment the block is removed or the membrane and joints regain their signalling powers. Until they do, that is *Outer-Ear Deafness.*

If the chain *and* all the membrane-doors function badly and almost refuse to respond to or to pass vibration-messages ; that is *Middle-Ear Deafness* ; in which the low tones are lost. Only middle and high vibrations are passed along ; and they gradually fail, but seldom, fortunately, does it take less than several years.

Poor *Inner* room ! In itself it may be as right as rain—but it just isn't getting messages and like a submarine (under a rock of bone) it gradually loses its vital life. That is *Inner-Ear Deafness.* Total loss of function. High tones are lost—all tones finally cease to cause response. Bone conduction *may* however preserve its function alive for hearing.

You can see the drum set in its bony wall, and we have been examining it through a speculum at the end of the canal of the *external* meatus of the ear. But no one can see into the *Middle Ear* except when the drum is perforated. What I have described (with submission) previously as unfortunate is that, as you see in the diagram, the three tiny bones the *malleus* with the *incus* hinged on it, the *stapes* (joined only) to the *incus*, makes a movable link between the membrane of the drum, the tympanum, and membrane

of the *Fenestrum Ovale* or oval window in a "closed" box of bone lined with mucous membrane. Yet it (the Middle Ear) is open to the *back of the nose* by direct communication as you see through the *Eustachian tube.* You will notice another membrane the *Fenestrum Rotundum* or round window, which separates it also from the Inner Ear. This equalizes pressures within the labyrinth of the Inner Ear.

This box, the Middle Ear, is probably the most, or at least one of the most, vital factors in the human economy —and yet it communicates with and secures its air and drainage from the Eustachian tube which is directly in communication at the back of the nose with all the sources of catarrh and infection to which the nasal and throat passages are the natural heir. True that the tube is normally closed by a kind of valve, but it opens every time you swallow.

No wonder therefore that the mucous and epithelial layers of the Middle Ear suffer abnormal conditions.

Normally it is part of the adjusting signal-box of sound. Sound waves, whether in speech or caused by other expenditure of energy such as noises, from a mere scratch to high explosive detonations, are dealt with in some wonderful way of adjustment through the tympanum-malleus-incus-stapes-oval-window-membrane chain, by which the different energies of pressure, caused by the vibration pass on to the minute nerve-hairs of the hearing nerve in the cochlea of the Inner Ear—which has the miraculous power of discriminating between them with the help of the hearing-centre in the temporal lobe of the brain. It enables you to understand their "differences"; not their meaning. That is the further miracle of experience and education. The lower animals know the meaning of very few sounds. If they hear them they do well enough to interpret them as tones. In this box of the Middle Ear there are also ligaments, tendons of muscles which control the hinge movements and the joint, a fine nerve called the *chorda tympani* which is

connected to the *vagus* nerve of the stomach and, of course, an arterial, venous and lymphatic system in full going order, with very large arteries and veins, the carotid and jugular passing round the cavity in bony canals, and the lobe of the brain above it. The Middle Ear is in some communication with the cavities of the mastoid bone behind it by means of what is known as the antrum, a portion of that bone.

The Middle Ear is, with the Inner Ear, the wonder of the world, yet it can go literally to pieces owing to its one-way direct route for catarrh and infection from the back of the nose.

THE diseases to which it is liable are therefore described as:

Catarrhal Infections, acute and chronic inflammation of the Middle Ear.

Suppurating Infections, known as acute Otitis Media and chronic Otitis.

These are of important significance to both patient and doctor, and of terrible significance to the patient and aural surgeon for it is the latter who knows the *extent* of their threatening the hearing and perhaps the life of his patient. The best way to deal with this Middle Ear (in order to convey its importance to the reader) is to relate the course of a catarrhal infection, and then to examine it. The patient, from the aural surgeon's point of view, knows only too well that he can suffer from what is known as a *Common Cold in the Head*, when: He feels stupid and snuffly in the nose and the head; he hears badly all of a sudden, as if the ears were stuffed up, and notices cracks and snaps in the ear after blowing his nose; if the nose is "pouring" the hearing is very bad. There may be *tinnitus*, which means noises such as reverberation, buzzing, or singing noises in the ear. He feels "rotten".

The patient, nowadays, calls it an "influenza cold" and very sensibly puts his feet in hot water, takes hot lemon drinks, goes to bed and tries with the help of hot drinks and warm blankets to sweat it out.

His doctor agrees with him and gives him medicines which are favourable to sweating and to skin and kidney and bowel action. This is *essential* treatment. In a few days he is better. His hearing probably goes back to normal. The *tinnitus* and noises in the ear disappear.

That is a simple catarrhal infection which concludes without ill-effect. If it was not (perhaps?) for the

Eustachian tube (the catarrhal infection being a systemic matter but yet all its ear symptoms local) the *Middle Ear* might well escape unscathed.

But the epithelium of the back of the throat and nose became inflamed and soggy and, though somewhat modified, the Eustachian tube's mucous lining is continuous throughout the tube right into the box of the Middle Ear.

Maybe the patient's *hearing* is affected.

He has *noises in the ear.*

They disappear. Because the Eustachian tube is open again. Its mucous membrane normal (which means that the epithelial cells lining it are no longer swollen) and the air can get through as usual to the Middle Ear, aerating it, draining it and allowing it to signal and function normally.

This sort of Common Cold in the Head, Influenza Cold, call it what you will, comes again and again to some people. It is favoured by the presence of glandular tissue such as in adenoids and tonsils. It is nurtured and fed by the swollen turbinate-bone coverings in the nasal passages; these bones masking (in normal health) the openings of the maxillary and other *sinuses* of the cheek, forehead, and those of the head. They help to warm the air coming to them and are folded and covered with epithelial layers for that purpose, richly fed by blood supply and drained by venous and lymphatic systems. But they all swell with catarrhal infection and help *to pour out* secretions.

Very well. One or a series of these attacks of " cold ", even provided they have not carried a violent germ like the *staphylococcus* up this Eustachian tube, and you may not hear so well as you did. It is very wise to see an aural specialist *at once.*

Let us look at a patient's (your) point of view (but not yet recounting the hearing tests which are given on p. 53).

You will tell the surgeon of the " 'Flu " and colds but almost certainly you will have noticed, or had it brought

to your notice, that *one* ear does not hear as well as the other.

If you are not in pain the surgeon will probably test your hearing with watches, acoumeter, tuning forks and whistle, and whisper ; but it is the tuning forks which will assure him, even before he examines your ear, that it is only your Middle Ear and not the Inner Ear which has been affected.

He will then examine your meatus with his speculum and forehead light-reflector and he may find wax blocking up the passage and remove it. He will examine the drum and make his own notes about it ; for it may be altered, have lost its lustre, be retracted back and have significances which he recognizes. Then he is sure to examine the nose. (It is better to practise as a specialist in a country which wisely expects an aural surgeon also to be a nasal surgeon. A knowledge of drainage and its essential operation on the nose are essential to aural work.)

The surgeon may find means to give you a better airway through the nose, since many people have a bent nasal septum, a swollen turbinate bone, etc., but in any case it is the Eustachian tube-opening at the back of the inferior turbinate bone in the pharynx which he must investigate. Experience and perhaps some sedative application will enable him to pass an instrument called an *Eustachian catheter* painlessly into the opening of the Eustachian tube on either side and with a *Politzer's bag* (a mere inflated rubber ball with a tube) he will be able to tell whether air freely enters the Eustachian tube and what the effect of it is on the tympanic drum. With another instrument called a *Siegle's speculum* which is a reflecting speculum placed in the ear (with an improved angled mirror to avoid the examiner's direct ray of light into your ear), attached to his inflation tube and bag, he will be able to gauge the mobility or fixation of the drum ; which unfortunately is affected by these constant catarrhal conditions. As he presses the bag the

tympanum is forced slightly inwards, when he relaxes it it is drawn slightly out.

His treatment to the Eustachian tube and to the tympanic drum, and perhaps his painlessly cauterizing the turbinate bone blocking air to the opening of the Eustachian tube, will benefit your hearing at that consultation and probably restore its function. An aural surgeon may also prescribe for you something to use and spray up the nose which will help materially to protect you from this liability to nasal catarrh and Middle-Ear trouble.

A course of this inflationary treatment through the Eustachian tube is often essential to restoring the hearing. Malformations of the septum of the nose, adenoids, inflamed turbinate bones can all be corrected, the air passage to the Middle Ear assured *and drainage improved.*

It is essential that you see an aural surgeon if you have the least liability to this far too lightly regarded Common Cold *which affects your hearing.*

Since both forms of inflammation of the Middle Ear, the *simple* (though not so simple !) and the *suppurative* (which is always severe on hearing and may affect life) can arrive from the same apparent reasons it is only a matter of degree, plus the presence of the highly infective *cocci* (that cause suppuration as their end-product) which differentiates them in descriptive terms. But the signs and symptoms of that degree are very different. Both are *Otitis Media* or inflammation of the Middle Ear and each is accompanied with definite ear trouble and profound systemic disturbance. In children Otitis Media may derive from inflamed adenoids and tonsils but it is only too often a complication of the infectious fevers, measles and scarlet fever. When the ear is in trouble *Pain* is immediately referred to it. *Tinnitus* or noises in the ear are vile. The *hearing* is nearly always affected, but possibly only in the one ear that is the seat of the infection. The child *tosses about* and is very *restless* in the early days. The *temperature* is raised ; but everything

may die down and clear up in two or three days. If the trouble does not resolve quickly, the picture is more grave. *Vomiting*, the *drowsiness* of deeper infection, *tense pain*, and *displacement* of the ear and even *pitting* of the skin over the mastoid bone, apathy at attention, are all signs warning the physician of deeper suppurative penetration.

Otitis media is a very serious condition which needs the highest of skilled nursing and the efforts of the physician. Though the ears can be examined and will keep the aural surgeon informed, the chief indications are to keep the patient warm and to ease the intense pain and the general inflammatory conditions of the infected side, upon which most careful watch must be kept.

Hot fomentations favour absorption by increasing the blood supply. An opium mixture of ten drops of the tincture in warm water used to be a favourite sedative, gently dropped into the meatus. There are more modern drugs on the market and pain can generally be relieved now rather more easily.

With children in infectious fevers I used always to have a bronchitis kettle blowing steam now and then into the room which vapourized a spoonful of Friar's Balsam. My children had these complaints of measles and scarlet fever badly, and did not have ear complications.

In the graver conditions drainage for the extravasated fluids, in such a narrow blocked chamber, must be established, for the sake of the ear if not the life. It is generally established, by the pus or muco-pus wearing away at the drum, bursting it and pouring out. It may do so quickly and unknown to the attendants; and it may then cause resolution of the whole trouble and the ear be repaired with hearing hardly affected.

That used to be the rule, if cure occurred. Now surgical methods are available to save the hearing and life. Fortunately in children it is comparatively easy for the aural surgeon by operation to drain the *antrum*, which is the bony covering at the back of the auricle

which directly covers the Middle Ear. There is only a a thin roof of bone over the Middle Ear between it and the *dura mater* of the brain, and the cells of the mastoid are not yet formed in a young child. This *antrum* in adults is fully formed and of hard bone, like the mass of the mastoid bone of which it is part. When the ear area is operated upon and the auricle reflected forward there is a triangle, in adults, easily recognized by boundaries of the bony meatus in front of it, the little holes in the surface of the bone itself and two ridges above and below. This antrum is opened surgically under a general anæsthetic and exposes the Middle Ear. The fluid in it is given a way of drainage when the skin of the outer ear is replaced. This is the *Mastoid Operation*, the aim being to drain by exposing the antrum and, having done so, to judge whether the mastoid cells (into which it leads) are involved and need ablation. The operation leaves little noticeable mark. Recovery is rapid and the hearing is generally maintained.

What is known as the *Radical Mastoid Operation* is far more thorough, more difficult and very complicated for it involves removal of more than the bony covering of the antrum and the superficial mastoid cells. It is undertaken for deep infection of the mastoid cells in which, if it is a long-standing infection, hard lumps of secretion, called *cholesteatomata*, are thoroughly turned out and the cells chiselled away. As this operation involves much more than in the so-called simple mastoid operation, it means working in an area in which the jugular vein, facial nerve and other essential structures pass through and around in special bony canals. It is undertaken only by experienced surgical operators and the aural specialist.

The results in general are good but convalescence and repair are rather prolonged. In acute infection, the hearing may be preserved by it, in cases where the Middle Ear has not passed through the slow degenerative processes. On the other hand the infection may be so

deep-seated as to need the sacrifice of the hearing apparatus in order to save the life. It is an operation *demanded* when the extension of trouble involves the Inner Ear and the bone between it and the brain.

We shall not be mistaken as writing *ex cathedra* upon this " demand ". It has astonished us to discover in conversation with medical friends not intimately acquainted with ear disease that they regard the " radical " mastoid operation as almost a necessity for acute otitis media. " If it doesn't clear up in such and such a time I always advise the radical operation." Hearing them say that sort of thing is somewhat terrible. It is almost as if they confused it with such a necessary (though not always successful in its object) operation, such as the " radical " cure for hernia.

Think for a moment what *is* wrong in otitis media. The mucous membrane lining a very tiny space has become intensely swollen and is (in such a state) unable to relieve itself by pouring out its secretion from the Middle Ear. Granted that if unrelieved it may force its way back into the mastoid cells—which it probably does since they are in communication with it—but surely simple opening of the cavity through the antrum, and drainage, is the normal surgical thought ? The Middle Ear has drainage normally through the Eustachian tube which is (temporarily) blocked up.

Take another view of it. The patient has been kept awake by the tension and pain of the pent-up fluid. There is œdema at the back of the ear to prove it is pent-up. If drainage is established by the simple mastoid operation the patient gets sleep—and mucous membrane does not secrete (even when it has been inflamed) in natural sleep. The " shock " to the nervous system, the long process of granulation and repair, the mischance of injuring an abnormally situated facial nerve, etc., in the radical mastoid operation even in the highest of skilled hands ought to serve as a restraint on this " radical " *necessity* ?

THE INNER EAR OR LABYRINTH

If you look once more at the illustration on p. 12 which shows the hearing apparatus embedded in the petrous portion of the temporal bone, on each side of the head, and that particular portion which is shown marked "3", you will see the Inner Ear.

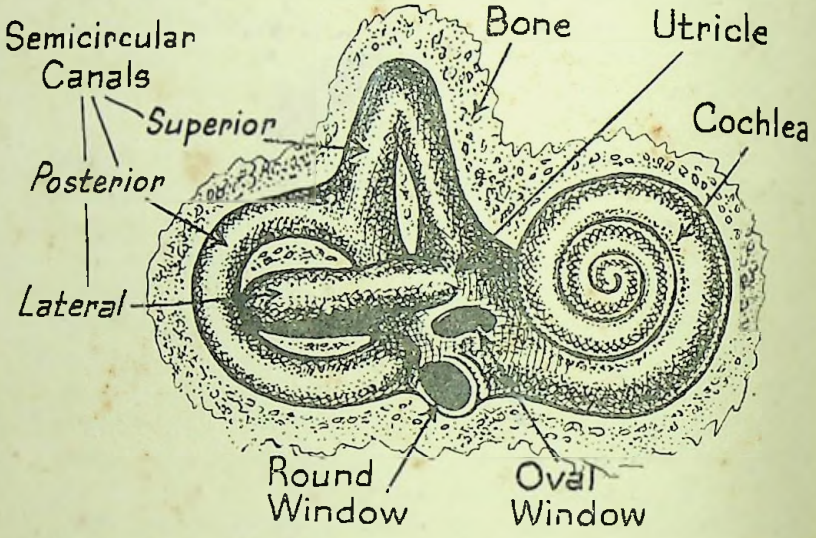


Fig. 7.

The Inner Ear, as it is placed in the temporal bone, showing the semicircular canals communicating with the Cochlea by the Utricle and Labyrinth.

In the diagram on p. 33 you will appreciate the connection of it with the Middle Ear. The illustration above is actually made from a specimen of the Inner Ear, cut out of the human bone (Fig. 7).

It is the most highly organized mechanism of the body, if one excepts the retina of the eye the function of which is very similar to that of the cochlea, which is to analyse

and to telegraph discriminative results to the brain-receiving apparatus.

You will realize that the Inner Ear does not stand separately as in the illustration. It is actually developed in the petrous portion of the mastoid bone and entirely surrounded by hard bone in connection with it just as is the Middle Ear, which is in the closest association with it anatomically and physiologically. The *stapes* (stirrup) is embedded in its *round window* membrane and that as you know is an essential part of the hearing chain.

But though it is possible to hear in some degree without the stapes-incus-malleus-tympanum chain, it is impossible to hear without the *cochlea*. As a comparison, supposing the pedals and very notes of a piano were entirely removed, there would still be " music " obtainable from the finely stretched wires even if they were not "in tune " inside. But without the piano wires there could be no musical sounds, though the piano might look quite normal to the eye with its external keyboard and pedals.

In actual fact the organ of Corti which contains the nerve fibres which are distributed and run around the snailshell-winding of the *cochlea* (divided into an upper and lower chamber communicating at the very top), do rather resemble the inside of a piano under the microscope. Unlike the piano, the cochlea is packed away inside thick bone and is, ordinarily, unbreakable. Once injured it is incapable of repair by outsiders. The coil of the cochlea when uncoiled is one and a quarter inches long and is coiled two and three-quarter times round its axis.

But, as you see in the illustration, the cochlea is only part of the mechanism of the Inner Ear. It is associated with three semi-circular canals each at right-angles to each other which are hollow, all leading into a wider chamber called the utricle and sharing the pressure effect of its oval window in the vestibule. These three canals, Superior, Posterior and Lateral, are filled with lymph and contain chalky bodies called otoliths, supported

by or attached to fine nerve-hairs in their inside hollows and they govern all the balance of the body. We shall discover their importance in the chapter on Hearing Tests.

The Eustachian tube must be able to open and close if these otoliths are to function properly and that is chiefly why partially deaf people cannot be taken as airmen. Indeed, one of the troubles in severe deafness is the likelihood of pitching forward and general unbalance, or (as in Ménière's symptom-complex) feeling that the bed-bottom is coming up and going round the head ; giddiness and actually falling. This will illustrate the close association which would be expected of them in the Inner Ear when part and parcel of the same " box ", with similar air-pressure through membranes and the same source of fluids and nervous supply as the hearing apparatus. But the *cochlea* is the *organ of hearing*. The *semi-circular canals* those of equilibrium and balance ; both comprising the Inner Ear.

INNER EAR DISEASE

SYMPTOMS.

When the Inner Ear is becoming infected by disease the symptoms are what, therefore, you would expect in their varying proportions.

Increasing noises in the head through disturbance of pressure and irritation ; which are called *Tinnitus.*

Increasing deafness and loss of hearing of high notes.

Liability to vertigo or imbalance. If the *superior* semi-circular canal is becoming affected, objects, such as the bed, appear to be flying up, as stated above, all of a sudden. If the *horizontal,* the patient may fall to the affected side because the corrective otolith is momentarily out of work.

If the Inner Ear, or Labyrinth, was *suddenly* affected by severe trouble you would *suddenly* suffer all the above symptoms. That is so rare as to be a negligible possibility. Apart from blows and violence to the head and tremendous explosions affecting the ear with direct compression and concussion, and a very rare condition known as hæmorrhage into the labyrinth, *sudden deafness is always curable.*

If you remember that and, if you experience it, go at once to your physician or the aural surgeon, you need have no doubt whatever about it. He will give you back your hearing as it was before that occurrence.

On the other hand, if you allow the slow process of degeneration to proceed unchecked, or to be prevented by the appropriate remedy, you will have seen for yourself by text and illustration how closely all these delicate organs of hearing are packed together and how easily degeneration can spread in this bare square inch of your head.

Both your hearing apparatuses, when they are isolated from the bone in which they lie (which is in itself highly porous and air-filled), are an infinitesimal portion of your body-weight and light as a feather without the Eustachian tube and external ear.*

* As an illustration of this I had made a point of gathering together specimens of the hearing-apparatus of animals in New Zealand when shooting and fishing or in the bush—bush turkeys, pukaka (a swamp chicken), duck, hawk, owls (" more-pork " they are named from their peculiar cry) black swan and quail to tiny bush-birds which follow one through the thick bush, cats, dogs, rats, mice, lizards, etc.

Cutting off the heads, I would clean the skulls and then remove with my circular lathe-saw the hearing apparatus of the animals, which certainly together weighed many hundredweight alive. A bush-turkey weighs from 20 to 30 lbs. These delicate ear apparatuses were labelled and some fifty of them wrapped in tissue paper and put in a small cardboard box in cotton wool to bring home to England; for some otological museum and hours of careful examination and continual interest.

It was not to be. Though another similar box full of mastoid and ethmoid and other bones (replaceable for a few shillings at an anatomist's shop) safely survived the journey, subsequent enquiry proved that the woman who had helped us to pack had shaken and opened the other box " to see if there was anything in it " and " *as it weighed nothing* " had put it on the bonfire !

In the collection there was the hearing-apparatus of the *Tuatara* lizard. This is the original mammal organ of hearing. The *Tuatara* has no outside ear, but when you look at it a long time (or at any lizard) you will see it gulp. It is listening. It possesses a basilar membrane between the angle of the jaw and the quadrate bone of the skull, which normally, it uses when feeding. It has also a vestigial third eye, on the top of its head. Since the animals are protected, specimens are rare.

SOUND AND HEARING TESTS

THERE will be no difficulty in understanding the simple explanations of sound and hearing given in this chapter, as far as concerns the human ear.

When you stand in an underground railway station you are often nearly blown aside by the train coming out of a tunnel. The train displaces a large volume of air, the air also rushes back to fill the vacuum in a wave. You know by experience that air can move if anything pushes it and that what is pushing it makes an accompanying noise, which, in this case, is a sound of *low pitch* because of the size of the tunnel.

If you have been in the boy scouts or the army, you have heard a bugle note, which has been caused in just the same manner, viz. a strong volume of air pushed out of powerful lungs, throat and nasopharynx, into a tube from which it sets up forcible waves of air. These are carried to you in air-waves and distinguished by your receptive-apparatus because of the rapidity of their vibrations from a narrow tube; which makes for *high pitch*. The first, the train sound, was so mixed that no note was especially discernible. The second was so perfected on the one or more continued waves of air as to be distinguishable as a note or notes.

If you pluck a violin string you will actually see the vibrations which are causing the sound and if you look carefully you will notice that it will not only vibrate in the middle but at each end; those latter vibrations are clearly conveyed to you as *overtones*. If you press your finger a certain way down the string and draw a bow across it, it will sound an octave higher; which means that it is vibrating at exactly twice the rate at which it was vibrating without that pressure. The *loudness* of the note-vibration depends on its distance

from the ear of the listener; but you know now that *sound is caused by some force which sets up vibration waves in the air, which reach your ear-receiving apparatus, and that they have quality, loudness and pitch.*

Further, when you see a gun go off in a flash you do not *hear the sound* until some seconds later. In short; light waves travel at 186,000 miles a second, sound waves only travel at 1,100 feet a second. They have a horrible habit of skipping over areas because of temperature, so that some, comparatively close, may not hear the

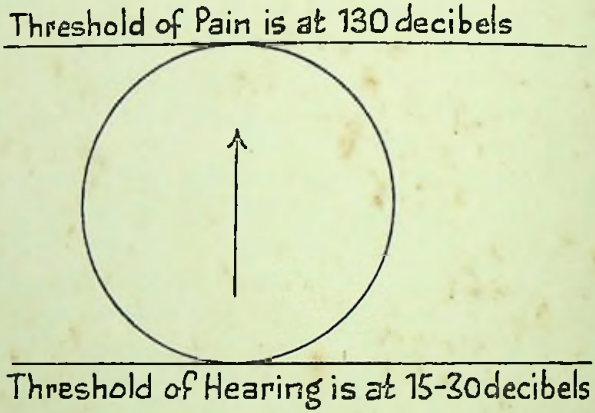


FIG. 8.

vibrations carrying the sound as quickly as those farther away, and of course they vary in quality. If the vibrations are abrupt and very forcible there is a noise. Vibrations are measured in *bels* and for convenience *decibels*, much as a metre is measured more easily in deci- and centi-parts of a metre. Here, diagramatically as a circle, is your measure of hearing:

The above diagram represents the range of amplification of sound, *audible* at 15 decibels and *intolerable* with comfort above 130 decibels. This is the enormous range any satisfactory hearing-device would have to cover if it is to convey to you all the variations necessary to reproduce human speech.

But let us keep to the number of vibrations-per-second as a measure since they are a convenient medical method of testing the hearing. (An electric audiometer is not yet quite a reliable measurer of hearing and even if it was it would teach you little of the subject.) Everyone

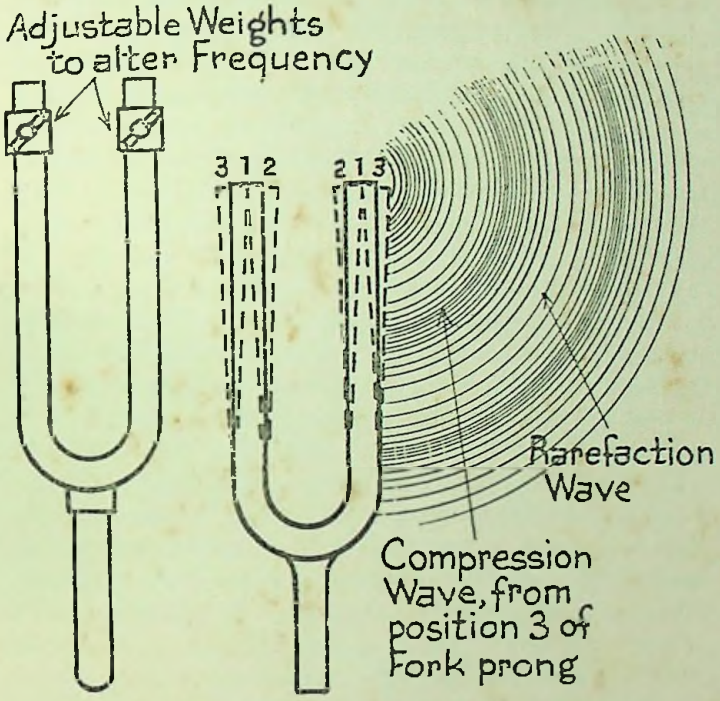


FIG. 9.

Tuning fork in vibration (R.), showing compression and rarefaction waves. Lower note fork (L.) showing movable weights.

knows what a tuning-fork looks like and it is obvious that if the prongs of it are set in vibration by being pinched and let go, or struck, each prong will pass rapidly between the positions shown in the illustration as 2 and 3; and as the rod flies to and fro between them it will alternatively push and compress the air in the vicinity and set

up waves. This is measurable as the *Amplitude* of vibration.

Tuning forks can be made of varying thicknesses and length to produce variations in vibration and, as you can see on the left-hand side, weights have to be attached sometimes to them to prevent overtones. Vibration causing sound waves can be got from plates and from a flat surface like a saw by drawing a bow across them, from a gong and a drum by beating them. But the vibrations of a tuning fork are the *transverse vibration of rods*.

The drum of the human tympanum is a stretched membrane for *recording* purposes, the edge of it fixed, but the alteration of its *tension* is a direct nervous-impulse effect of sound waves of air reaching it as vibrations.

Whether it would make a drum-sound if it was hit is quite probable, but the slightest touch on it would make you faint. It is meant to record and since we can easily find what is called a C2 tuning fork, which is measured to give 512 double vibrations a second, we can use it as a yard-stick and record of your hearing. We can stock a series of them from $-C2$ for very low tones to C7 for very high tones, which are all that are necessary for human hearing of the highest and lowest perception, though the human range can vary from 23 vibrations a second up to 40,960 ; so they say. It would be an E8 tuning fork, that. The $-C_2$ fork vibrates 32 times per second the $-C1$ at 64 v.p.s. and so on, exactly double (or an octave) all the way up. There is no deception. The longer the bar the lower the tone of the fork and when anyone attempts to deceive the aural surgeon, as alas they sometimes do in insurance cases, a movable weight can vary the tones quickly and as required. Which is useful !

Tuning forks, then, of known vibrations, are used to give a measure of the hearing by the extent of the recognized conduction of the vibrations through the air to the ear.

They can also be used to measure vibrations through the bones of the skull and thus play a most important part in the record of hearing. Additional means are available ; tests by watch, words, whispers, acoumeter and whistle, by which a complete estimate can be made of deafness, where the seat of catarrh or disease lies, and the improvement of hearing or the opposite by comparisons with past accurate records.

Each ear is tested separately and, in the case of words, watch and whisper, the end of a tape measure is held by the patient under his ear. Two watches are used, a Waterbury and a vest watch, and always the same pair. If the patient cannot hear at a distance, the approach of the tester carrying the watch or using the words can be measured fairly accurately each time and the *distinct* hearing point noted down at once.

Uniform words and whispers must be used. All words that have an " r " in them are lingual low tones and best heard in nerve-deafness cases. All high tones, sibilants, " sixty " and " sister", are best heard in Middle-Ear deafness. Sentences can be composed and varied. Already, then, the aural tester has a yard-measure of the hearing. An *acoumeter* is now used, because it is a fixed bar on a striker which always gives the same pitch of note. The distance is noted. It *can* be heard at 15 yards away.

The Galton-Edelmann whistle is a very accurate mechanical instrument since by a turning adjustment and pressing of the bulb, it can be made to give out vibrations of 40,000 a second. It is a valuable test as to Middle-Ear trouble and the capacity for air conduction A graduated scale enables one to read off each measurement.

HEARING TESTS.

In normal hearing we know that hearing by air conduction is twice as strong and long as by bone conduction.

We can therefore use the tuning fork vibration in the following ways:

Taking the C2 fork of 512 vibrations each second.

Weber's Test. The C2 fork in vibration is placed on the top of the skull (with the patient's eyes closed). It is heard (normally) equally on both sides, but if it is heard distinctly and at once on one side, that is the affected side; if the Inner Ear, the Labyrinth, is not the seat of disease. No test *by itself* is reliable but if the tuning fork on the top of the skull is lateralized to the good side then the labyrinth of the affected side is bad. The lower-vibrating forks are useful as additional tests here, but not the high ones.

The Rinnè Test determines the difference between hearing the C2 fork by air conduction and by bone conduction. Normal air conduction by air is 40 seconds as compared to bone conduction 20 seconds, but this is often reduced in disease. Greatly prolonged bone conduction of the C2 fork means Middle-Ear deafness. The tuning fork is still heard on the mastoid bone behind the ear after the sound of the fork, when held to the ear, has disappeared.

In cases of nerve-deafness, bone conduction on the mastoid is diminished in relation to air conduction (fork held to ear).

It is also good practice, after the patient has ceased to hear the fork-sound on the mastoid, to place it on the observer's own mastoid (if his hearing is normal) and note it down (Schwabach's test, in part).

Gelle's Test consists in increased pressure being put on the Inner Ear by an air bag in blowing air against the drum of the ear through a Siegle's speculum in the external meatus. If the tuning fork is not heard so well during momentarily sustained pressure it is a valuable sign and good, inasmuch as your drum is obviously movable and not fixed by diseased conditions. But it is a specialist's business to apply it, for obvious reasons.

The result of all the tests can be accurately summarized

and as a result of the subsequent treatment given, the surgeon can scientifically assess the benefit you have gained, by repeating them, and then comparing them to the original. Often by simple inflations of the Eustachian tube, which was blocked, your hearing may be restored to normal. This is not taking into consideration the innumerable cases in which blockages, catarrhal, skin and other troubles in your external meatus, diagnosed, remedied and cured, may completely remove your deafness and discomfort.

In a simple textbook it is not necessary to record fully the tests for labyrinthine, or Inner Ear, disease; beyond stating that they are made to determine your powers of equilibrium. The patient is turned quickly in a revolving chair in one of the tests; and, in another, first cold and then warm water is poured in the ear because they are known to produce certain measurable results. These tests afford additional help to the aural surgeon, both as to the site of the trouble and extent. They are what is known as functional tests, in response given to stimuli. They depend on the otoliths which, as you have seen, are placed in the semi-circular canals to govern balancing; which canals are in the same division of the hearing apparatus as the cochlea, viz. the Inner Ear.

In this survey you will have realized that the ear, just as all peripheral organs of touch, etc., is a mechanism adapted to transform one form of external energy into nervous impulses.

Even bone, as you have noticed, can convey vibrations and so transmit nervous impulses by exchange stations that are connected to the physiological systems in the body. Snakes have no ear drums. Their "hearing" apparatus enables an immediate reception of vibrations communicated to the ground. That is enough for their purpose. Deaf people become increasingly sensitive to vibrations they can feel, vibrations of people walking on floors; and shrieking noises often "deafen" them.

With further reference to the Audiometer, mentioned above. This word generally signifies, now, an electrical vibrating instrument for the measurement of hearing, sometimes referred to as an "Audioscope". In its development it was discovered that a graduated series of humming noises could be produced satisfactorily by graduated electrical vibrations. A known vibration therefore presented, if its hum was recognized, a known measure of hearing. The difficulty was to obtain the same hum for the known vibration on differing electric circuits of varying energy.

This has to a great extent been got over by gramophone records of actual notes which are picked up by an electric-coil and, for the purpose of testing school-children, may be heard through several head-phones at the same time. A number of figures (which are usually heard better than words) are recited in turn, each one a third above or below the preceding one. To some children the sounds die away soon but meanwhile they have written down a record of their hearing, of what was received. This ingenious method quickly discovers the children who need aural attention.

A similar method is used in Hearing Clinics at the hospitals where under medical supervision it is entirely reliable, particularly in suggesting the type of hearing aids likely to be of use.

But in no degree, other than simplicity of application at the one time of test, does it take precedence over the deliberate and careful series of tests which the aural surgeon carries out on the lines above; which together with the physical examination form a complete record of the aural picture.*

* It is odd how this generation likes to introduce a complicated machine (depending on outside energy and an intricate mechanism which can break down since very often little or nothing is known of "the works"); when the accuracy of a craftsman, as in this case, only needs the simplest, easily replaceable instruments for a more perfect result!

ON DEAFNESS

In the previous chapters we have described the anatomical construction of the ear-apparatus and its function, with the principal diseases to which it is liable ; of which the most important practical end-product for the sufferer may be gradual loss of hearing, or deafness.

That sort of deafness is *acquired* deafness, which we will return to in a moment.

Another form and by far the worst form of deafness is to be born with it, i.e. *Hereditary* or *Congenital* deafness.

The researches of an Abbé named Mendel in 1866 on the culinary pea, in its familiar pod, proved that in every generation grown, if it was "crossed" with another known variety, its peas exhibited the *dominant* character of the two of its parents. In the second generation some of the peas exhibited the dominant and some the recessive character and so on. Upon this basis of research immense improvements have been made, in botanical crops, of which processes, Luther Burbank, the Californian horticulturist, was the master pioneer.

His theories have been the subject of research workers ever since and have proved reliable. They are equally so in human breeding.

Children born deaf have in their composition that *gene* as it is called, from a previously deaf parent *or* as many think with a *gene* of a parent who has had syphilis. Some are not inclined to accept this theory in general as the children of syphilitics of the older generation were hampered in many other ways of debilitation and of toxins which produced marasmic children ; but syphilis in its tertiary and sometimes in its secondary stage can produce deafness. The *spirochaete* of syphilis is so active that it can penetrate anywhere, and the Middle-Ear penetration is only too possible from the throat via the

Eustachian tube, and by infection of the blood in the blood vessels.

It should not, however, necessarily produce children who are both deaf and dumb, or children having two thumbs (which is not unusual in England and is common in India). This is distinctly traceable to an hereditary *gene* and we may more confidently accept the *congenitally* deaf as due to that reason. A *gene* of a deaf ancestor.

To correct it we should have to go back several hundred years! But obviously in this generation deaf families should be careful in marriage as they may pass on the *gene* unwittingly. Deaf mutes will breed deaf mutes; and if they know that, there it is.

Ante-birth clinical examinations of the mother's history and condition (and of her blood) ought to eliminate the danger of a syphilitic deaf birth; and they are doing so. Syphilis should be a notifiable disease, and its eradication by treatment compulsory. We are on the way to that.

There remains the question of how to Prevent *Acquired* Deafness; and to see what can be done with instrumental aids to help it when established. The Prevention of Deafness is a very difficult and complicated matter. Let us tackle it as a practical subject.

We have shown the ways in which its insidious onslaught arrives. Through the throat and nasal passages and through the external meatus.

"Colds" in the nose and head, causing "stuffing up", do by their constant visits gradually stuff-up (literally) the Eustachian-tube-drainage and air-ventilation of the Middle Ear. Habitual mouth-breathing is established. *It is in the child that this is so important.* Some medicinal substances are valuable aids in use and they are given on p. 65.

But other practical methods can be taken. Your medical man or one in an out-patients' department (see p. 76) can make sure that your child's nasal and throat

passages are clear of obstruction. The tonsils are useful to a child, but if they are subject to constant attacks of inflammation they become a source of (though in themselves originally, no doubt, a help in combating) infection.

Now paper handkerchiefs are comparatively cheap at the universal stores. If your child is subject to snuffling colds let him or her clear his nose with one *frequently* and throw it afterwards in the fire. Try to afford this for the child's sake.

If you can in any way afford it, let him have plenty of handkerchiefs—and not let him use *one* (soon infected) handkerchief plentifully. Boil the linen handkerchiefs after use, thoroughly, and hot-iron them. It may save your child having permanent changes in the throat, nose, and Eustachian-tube mucous membrane and prevent the *gradual process of deafness.*

Earache is a pointer. If your child has it, remember it is pointing at you. Give it attention and your child warmth, care and attention. It may be due to wax in the ear or some obstruction so take him up to a doctor or an out-patients' department and make sure. Tell the schoolmaster and get him to draw the school-doctor's attention. Don't *tolerate* its constant recurrence.

Since these snuffling colds disappear with immediate attention it is economical and sensible to look after them. You do your share and some prescriptions can be used medicinally and are valuable (see p. 65). Our chief hope for future prevention must lie in the researches of the bio-chemists in the laboratories who will one day find a remedy for the common cold in parallel to the sulphanilamide-reaction mentioned previously.

ON NOISES IN THE HEAD—TINNITUS AURIUM

An invariable accompaniment of a " stuffed up " cold in the head, as it is called, is *Tinnitus*, literally a ringing noise in the ears. As the catarrhal conditions spread to the Middle Ear they produce alterations in fixed tension through the tympanum-malleus-incus-stapes-round-window-membrane chain, between the membranes of the external and the inner ear. Noises in the ear are invariably the result, and they reverberate through the head.

They are symptomatic of an irritation of the auditory nerve and, later, of its terminal filaments in the cochlea, or labyrinth, of the inner ear.

Changes of temperature, winds, draughts, cold, rainy, damp weather and hot stuffy atmosphere, emotions such as fears, gases, as for example inhaling an anæsthetic, make them very much worse and they may become almost intolerable.

In view of the physical situation of the Inner Ear, carved out from and encircled in a heavy covering of bone it is logical to base the conception of these noises as similar to that of a conch or a hollow sea-shell as held to the ear. Though there might be no appreciable wind in the room such a shell communicates to the normal hearing a series of broken reverberations which vary from whispers to roars of added sound. But *tinnitus* is not intermittent, it is generally persistent in its basic sound and the " roaring " is what is mostly heard.

To those growing deaf these subjective noises are terribly distressing. Sometimes as in ill-health, or through a worrying period, they can be adequately described as that of entering a high-domed archway, like St. Pancras Station, and hearing *layers* (sometimes three or four layers of different height, tone and quality) of steam being blown off by engines with their hissing and

puffs, coupled with the tramp and shuffle of thousands of passengers in a tunnel, the slamming of doors and the thumps of bundles of newspapers as they drop on the wooden floors. There may be, quite suddenly, a real ringing note added, which starts loudly, and at no definite or expected moment fades away into the silence of the abnormal, but now usual roar. It would seem impossible to hear an outside, real, sound though the noises, yet if they hear at all, they do and are at once aware of it.

It is possible to have noises in the ear without deafness or Middle-Ear change, but they are symptomatic of a definite neurosis of a different kind. What is to be done with this distressing *tinnitus* accompaniment of deafness? The big surgical tomes are full of unsuccessful attempts at cure. All who have to do with ear trouble have endeavoured to cope with it and have sometimes temporarily succeeded, but too often failed.* Operations to separate the "osseous chain", so often mentioned, from its connection between the two drums are unsuccessful. I have carried it out and in simple mastoid operations, with nerve deafness, it is justifiable sometimes to remove an ossicle. When the auditory nerve ceases to function the noises may die away. They are supposed to, but ears do not always obey rules. There is always the "other ear".

* A personal attempt to solve the problem was based on the logical assumption that *ankylosis* of the malleus-chain of ossicles between the two tympani (*ankylosis* means matting together and loss of movement in a joint by calcareous, chalky or degenerative, but not necessarily naked-eye-visible, changes) that this ankylosis might be *shaken* free and so restored to function by very high vibrations, above the painful-hearing mark. Such high vibrations can be produced electrically but the tester should have his ears carefully protected!

In conjunction with the Western Electric Company, after consultation with a London aural-surgeon friend, I submitted to an experiment in high vibrations; over the 30,000 vibrations-per-second rate. The result was that my auditory nerve was completely shocked, the noises were terrible thereafter as there was great deafness, and it was three months before I regained my hearing. I cannot recommend it with any hope to relieve tinnitus or with a view to accomplish any sensible result. Heroic remedies are seldom successful. The human body, and particularly the hearing-apparatus, is a system, not to be attacked at any one gate. Destruction even of the auditory nerve of one side may not remove noises in the head.

As some guide to the general practitioner, nurse or friend when confronted with the despairing request of deafness to relieve this very distressing complaint, I would humbly submit the following procedure, which I followed in aural practice :

1. To give some palliative remedy which can do good to the ear conditions and attempt a medicinal cure. See p. 65.

2. To instil into the patient's mind a line of conduct, of common sense, and of fortitude and character :

(*a*) That the noises were now and would always remain entirely *subjective*, i.e. that they were not due to any cause outside and that it would be foolish to think so. They may, for long periods, disappear.

(*b*) The argument is that if thousands of people could live *comfortably* within sight, hearing and feeling of the intense noises and vibrations of thundering trains and traffic, he, the patient, could surely control himself to the sounds of a shell held against the ear ? They are, unfortunately, continuous, but can be forgotten in work and play.

(*c*) That if he was always busy and occupied and, above all, could get interested in his daily occupations and a hobby, the noises would *always* disappear. As they do.

(*d*) That the noises (in this case) mean that as time goes on he would become a little more deaf, therefore he must fit himself for that outlook by becoming so proficient and efficient at his job or work that he would make himself indispensable. And, if possible, become his own master and be able to employ others. It is possible to become *extraordinarily* efficient.

(*e*) In any event the good health he would enjoy by abstention from luxuries such as drinking, smoking, and late hours, the strength and determination

of character he would acquire in the deliberate devotion necessary to acquire *exceptional* skill at his work would mark him out as worthy of promotion in any line of his life.

(*f*) Let him not think that hearing of the highest kind is essential to earning a living. There are ever so many evidences that it is becoming less so every decade.

I need not add that it would be criminally foolish to try to assure the patient that the noises he complained of were not there. They are very much there and unfortunately they are going to recur and he must be made to realize it.

(*g*) In addition, this is the time to bring before the patient's mind the importance of learning lip-reading. Not, as used to be considered the best way, by taking immediate and intensive lessons in it (though very beneficial to the child) but in common-sense applications in his ordinary life. To understand (as you show him) that the words Pea and Sea, for example, are quite typical movements of lips and teeth, but that " ea " and " ee " can be done with no noticeable movement. Then suggest that the moving pictures, though he may not hear the words spoken, afford him a cheap and pleasant opportunity of learning (even if he has for some time to guess) the essential lip-movements and *phonetic* sounds of the chief word upon which the context stands. Words like come, go, daughter, brother, wife, vacation, holiday—to see if he can " spot " the context as an educative game, which will at the same time afford some relaxation and enjoyment.

(*h*) A suggestion that he hears too well at present, but that a hearing-aid of the right sort will be of great help to him, if he did get worse, is generally well received, and he has time to consider the

serious advice you have, as your duty, given him.

(*i*) If the patient has what is called *Paracusis Willisii* and hears better in a noise then let him bear it in mind. I have known a city merchant who did all his bargaining, travelling in his motor car for that reason. This *paracusis* is supposed to be a bad sign for future hearing, but nothing follows the rule in ear trouble, save that all deafness grows worse in age.

REMEDIES AND MEDICINES IN EAR TROUBLE

In considering medicinal remedies for ear trouble it is better to understand logically what you are giving them for, and why? rather than to accept them as just "Prescriptions".

The external ear and the nasal passages can evidently tolerate both fresh and salt water immersion, since they do so constantly in the swimming bath and the sea.

No doubt both do them good, but unfortunately swimming baths are often covered with nasal discharges of others and thus both passages can be infected with unusual micro-organisms. Therefore clean boiled water applied to both ears as a warm lotion can do no harm, and effect cleaning.

The Ear Passage.

Very weak disinfectants are well tolerated by the drum but it is wise to remember that it is a vibrating drum and not a teak door. Here are good prescriptions for simple irritation in the meatus:

℞ Boric Acid gr. x
Glycerine mx
Aq. distil. ad. ℥i

or

Liq. Plumbi Subacetatis dil. mv
Aq. distil. ad. ℥i½

S. 5 drops, warmed in a spoon, to be put in the ear night and morning.

or

℞ Argyrol (1%) mxxx
Aq. ad. ℥j

S. 5 drops, as above.

For pain in the ear (provided all obstructions have been seen to and removed) :

℞ Cocain. Hydrochlor. gr. ii
Morphin. Hydrochlor. gr. iii
Parolin ad. ℥ ½

S. 5 to 10 drops, warmed in spoon, to be used every two hours if pain persists.

Never syringe a painful ear.

Use drops with the patient's head recumbent on bed or couch and pull the auricle gently back or press lightly afterwards on the tragus—the angular piece of cartilage in front of the meatus—two or three times, to work the drops in and work air out. Pain in the ear is a sign calling for a medical man's attention.

As regards drops for *earache*, it must be kept in mind that the cause of the pain is usually an inflamed tympanum and an inflamed surface does not always absorb solutions easily.

If an aural surgeon wanted to anæsthetize an inflamed drum for operation, he would use a strong solution, say, of cocaine, menthol and carbolic crystals in solution and would be ready in case of toxic symptoms to wash the ear out with alcohol, which removes them. The cocaine and morphine prescription, given above, should be repeated with caution after watching its effect. The earache can be intolerable and may demand such medication, but it is a serious matter for skilled medical attention. There is always a cause for pain in an ear.

A sleeping draught is often effectual in tiding the ear over its highly inflammatory stage, combined with warmth locally and some drops like this :

℞ Tr. Op. ii ℥ j
Aq. ad. ℥ i

S. 10 drops into the ear for the relief of pain every two hours.

CHRONIC OTITIS MEDIA.

This is a condition when the patient has a chronic discharge from the ear. He either refuses an operation or there is good reason not to press one, i.e. the disease is quiet, of old standing and the general health good.

Various antiseptic drops combined with local attention and examination may affect a lessening of the discharge and cure.

These are useful prescriptions:

℞ Hydrogen Peroxide ℥i
Aq. distil. ad. ℥j

S. 30 drops to be put in the ear night and morning before the next consultation.

℞ Sp. Vini. Rectificatus ℥ij
Aq. distil. ad. ℥j

S. 10 drops to be put into the ear, warm, night and morning.

℞ Acid. Borici gr. xx
Sp. Vini. Rect.
Hydrog. Peroxide āā ℥ij
Aq. distil. ad. ℥j

S. 10 drops to be put into the ear, warm, night and morning.

℞ Bismuthi Subnitratis
Liq. Plumbi Subacetatis Fort āā ℥j
Parolin ad. ℥j

S. Shake for a long time and allow 10 drops to seep into the ear with the head downwards on pillow once a day. Then close the ear lightly with cotton wool.

All the above remedies should be subject to the surgeon's examination. He may do a great deal by inflation of

various kinds to clear up old Middle-Ear discomfort, perhaps from old secretion, and encourage it to emerge through a hole in the drum. There are many methods for varying conditions but the idea should be first to clear up the cause of the pain and the character of any discharge. Alcohol drops are good, but painful if caution is not used as to strength. Hydrogen peroxide drops are often sufficient as they combine in bubbles with the septic matter and urge out old secretion. But the amount of bubbling is, unfortunately, not the measure of any cure.

My impression, from many years of experience with this class of case, is that with care and attention the discharge can be cured and the drum healed up. The Bismuth-Lead has been the most successful way of doing it, but the ear condition should be regularly cleansed up before each application. Knowing the seriousness of the condition, I took every case into private or public hospital and assured it. The surgeon's personal hygiene of the ear in cleansing it is a determining factor, and he can himself do more with safety by all the means at his disposal; and they are many.

No one method should be continued indefinitely.

The ear should in every case be protected with a clean plug of cotton wool.

In ear and nasal catarrh of the acute kind sending the patient home to bed very often will save the hearing becoming affected. A diaphoretic mixture will help materially:

℞ Pot. Nit. ʒj
Sp. Aether Nit. ʒj
Liq. Ammon. Acetatis ʒ½
Aq. Menth. Pip. ad. ʒviij

S. A tablespoonful every three hours in water.

Friar's Balsam is Tincture Benzoinæ Co., an old remedy. Put a teaspoonful in the "bronchitis" kettle (of which in time it makes rather a mess). Benzoin is incorporated in many cough lozenges. Friar's Balsam

is a varnish which used to be put on all wounds, much as Iodine is now, as the universal protector. It can also be inhaled through nose and mouth, in the strength above, by wrapping a towel round a jug-top and taking in the steam of the freshly boiled water.

TINNITUS AURIUM.

For the medicinal treatment of Tinnitus every line of thought is permissible:—

The bowels *must* be kept open, in case there is an intestinal toxin causing it.

If the patient is very aware of the noises and sleepless, sleep must be obtained medicinally.

Dilute Hydrobromic Acid mx in two tablespoonfuls of water every four hours, after food, may disperse them.

If the patient is smoking or drinking too much, these faults must be stopped. Anything likely to cause high blood pressure, too much meat, not enough gentle exercise, must be seen to.

The patient should drink plenty of water, Lithia, etc., every day.

Quinine in large doses causes noises in the head. In infinitesimal doses it may stop them.

Inflation of the Eustachian tube helps sometimes. The patient may blow his nose while holding it tight and thus inflate it himself, but not more than once or twice a day.

The best "medicine" is something (like a hobby) *which takes attention off* the noises.

Camphor-ointment applied to or in the auricle will always relieve itching. Subnitrate of Bismuth powder blown into the ear quiets and cures any skin disorder which is causing the smell of decomposition. Such cases are rare now, but used to be common. They were often painted over with ichthyol, iodine and carbolic acid solutions with the old idea that antiseptics and styptics cured diseases rather more than they do. Certainly they help to cleanse them, which is halfway to cure. Never let the ear passage get in a mess of sticky

applications. Gently clean it out before reapplying a remedy.

NASAL PASSAGE, MEDICINAL APPLICATIONS.

These are used with a view to increasing the resistance of the mucous membrane to infection, by encouraging hyperæmia and leukocytosis.

℞ Sod. Bibor.
Sod. Bicarb. gr. ii āā
Aq. destil. ad. ℥j

The above is a simple alkaline which the patient can buy very cheaply, as powders Biborate and Bicarbonate of Soda, to make a solution say of a teaspoonful of each to a pint of hot water. A handful is sniffed warm up the nose. Some patients can "drink" this alkaline water up the nose without trouble (with the mouth open) and when used intermittently it cleans the passages and prevents the snuffling cold which is inimical to the mucous membrane of the Eustachian tube.

Dobell-Pynchon Solution :

℞ Sod. Bibor.
Sod. Bicarb. āā ℥ij
Thymoline O½
Glycerin O1½

S. One ounce to a pint of water (see below).

This prescription is a valuable stock remedy where the physician has a dispensary. The two salts are rubbed down and half the quantity of glycerine is added and, with frequent shaking, left for 24 hours in a Winchester quart bottle. Then the remainder of the glycerine is put in and again shaken intermittently for another 24 hours with the bottle uncorked, both times, as it becomes gassy. Add the thymoline and let it stand again for 24 hours.

One ounce of this solution is added to a pint of water and makes an excellent spray in an atomizer for throat and nose or as a gargle.

It is particularly useful in keeping people free from prevailing infections and as a preventive of the common cold.

Smaller quantities can of course be made up than the large stock-quantity in the prescription, but the same method of preparation should be adopted. It potentizes the constituents by thoroughly mixing them.

These soda-alkaline snuffling and atomizing remedies are under some criticism. There is a school of thought that claims the "sodium habit" (in preservation of foods, cooking and intake of common salt) as a factor in causing an excess of carbonates in the blood which, in its turn, by forming caustic soda, causes dangerous deposits and thickenings in the various organs. The sodas in the Dobel-Pynchon solution and the Thymoline (which is a chemical derivative from oil of thyme) are the basis of a *possible* caustic interchange. Nevertheless the solution is useful for the purpose claimed.

There are many patients whose mucous membranes respond better to a slightly acid application, without a smarting reaction:

℞ Zinci Oxidi gr. ii
Acid Borici gr. v.
Aq. ad. ℥j

This may be used as a snuffle and, further diluted with the addition of equal quantities of glycerine and parolin, be comforting as a spray. It is a slight astringent of the mucous membrane.

There are many proprietary oily preparations of menthol, etc., which claim to prevent nasal infections and colds. The action of all of them, when successful, is to reduce any swelling of the mucous membrane and free the air passage for natural breathing and ventilation.

The proprietary solution "Kasemol", which is a menthol derivative with camphor and aromatics, is very soothing as an *outside* application in all neuritic conditions. It may ease the pain of earache if applied behind the ear, by its anæsthetic action.

HEARING AIDS FOR THE DEAF

THERE is no doubt that the deaf and those in the gradual process of becoming so are in a more fortunate position now than they were even ten years back.

But in all cases of deafness in which it is occurring gradually in adult life there is a period of self-consciousness, during which, though the man or woman realizes he cannot hear perfectly, he, or she, is very unwilling to admit that he is deaf or needs an " aid ".

Fortunately, deafness and the amount of it is very variable in these earlier years. They are (albeit unconsciously) learning to what degree and in what ways their lack of perfect hearing is becoming rather more than a nuisance, and in fact may turn into a menace to earning a living or of them entering into social intercourse quite in the way they did.

Here is the opportunity of the unscrupulous vendor of an " inconspicuous " hearing aid and a good reason for those becoming deaf to know what the various hearing aids are that are on offer.

Speech, as you know, is a form of energy which produces waves of sound in the air. These are gathered by the auricle to the hole of the external meatus of the hearing ear and they strike or are wafted, with all their variations of quality and force, against the tympanum. The vibrations are carried instantaneously across the middle ear by the chain of ossicles (which are in essence a variable electrical switch) to the cochlea and piano-fibres of the hearing nerve.

Therefore the gathering-power of the shape of the external ear has naturally attracted attention. (If you watch the ears of a horse, you will receive an education in the use of long auricles. The horse tribe had to have sounds brought to them when feeding and drinking or

they would have been scuppered by wild beasts at will. They can turn them in any direction but one. Man's nine ear-muscles have lost the art.) Small "ossicles" or similarly named artificial "aids" are offered for sale with the idea presumably of their being inserted in the ear to "gather" the additional sound vibrations; or to do something? I have had patients bring them to me and ask me to insert them and I have always done so. They pay as much as £2 2s. for them but one can prove to them they are useless by the simplest tests.

Larger cup-form additions to the auricle might aid in gathering sound, but not as much as the cupped hand, which brings, when first raised to the ear, additional air as well as size to the auricle. It increases the sound waves to one and a half times natural hearing.

Speaking tubes do enormously increase the sound-waves as they bring the speaker's voice right against the drum, a magnification to 130 decibels from a mere 20 or 30. They are also a great advantage to the speaker; and to the hearer in seeing the speaker's lips more close to hand.

Buyers of speaking tubes may like to pay up to £2 2s. for one but all the essentials of them are a voice cup, a sealed flexible tube and an ear-piece. No additional *alleged* vibrating attachment to them has any hearing value.

Shorter collapsible or bent tubes of the metal or vulcanite type have the same good value, provided the speaker can speak into them and the hearer listen with the other end in his ear. Supposing there are no turns in a tube, a deaf person who can hear through a speaking tube, ought to hear through a fixed pipe from the top of the house to the bottom. So in that way we arrive at the idea of an electric telephone which is so much more convenient for the purposes of conversation.

There are so many different degrees and varieties of deafness that the term Middle-Ear deafness and nerve-deafness do not by any means cover them, but a rough and ready description of an electrical instrument for

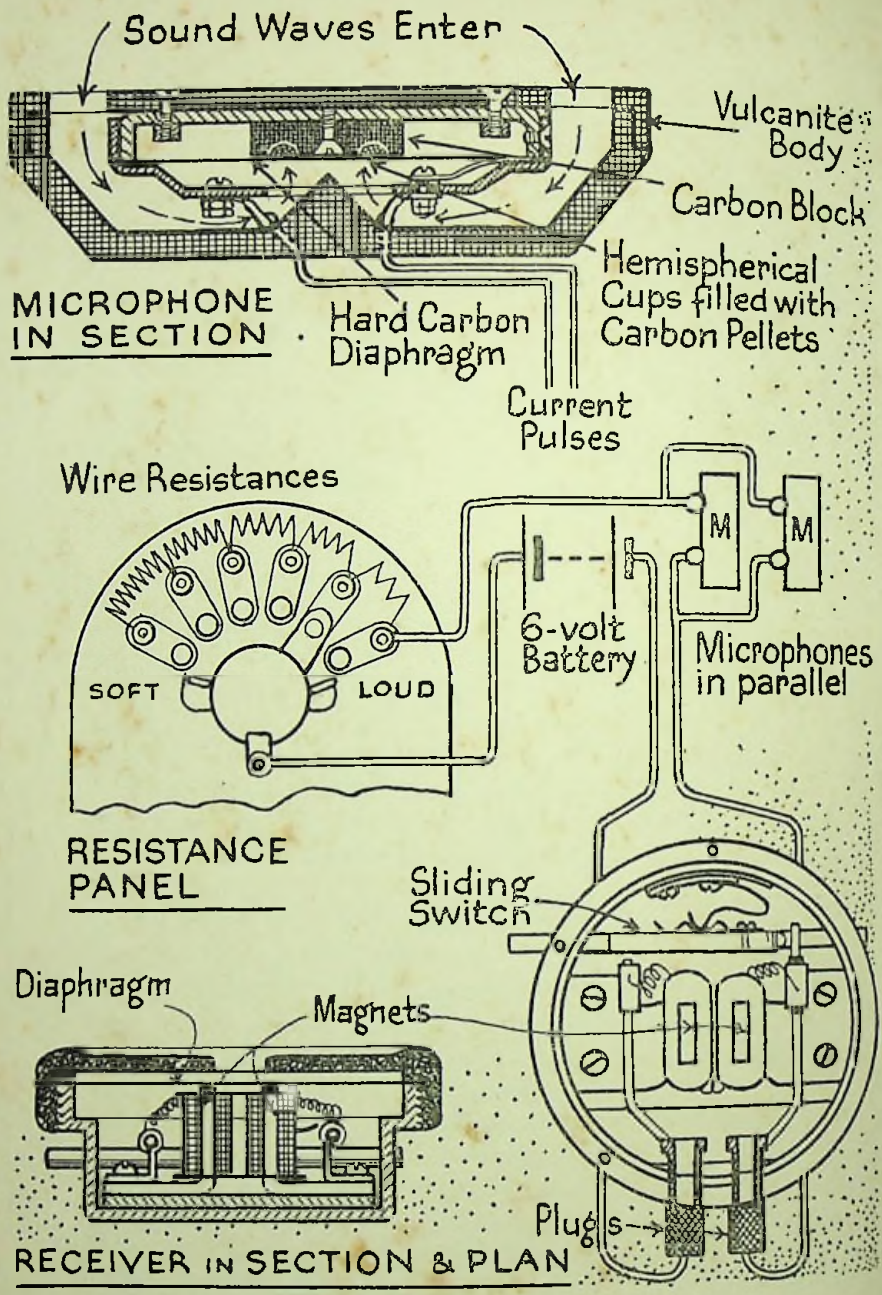


FIG. 10.

An analysis of the parts of a telephone deaf aid, using two simple carbon-granule microphones, spaced so as to give perspective effect. One only is shown, the letters M M represent these microphones in the circuit diagram. The carbon pellets soon get gummed up.

hearing is obviously the post office telephone. This is arranged so that its internal mechanism will turn vibrations into electrical impulses from the speaker's end and back again to sound at the receiver's end ; covering the normal average vibration-rates of normal speaking and hearing. That is to say it is a low power electrically energized conveyor of a few hundred vibrations, only, because that is all that is necessary.

Opposite is a drawing of the fundamental essentials to such a system which, offered to the public some years back at £16 16s., as a Hearing Aid, did only a little more than that. We will say more on this question when Barnard Way has explained the electric and magnetic principles of hearing aids in the next chapter but one (page 77).

HOSPITALS AND METHODS OF OBTAINING ADVICE ABOUT YOUR EARS

With the exception of those born deaf bad hearing is always the result of some disorder or disease of the ears *which has been neglected.* In what we call the Olden Days there was some excuse for that neglect since very little was known about ear diseases and there were few opportunities for special ear treatment.

That is not the case now. Your family doctor will help you. Every London and every County hospital, and town which has a public hospital, has an Ear Out-patient department *which is at your disposal.*

There are four special London hospitals for the treatment of Throat, Nose and Ear :

Central London Throat, Nose and Ear Hospital, Grays Inn Road, W.C.

Golden Square Throat, Nose and Ear Hospital, Golden Square, W.1.

Metropolitan Ear, Nose and Throat Hospital, 2 Fitzroy Street, W.

Royal Ear Hospital, Huntley Street, W.C.1.

If you are in any doubt about obtaining *any* advice about your ears and hearing, ask The National Institute for the Deaf, 105 Gower Street, London, W.C.1.

You will discover that there is some institution, some practical treatment for you or your child, explained to you so that you can take advantage of it. If you need a hearing device they will tell you where to go and how to obtain one, with the least expenditure of money you can afford.

The National Institute has been carrying on Deaf and Dumb Schools, Lip-reading classes, etc., for many years and is in every sense worthy of the support and prestige which it has earned.

THE ELECTRIC AND MAGNETIC PRINCIPLES IN THE HEARING AID

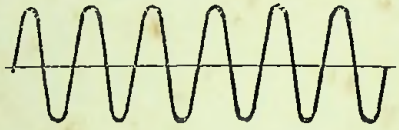
(By Barnard Way)

Sound consists of waves set up in the air by some source of vibration. These waves are somewhat similar to those outward-travelling ripples set up on the surface of a smooth pond by an object breaking that surface. In just the same way the waves of sound move outwards in ever-widening circles, but with this difference, that they move in all directions and not merely in one plane as on the pond's surface. It is not hard to believe that the energy is soon dissipated. There is a very distinct limit to the distance that a sound can be expected to travel. To demonstrate this, the scientist's rule about inverse squares may be quoted, for it applies exactly here. Listener A, stationed 10 feet from the speaker hears four times as much as listener B, seated 20 feet away, nine times as much as C, who is 30 feet off, and sixteen times as much as D who is 40 feet from the origin of the noise. That means that if you are twice as near you hear four times as much—given perfect hearing—four being the square of two.

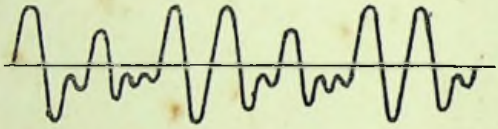
These remarks may seem hardly to the point, since we are studying electrical reproduction, but wait a moment. Sounds that we want to transmit to a distance cannot be transmitted by ordinary means. Of course sound waves can be directed by means of megaphones (speaking-trumpets) or similar devices, but the limits are still very short.

We can record the sounds mechanically, making a picture of them upon a wax disc, from which they can be repeated often enough. As this process is something akin to what we are dealing with, we may perhaps briefly describe it. The sounds are concentrated upon a

diaphragm of mica to which one end of a light lever is fastened. Movement of this diaphragm is thus imparted to a needle point at the other end of the lever, and this point engraves a line on a wax disc moved at a steady pace beneath it. The character of this line corresponds with the frequency of the sound vibrations, so it can be used to drive a similar needle, imparting these movements to another diaphragm, the resulting sounds being more or less a reproduction of the original ones.



Pure Sound Wave



Vowel Sound "O"

FIG. 11.

It is this ability to " shake " a mechanical arrangement by means of a diaphragm subjected to the sound which is the beginning of all sound transmission. Very few sounds are pure sounds, represented by a simple wave-form such as the ripple on the pond, and which we reproduce here as the scientific man does it. Below it we show the wave form of somebody making the vowel sound " o ". This is not a very complicated wave, but you notice it is very different ?

Electricity exists also as a wave form, though its frequency is of such an immeasurably fine texture that we cannot separate one wave from the other. It has

certain properties that make it very suitable for what we need. It is instantaneous in its movement, it seizes every opportunity to flow through any path that offers, however fleeting the opportunity may be. The vibrations of a diaphragm responding to the top notes of a piccolo may be 4,750 to the second, but an impulse would pass every time one of those vibrations offered passage, as we can easily make it do electrically. Let us see how; but first we ought to know an odd trifle or so about electric currents, not much, but what there is of it, important. Let us pretend you know nothing about it!

There are three influences governing the movement of electricity along wires—or conductors as they are better called, because they are not invariably wires. Two of these influences are properties of the current, and one of the conductor. The first two are Pressure (measured in volts) and Current or Rate of Flow (measured in ampères, amps for short). The third is Resistance, (measured in ohms). To understand more fully the import of these, consider water flowing through a pipe. To increase the rate of flow, so as to overcome the resistance of the inside of the pipe, we have to increase the pressure behind the water; not much difficulty about that. If the pipe offers the minimum of resistance then a good flow may go through, but a high resistance will reduce the pressure and consequently the flow. So much being understood, we can look into one other quality of electricity, which is of primary importance.

If a coil of wire be wound round a bar of soft iron and a current of electricity permitted to pass through that coil, the bar is instantly magnetized and will attract any piece of iron near to it. This magnetic power is thrown off as suddenly as it was assumed directly the current-flow is stopped. No matter how rapidly (within certain limits) the stop-and-go effect is carried out, the response is unfailing. Even those 4,750 vibrations a second of the diaphragm shaken by the piccolo will make and mar the magnetism of a well-designed magnet.

In practice we do not do it quite so simply as this, since such a simple form of magnet would have neither the power nor the sensitivity necessary for any sort of quality performance. Instead, we put as powerful a permanent magnet as we can get into a small space, and wind our coils on to soft iron extensions of the poles—which, by the way, is the name given to the ends of a magnet. Between these poles the magnetic force may be considered as flowing, or otherwise active; strongest between them but extending outwards in all directions up and down, side to side. This is known as the magnetic field, the sphere of influence of the magnet, and research is always being directed towards the production of steel that will take and hold more and more magnetism. The flow of the lines of force between the poles is immensely assisted by laying a plate of iron across them, in telephone practice this plate does not touch the poles, and is made of a springy sort of iron that permits the passage of the lines of force but does not accept permanent magnetism. This plate is usually circular, and is called the diaphragm. (See Figs. 16 and 21.)

When the small current-pulses from the battery, through the microphone, pass into the magnet coils, they either strengthen or weaken the field a little, setting up disturbances. These shake the diaphragm of the receiver held to your ear in the same manner as your voice has shaken that of the microphone and sound waves result, more or less reproducing what you have said.

Curiously enough, the principles of this sort of telephone receiver were laid down by Dr. Alexander Graham Bell and the first one was made by him as a hearing aid. His apparatus was double-ended, and needed no battery at all; it consisted of a pair of these permanent magnet devices with their coil windings connected by a pair of wires. If you spoke to one of them, the diaphragm vibrated and disturbances in the magnet field were set up due to the varying distance between the diaphragm and the poles. These disturbances set up tiny impulses

FIG. 12.
Dr. Graham Bell's original telephone.

of current in the coils, and these being passed to the coils on the magnets of your opposite number's instrument, they set up disturbances there that resulted in sound waves corresponding to your voice. The same instrument was used at either end as transmitter or receiver in turn. (Fig. 12.)

This principle of setting up disturbances in the field of a magnet is made use of to a considerable extent in electrical engineering, it is, in fact, the basis of the generator that provides us with all our power, light and heat. The better types of hearing aids employ it occasionally in their microphones, but it can only be employed where some form of valve amplification is available. The currents from a moving-coil device driven by sound waves are insufficient to work a telephone with power enough to be of use to the deaf. Later we shall see how a deaf scientist did succeed somewhat on these lines.

Our sound reproducer begins then with a diaphragm and ends with one ; in between are the simple " works ". To demonstrate how simple these works can be, we have analysed a hearing aid as sold to the public for the considerable sum of 16 guineas, putting the essential parts down in diagram form for the benefit of those who can understand them (see Fig. 10, p. 74). If you now follow carefully you will understand them.

The diaphragm on to which the sound waves are directed is made of a thin sheet of extremely hard carbon, very brittle, so brittle that it will fly into a hundred pieces with the slightest mishandling. This is held firmly so that its face is almost in contact with a circular block of carbon in which six little hemispherical cups are formed. Each of these cups contains a quantity of tiny pellets of carbon, enough almost to entirely fill it, and enough to make continuous electrical contact between the diaphragm and the block. The fact that the pellets are loose, however, means that the contact is not a perfect one all the time.

Consider the electric current as flowing through this

arrangement, for that is what we make it do, by hooking up one wire from the dry battery, included in the device, to the diaphragm. Current passing through is led away from the carbon block; where it goes we shall see presently.

Speak to the diaphragm, and it will respond by vibrating in time to the unseen waves your vocal chords set up in the air. Those vibrations are too small to be seen, but they are quite sufficient to be detected by the little carbon pellets in those cups. An inward movement of the diaphragm, caused by a compression wave, squeezes them closer, making better contact, thus permitting more current to flow. The outward movement due to the springy nature of the diaphragm, permitted by the rarefaction wave that inevitably follows, releases the pellets, and reduces the degree of contact. Less current flows, probably not enough to do any work, and so we get alternations of current and no current flowing through, just as long as there is any life in the battery and the switch, controlling it, is turned on.

Incidentally, this will not be very long if the instrument is used continuously, for the system is somewhat prodigal of current. This is the chief difficulty with regard to hearing aids of the electrical type, for it must be borne in mind always that there is a very distinct time-limit to the capacity of even the heaviest battery, let alone any battery that can be carried around in one's pocket. We shall say more about this presently.

The oscillating current passing through our microphone is now led through a device called a variable resistance (potentiometer if you prefer it), by means of which the intensity of the sound can be varied between loud and soft. Don't run away with the idea, as some people do, that turning the knob round to " soft ", saves battery current, it does not, it merely heats up some fine wire. Its work is to choke down the strength of the current impulses so that they do not produce so strong a magnetism as they would do otherwise. You are simply running the same current through more or through less wire.

Passing through this resistance, the current arrives at the receiver we have already examined, producing vibration of the diaphragm that you clip close to your ear. To complete the electric circuit which is necessary, a wire returns to the other pole of the battery. In the receiver is a little sliding switch that cuts off the current entirely, so putting the whole device out of action.

This, in effect, is the whole principle of the transmission of sound by electrical means, but there can be

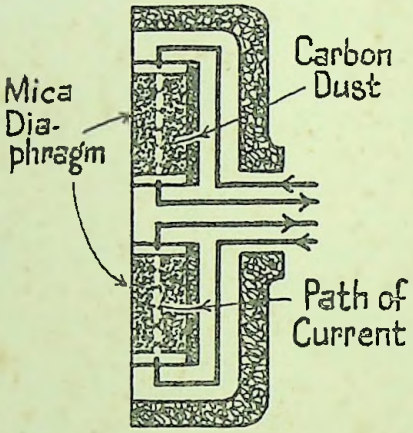


FIG. 13.
An improved form of Carbon Microphone, using carbon dust and providing transverse current flow.

and is much more in it than that. We have described the simplest possible system, but it is far from being the best possible, very far indeed, even though it is the basis of all our public telephones and of all electric hearing aids prior to the invention of " valves ".

Now, just as we can reproduce sound electrically, so we can amplify it, a fact that is brought home to us somewhat painfully at times when the neighbours overdo the volume control on their radio receivers! There are much better microphones than those of the carbon-pellet type, but these need an entirely different

system of reproduction for their use—we shall be seeing them presently. The trouble about the carbon-granule microphone is that there is little or no free passage for electric current through it, as we have only the minute contact points of tiny carbon-granule spheres touching each other quite lightly. Consequently a good deal of sparking occurs as the current flows; only tiny sparks it is true, and quite invisible to the eye, but they produce those " frying " and crackling noises in the headphones; noises that can be most distressing. The pellets and

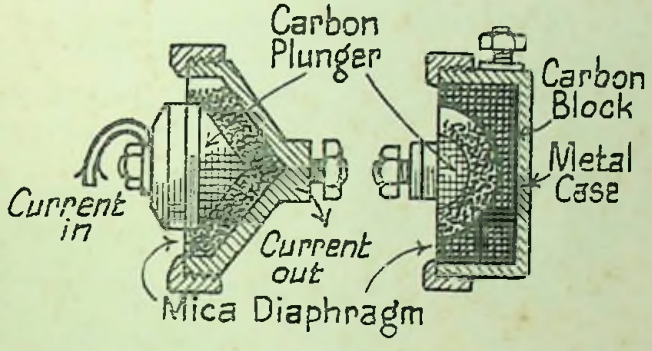


FIG. 14.

Skinderviken " button ". On the left the original form; on the right the improved form.

their cups, as well as the diaphragm must be highly polished to be efficient, yet a few weeks' service may see them worn rough, and in a state in which sparking will be continuous as long as current flows.

Some of this trouble has been got over by using carbon dust (see Fig. 13), and leading the current across it in a direction at right angles to that at which the diaphragm compresses it.

One of the best microphones of the carbon sort we ever saw was the Skinderviken Button (see Fig. 14), in which the carbon pellets were contained by a hollow conical box into which a conical piston projected. The piston was fixed to the centre of the diaphragm, and that was all.

The particular advantage of this arrangement lay in the fact that it would perform equally well in any position. Later the design was modified to the hemispherical shape also illustrated in left portion of Fig. 14; it was extremely economical of battery current and was made in very small but sensitive sizes.

The makers claimed with some justice that the design did away with what is known as "packing", the jamming together of the pellets with consequent failure in action until they had been shaken up again. Probably

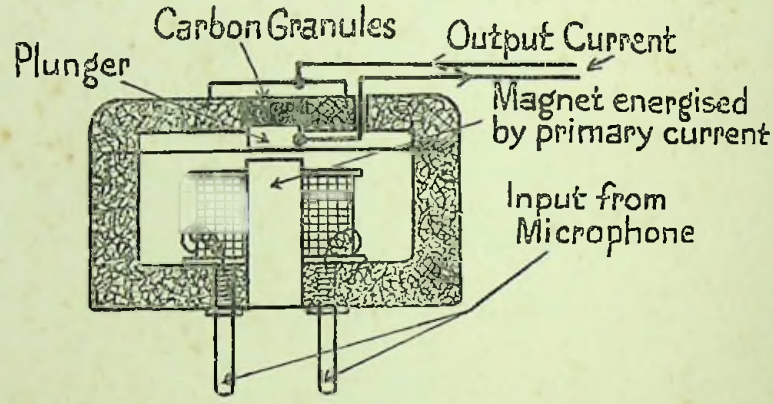


FIG. 15.

An Amplifier for Carbon Granule Microphones, using the same principle.

most makers of such devices would claim this for their products, long personal experience of the telephone, in which a carbon pellet microphone is used, show that the efficiency of a well-designed device of the sort is pretty high.

There is a useful device for amplifying the currents from the carbon microphone employed by some hearing "aid" makers (see Fig. 15). In this, the currents pass to a magnet, working a diaphragm with a piston in its centre. This piston is the plunger of a second carbon microphone supplied with current from the battery, and the result is a considerable increase in strength of the original signals. Obviously, such an amplifier will deal equally

faithfully with all the things that are given to it, and if those unpleasant crackling noises are amongst them, they will be magnified also.

This failing, if it can be so described, cannot easily be dealt with, for here we have the unthinking machine that does precisely what it is told and designed to do. Much thought and experiment has gone into the subject, with a view to filtering out the objectionable noises, and passing only those that are useful, without much

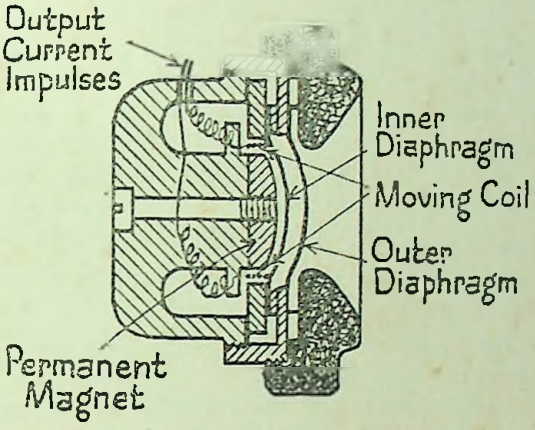


Fig. 16.
A moving coil type of Microphone.

result. It is obvious, or ought to be, that if any sort of speech range is to be dealt with, we must not expect to filter out high-pitched noises, for that would mean the elimination of sibilant sounds, to quote only one instance.

It is sad, perhaps, to have to state that there is at present no substitute for the carbon microphone for the simplest type of portable hearing aid. The excellent performance of microphones of the moving coil and piezo-electric crystal types can only be applied to instruments of the valve amplifying sort, which we can now pass on to review briefly.

Some mention was made of the moving coil microphone

a little way back, here is a diagram to give an idea of its arrangement (see Fig. 16). A coil of wire of a few turns only is suspended, between the poles of a specially shaped magnet, by a diaphragm. The sound waves are concentrated on an outer diaphragm and the inner diaphragm that carries the coil is driven by the air trapped between the two. You will recollect our remarks about disturbances in magnetic fields, well, here it is again in a slightly different form. This time we move a coil in the field, and the result is that tiny currents are set up in the coil, proportionate to the amount of movement. In the opposite direction, if we passed currents into the coil, the result would be to move the coil, and so we get a receiver. This is the principle of the best types of radio loud speakers.

The other sort of microphone in regular use is the piezo-electric crystal, a very simple device, based on a long-known scientific fact. Certain mineral crystals, when subjected to stress, such as bending or twisting, will emit tiny pulses of current. The reason for this is not precisely known, and it hardly matters much to us, we can be satisfied that it is so. At any rate, microphones of this sort are most effective and sensitive, being also quite clear of those objectionable noises that characterize the carbon types.

Rochelle salt is the crystal generally used; for those inquisitive about such things we might record that it is a tartrate of sodium and potassium, better known as one of the components of the blue packet of a Seidlitz salt. In practice, the diaphragm is conical in shape, and a light metal rod projects from the apex of the interior of the cone. This rod is secured through the crystal, which is supported at its corners so that movement of the diaphragm flexes it slightly. Rochelle salt crystals have the property strongly marked of cleaving easily along a certain plane, and if the crystal is set in the proper direction the bending effect of the diaphragm movement tends to make its layers move relatively to each other.

Protest against this treatment comes in the form of those useful pulses of current that we can employ to record speech and music; music, because these crystals are used in the " pick-up " device on your radio-gramophone.

The currents from microphones of this sort are so small that they can only be magnified to a useful extent by means of thermionic valves. Incidentally, these valves were first invented by Dr. Ambrose Fleming as part of a hearing aid for himself, and were perfected later by others for the purpose for which we use them, the amplification of tiny electric currents. By their aid, we can magnify a current many million times without distorting its original character, a very considerable achievement.

This is not a book on wireless, so we can hardly expect to deal in full measure with the mysteries of the radio valve, but a few details about it ought to be included. The trouble is that it necessarily brings in further elementary matters needing explanation. However, if we set out to inform, we ought to do it thoroughly (!) so let us see what can be done.

So many thousands of people are now carrying hearing aids in which valves are doing the amplification work, that no book on the subject could be considered complete without them.

Figure 17 shows what there is in a radio valve of simple type. There are valves of much more elaborate construction than this, with all sorts of safeguards incorporated, but you must read about those in a wireless book. Three items are essential, the Filament, the Grid, and the Plate, all enclosed within a glass bulb cleared of every possible trace of air that can by any means be extracted from it, and then sealed up. Platinum, or some similar metal wires have to be sealed through the glass to enable us to communicate electrically with these parts.

The work of the filament is to produce a continuous stream of those nimble elementary particles known as electrons, this it does by virtue of its constitution and a

current of electricity passed through it by a battery: the "filament battery". The plate has a connecting wire to the positive pole of another battery giving a voltage of about 35 or so. Now electrons are particles of negative electricity, and it is an axiom in electrical matters that "unlike poles attract and like poles repel", so the negative electron particles fly immediately from the filament to the positively charged plate, making a

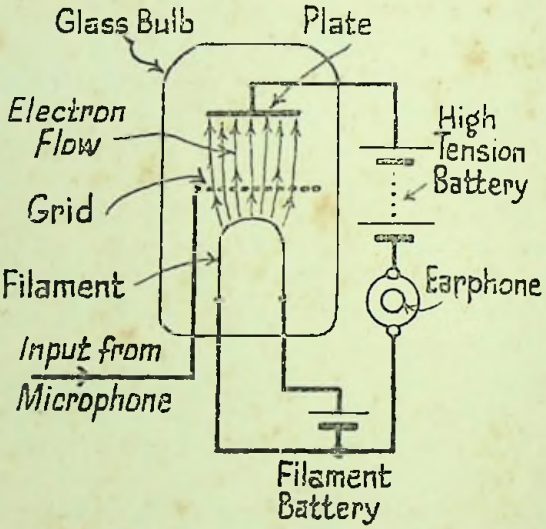


FIG. 17.

A diagram to show the necessary parts of an Amplifying Valve and Telephone Circuit.

path by which the current from that high-tension battery can flow.

The grid consists of a fine mesh of wire placed in the path of the electrons on their way to the plate, and it has a connecting wire through the glass to the outer world. So long as there is no charge on the grid, it does not interfere with the flow of current, but if a negative charge is put on it—as for instance a connection to the negative side of a battery—then remember—"like poles repel"—

the electron flow is stopped. Alter this, change to a positive one, and the flow is intensified.

These changes on the grid need only be of the smallest description, but they result in a greatly increased current flow from the high-tension battery supplying the plate. Now, if we connect a telephone up in the circuit between this battery and the plate, the changes in current will be recorded in the phones, that is, of course, if they are in the nature of speech currents.

The grid being in control of the situation, the slightest change in its state results in a much magnified movement

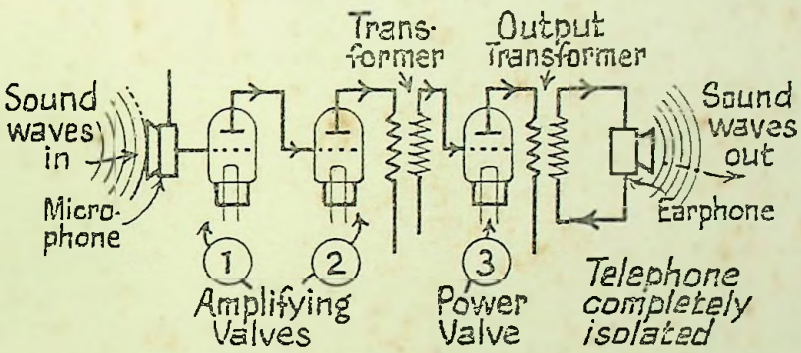


Fig. 18.
The sequence through the stages of a Valve Amplifier Set.

of current in the plate circuit, and the response is instantaneous. We can make a million changes a second on the grid, and not one will be lost, each will be dealt with faithfully! (See Fig. 18, the diagram of electric circuit for such an instrument as shown in Fig. 19 below.)

The degree of amplification that can be had from ordinary valves is very great, 1,200 times is quite usual, but we never work them to this extent. We should prefer to put in two or three valves, leading the output from one on to the grid of the next and so on, using only a fraction of the possible magnifying power. Doing this of course means more current from the battery to keep the filaments heated, but it means also that no valve

ever runs the least risk of getting overloaded; which has the important significance that there will be no distortion.

Mention of batteries brings us back to that subject again. The portable type of hearing aid, using valves, depends on an ordinary pocket torch type of battery *for the valve filaments*. Small as the current may be, it will clear a good battery right out in ten hours continuous run, though nobody should want to run it for as long as that. The makers suggest, and it seems a common-sense idea, that the user should get seven batteries and mark them with the names of the days of the week, using one for each day, changing it every morning. These small dry batteries benefit greatly by a rest, and will actually recuperate if given the chance.

With the so-called high-tension batteries the trouble is not so acute, for they should last out about two or perhaps three months.

Small accumulators are to be had for use instead of dry batteries for the filaments, these can be put "on charge" at night time, but they entail the installation of a "trickle charger" at home. They are of the type in which the acid is carried in a porous jelly, so that there is no danger of spilling what is an extremely corrosive liquid.

The development during the last few years of the mains-driven radio-receiver for the home has pointed the way to the hearing aid maker, so that there are now several excellent devices of this sort on the market (see Fig. 19). The idea is to sweep away all the tiresome batteries, that only enable the receiver to work at full performance while they are fully up to their power, and which need recharging so frequently. Instead of these, it is possible to take all the power that is required—and it is really very little—out of the public supply mains. *Apparatus inside the case accepts the bulk supply, divides it up, and issues just what each valve requires.* Let us go into this briefly.

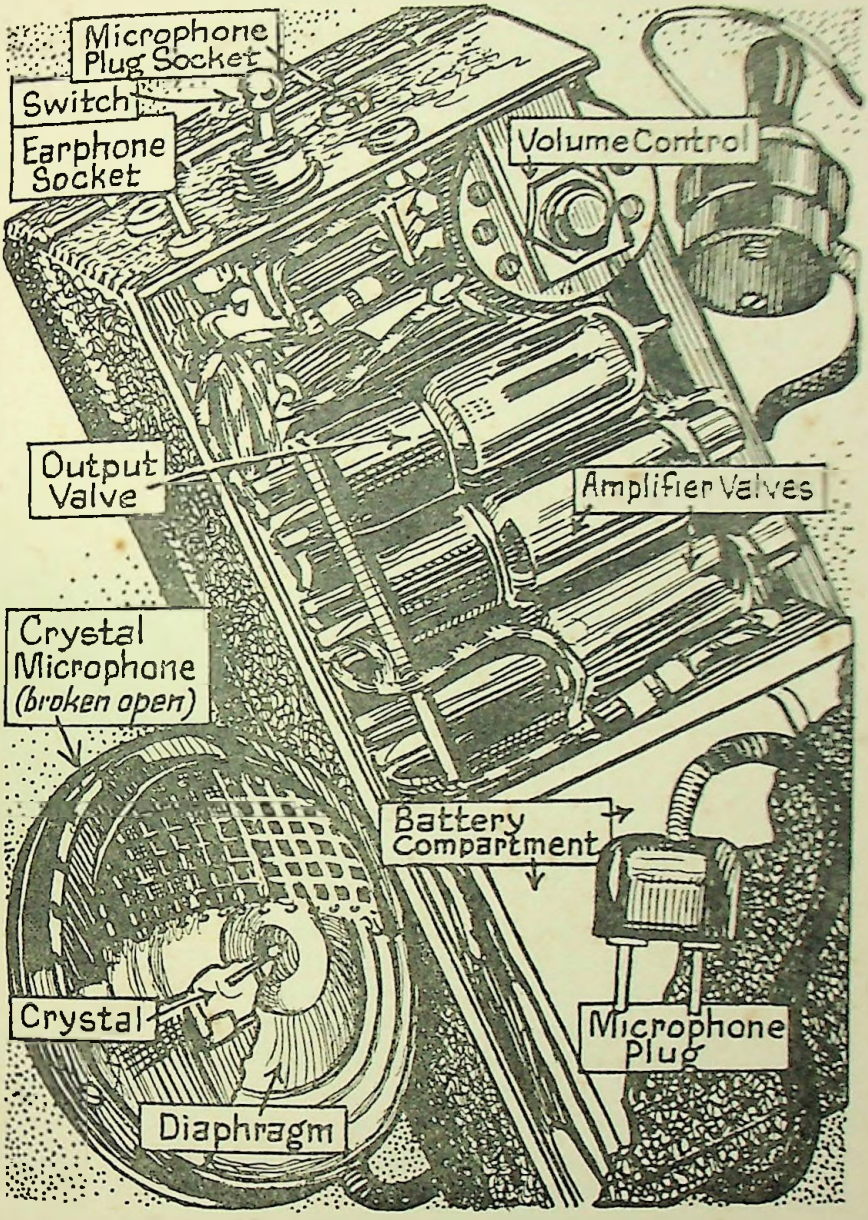


FIG. 19.

A valve amplifier deaf aid opened up to show its contents. The crystal microphone has also been opened to show the simplicity, and consequent reliability, of its parts. At the top is a small type of earphone. (Approximately actual size.)

The public supply almost everywhere in this country consists of what is known as alternating current, as distinct from what it used to be—direct current. In the latter case there was a continuous flow always in one direction, and always at a constant pressure. With alternating current the flow is first one way, then the other, with a constant rise and fall in voltage with each reversal. These reversals occur 25 times a second. Altogether it sounds an elaborate sort of business, as it certainly is, but it has many advantages so we use it.

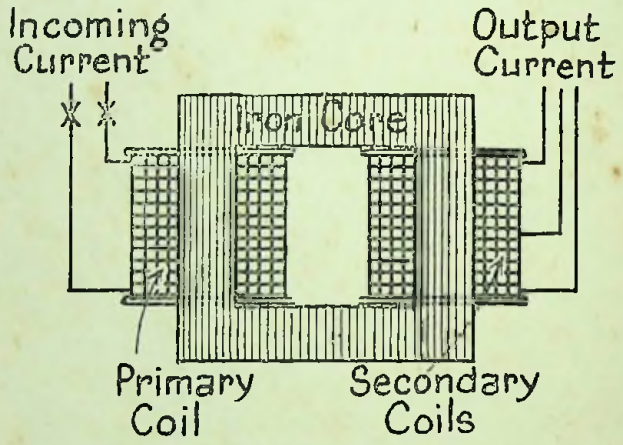


FIG. 20.
A section through a simple transformer.

The chief advantage is that we can alter its voltage, or pressure, with great ease by means of a device called a transformer (see Fig. 20). This consists of two coils wound over a square iron core—see the diagram above—and through one coil we pass the current supply from the mains. Every pulse in this coil sets up a similar pulse in the secondary coil, and this *can be varied in its voltage exactly in proportion to the number of turns of wire in it.* If the secondary coil has only half the turns there are in the first—or primary coil—then the volts turned out will be half, and this applies to all the windings. In

a small amplifier we shall need only one voltage of alternating current, and this is used for the filaments of the valves. The other parts of the apparatus call for direct current, and this we shall have to get by converting some of the alternating supply, which comes also out of the transformer. It is converted by a rectifier and its voltage modified to whatever we want by means of resistances.

All this rather suggests that the mains-driven type of hearing aid is a box of tricks, but it is not so to the man who knows what it is all about. True, the details have to be packed closely, but that is no great matter. The method of amplification is the same, and a third valve is used to turn the work of the first valves into a good flow of current that will give strong signals in the telephone.

To reassure the nervous user who might be afraid of putting on a telephone headpiece energized by a supply of power drawn from the mains, it ought to be emphasized that *there is no direct coupling at any point with the mains*. Thanks to the transformer idea, which is employed first at the beginning of the set and also in the last passing-out of the impulses to the telephone, there is not the least risk of this. A due respect must always be paid to any device that has unlimited power at the other end of a wire, but there is far less danger to the user in actual service than there is in facing a hungry tiger at the other end of a rat-hole.

This is a most important point, and one to which due regard must be given by anyone considering the purchase of any mains-driven appliance. A guarantee should be obtained from the manufacturer to the effect that an output transformer of reliable make is incorporated in the set.

This detail about the working of a mains-driven outfit as a hearing aid is somewhat of a digression, so let us get back to our real subject—that of the assistance electricity can give in the reproduction and transmission

of sound. Not many people can afford to buy two such devices, one for home and one for office, with a portable aid to carry about with them. The pleasures they can thus add to life must be considerable for the deaf, and there are systems by means of which church services are available, and also the cinema show that has become such a part of the national life, and which can thus be enjoyed by a limited number. The number is limited at present.

Many cathedrals and churches have been wired up for electrical reproduction of the services and sermons, for general improvement of hearing in places where acoustics are not too good.

The placing of microphones at different points in the church—prayer desk, lectern, pulpit, and elsewhere, having been done, what is easier than to carry lines from the amplifier to some of the pews, and provide plug sockets to enable the deaf worshipper to connect up his or her earphone? There is no more in it than has been dealt with so far in this chapter, and it has been done in hundreds of churches.

At the cinema, the idea is the same, but there are different ways of doing it. The more usual way is to run pairs of wires around the auditorium, through which the speech and music impulses flow, and to pick these up by means of a coil called an inductor. This same arrangement is available for the deaf person who wants freedom to use the telephone. All that is necessary is to lay the coil over the flexible cord connection to the telephone stand and use an earphone connected to the coil through an amplifier. The basis of this idea is the fact that the passage of electric currents through wires sets up a magnetic field surrounding those wires. As the currents change, so does the field rise and fall. Now if we lay a coil of wire across this field, similar movements are set up in the coil, the more loops there are in this coil, up to a certain limit, the stronger will be the gathered impulses. It is only necessary to wire this coil through an amplifier

to the earphone to get adequate hearing for almost everyone.

Adequate hearing. What does that mean? If the well-tuned ear listens by way of a hearing aid to a voice he knows well, or to music, or any other sound with which he is familiar, is he invariably pleased? The answer to this is easy to give, for he is not. It is one thing to reproduce sound and to amplify it, but to do so without considerably distorting much of its quality of character is difficult and rare. To achieve perfection is—in spite of all the advertising—not done. Very good results can be had, but the usual sort of thing is nowhere near this category. Too many technical men, who ought to—and do—know better, are content with what Shakespeare said:

"What matter how it be in tune, so it make noise enough?"

Amplification is so appallingly easy that they go out for that, forgetting that quality is more important and that quality depends upon all those irregularities in the frequency of vibration known as harmonics or over tones. These are most difficult to deal with, and cannot be included in the final performance if noise is the main idea.

It is the amplification of the human voice that provides the greatest difficulty if it is to remain recognizable as to its ownership. To the man who has always been deaf and has only known a voice by way of his earphone perhaps it is not quite so important as it is to those who have slowly become deaf. The range of frequencies—that is, the number of vibrations a second of the sounds produced—covered by the human voice may be said to be between 90 and 8,000. The human ear can distinguish sounds varying in frequency from 20 up to 20,000—though not all can do this. It is quite easy, by putting in a filtering device, to cut off, or limit the range of frequencies in any speech, and it is astonishing how the clearness, or articulation suffers as a result. Experiments

show that so long as the lower limit is at about 500 and the upper about 5,000, then more than 90 per cent. articulation is attained.

The G.P.O. telephone engineers consider that it is quite sufficient for ordinary conversation purposes if they transmit the frequencies between 300 and 2,700, asking subscribers to speak very clearly, thus putting the blame on them if there is to be any. The lines they put down for the special use of the B.B.C. can carry frequencies much higher than this, but these lines cost a great deal of money.

It is interesting to observe the result of this cutting down of the frequencies in speech, but it would seem that the upper range is the most important from the point of view of clear articulation. Soft, sibilant sounds, whispers, the letters t and f, the combination th, all come in this category. Cut down the frequencies to nothing above 5,000 and most of these sounds vanish. This is somewhat surprising perhaps, but its import to the deaf is considerable, for it means that they are cut off from half the qualities of English speech, for few, if any, of the deaf aids on the market can deal with these upper frequencies. It rather sounds as if we are all becoming satisfied with a steady deterioration of speech articulation, having in mind what a small proportion of English is transmitted by the public telephone service.

By cutting off at 3,000 we are deprived of clear reproduction of the consonants v, j, r, ch, th, t, s and z. Fortunately, however, it is not so serious as all this would seem to suggest. It is well known that the B.B.C. find no difficulty in broadcasting a range of frequencies between 50 and 8,000 per second, and they could, if listeners really wanted it, increase the upper range to 10,000. Any deaf aid using a microphone of the piezo-electric type, with valve amplification should be able to handle frequencies at least up to 8,000. It is no great matter to adjust the amplifier to that, but it is of no use to hope for any such results from a carbon microphone

and amplifier of the sort we have described previously. They cannot do it.

The use of the valve amplifier permits another considerable improvement to be added. Those who own up-to-date radio sets will have heard about automatic volume control, which desirable fitment prevents the sudden increase of performance-volume beyond a certain pre-determined limit. Once this limit is set, there can be no sudden noise to blow the roof off, as we formerly knew it. For the deaf-aid, this means that banging

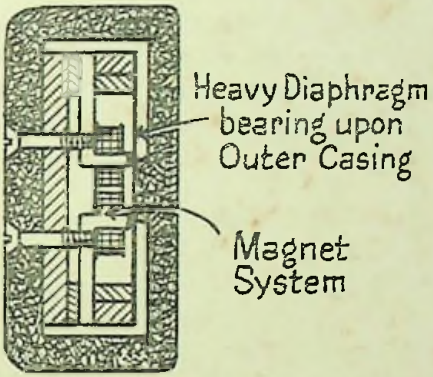


FIG. 21.
Bone Conductor-Receiver.

doors, or any of those occasional small noises that seem to affect the microphone to a disproportionate extent, are absorbed quite automatically. We do not know whether all such aids are so equipped, *but it is possible, and it ought to be done.* The method is a little too technical for the scope of this book, but it is explained in most books on radio.

There remains one type of *receiver* that we have not yet mentioned, the bone-conduction system for those with nerve-deafness. The inner ear is surrounded by very hard bone, and it is quite sufficient to have some sort of " oscillator " placed in firm contact with the mastoid bone at the back of the ear, to receive the sounds

quite clearly. To do this requires a higher degree of amplification than is needed for an earphone, with most people.

An approximate section of a deaf aid of this sort is shown here, though it must not be taken as illustrating any one in particular (see Fig. 21). It consists simply of a magnet system having a heavy diaphragm with practically no gap between it and the poles of the magnet. The centre of the diaphragm bears firmly against the body of the casing so that all its movements are transmitted to the case.

If this very small receiving apparatus is held against the bone of the head, say behind the ear, all the impulses are conveyed as speech to the brain centre, with more or less clarity according to the stage of deafness.

THE HEARING AID IN *USE* BY DEAF PERSONS

LITTLE need be said about the voice-trumpet, or speaking-tube, in its application to the deaf, except that this simple instrument, in its various forms, is sold at far too high prices to the public. The " little inconspicuous aids " which are advertised (by themselves) to aid hearing by insertion into the ear are not the least use for the purpose. They block up the admission of air waves to the ear and do nothing else.

As regards the Electric Hearing Aids you will have read what Mr. Barnard Way has stated in the previous chapter and have understood for yourself now that there is no " mystery " about them. They are not " medical ", though mostly financed and officed in or around those localities in which medical men consult. The fact is that medical men, taken as a whole, know little about the electrical hearing aids and care less ; which is natural enough since they can hardly be expected to possess specimens or to have made a study of them.

Nevertheless makers of the machines possibly inspired by the vicinity, pretend that they can " prescribe " the exact instrument for the deaf " case ", just as if it was a medical plaster or intricate splint.

Nor, in some ways, have the societies, which do undoubtedly serve the interests of the deaf in countless ways, such as the National Institute for the Deaf, done much yet to prevent some phases of exploitation of the deaf by unscrupulous vendors of " aids ". They insist on makers allowing " trial " of the particular machine which the deaf person has found suitable, or one that is recommended by the Hearing Clinics with which they are associated. This " trial " period suits the vendors admirably for the simple reason that the instruments in themselves are not fakes. There is no need for them to

be since they can make carbon-granule telephone-instruments and valve-containing machines for very little money and sell them to immense advantage ; and even a fortnight's trial may not exhaust the batteries, or the carbon-granules glue together, the valve-connections burn out, etc., in that time. But the system of trial is a check which the best instrument-makers accept unconditionally. The smaller the instrument the more " wonderful " most deaf people consider it and it is not difficult to persuade the unfortunate deaf person that the " case ", which looks so neat, contains " automatic volume control ", etc., for there is no way of disproving it except by taking it all to pieces ; which is the last thing the deaf person is going to do with an instrument for which he has paid many guineas ! In general, the smaller the instrument, the less battery-power and lasting qualities.

To sum up. Every electrical hearing aid, if it is of use to the deaf, must be one of two sorts—either a simple carbon-granule telephone instrument, or a valve-amplifying instrument. This latter has revolutionized hearing for the deaf and it should be available cheaply.

Every necessary component in either of the machines can be bought at an electrical instrument or valve-maker's shop. The smaller each component in it is, the less lasting and the less reliable.

Patients have told me that makers of these machines have charged them as much as £2 10s. for " repairing " a machine. The whole instrument of either sort hardly costs the maker more than that sum, or at least if it does he is not getting his supplies at wholesale rates, or running his workshop to advantage. Supposing that it does cost that sum, the person having a repair done should be able to know which part of it, when repaired, was defective.

Now exactly what can a deaf person hear with electrical hearing aids ? To ascertain this it is necessary to take a typical case of middle-ear deafness (the ordinary type) in the average. Such a case has lost the ordinary chances

of conversation between individuals and himself; he cannot hear at theatres, church or moving-picture-shows, or meetings. He can hear, generally better with one ear than the other, when spoken to loudly. That is to say that his auditory nerve can carry impulses to the brain but in the ordinary way they cannot reach it through the external and middle ear. It is necessary to amplify the vibrations and increase the strength of them before they reach the brain.

A carbon-granule telephone-instrument will do this in vibrations up to about 3,000 per second, and this covers nearly all that is necessary when the deaf person, in addition, can watch the speaker's lips. Therefore with a little telephone-instrument, provided its granules are activated by sufficient low-battery power to respond to sound waves, this deaf person can carry the machine on his person and with the receiver held to his ear he can hear what is said to him a yard or so away; provided the speaker's voice is directed towards the microphone. He can also hear something of what is said in a room from all round but no additional loudness (by turning the " volume-control " knob) will make him hear better. It increases all the added noises in the room. In short, there is a distance at which he can hear with it; and a distinct use for it, up to that point. I have known tradesmen able to " keep shop " with such an instrument, but necessarily they are under great drawbacks in catching unfamiliar conversation.

They cannot hear with it except for the purposes for which it is suitable. The user must keep it supplied with its two or three-volt battery and it may be six months or more before the carbon-granules gum up and need renewal. If he can make himself familiar with the internal mechanism of such a simple machine he ought to be able to keep it going for a long time, and for short and necessary conversations it will be invaluable to him. The bigger battery he can carry upon him the better. A large battery does not mean stronger current but it

contains a more lasting quantity of it ; and the shorter each individual conversation the better.

If it is sold to him in toy size ; he has himself to blame for buying it. It is a small telephone. Remember that. A house telephone outfit, with a transformer to run it off the electric-bell system can be bought at the stores for 25s. thoroughly reliable. The finer granules, more responsive diaphragms and more resonant cases of most of these telephone " aids " tend to short life. There is great skill shown in designing the instruments, but if the price was reasonable for what one gets these small telephone-aids would be really worth their money in their use for the deaf ; up to the point stated above.

The Valve-Amplifying Instrument is in another category and can be a most useful aid in every way. In fact if makers were not hampered by the unintelligent demand for " smallness ", " inconspicuousness " and the hiding-up of the machine on the person there would be almost no limit to its use for the deaf, except total destruction of both auditory nerves or absence of the hearing faculty as in congenital deafness in the deaf and dumb. Even then it has some application.

There are two types of this Valve-Amplifying Instrument : The battery machine, which means that the electrical energy is carried in the case of the instrument. The Mains-energy machine, by which the electrical current is taken off the electrical lighting supply in the house.

The make-up of both these machines is shown in diagram on page 91.

What can the deaf person, of the type mentioned above, hear with such an instrument ?

With the battery-type, which means (in practical use) a small case into which must be packed a high and a low-tension battery, the valves for amplifying and the transformers for reducing and changing the current, the use must necessarily be somewhat modified, though the quality of the sound-amplification is the same.

The deaf person can hear conversation in a room

fairly distinctly and can hear anyone addressing him close-by quite distinctly. Provided the conversation is just a trifle above normal the deaf person is able to take part in it, particularly if the speaker's voice can be directed towards the microphone.

He can hear the wireless with it and it is in every way a very much better proposition than the telephone-type. The small ear-pieces often supplied with the instrument naturally are not as powerful as the larger magnet-receiver held to the ear, by a band, etc., but they do enable the deaf person to hold up his end in general conversation. Claims that the deaf can hear at meetings, church, etc., are not true. The deaf hear something of them with it, but there is (naturally) too much amplification of extraneous noises. The instrument cannot differentiate, cannot know that you want to hear General Q. and not the inevitable rustling of the next person's papers! But if the church or theatre is wired for the purpose of " pick-up " a coil can be attached and the instrument will be then useful.

In short this battery-energized valve-amplifying instrument, though made in general too small and too tightly packed to last long, does help the deaf materially. Naturally a " trial " of it for a week or a fortnight is to the advantage of the makers. The more particularly if you are made to pay " something down ". But the upkeep of the low and of the high-tension battery must be added to the original high cost of the instrument. Some of the best are very good instruments.

The *Mains*-Energized Valve-Amplifying Instrument is a good proposition because it is (in essence) exactly on the receiving-plan of any ordinary wireless valve-instrument. The incorporation of a crystal in the microphone (instead of carbon granules) not only should make it cheaper but does render it much more efficient. The crystal takes more current, but there is already far too much current in the mains supply. The " frying-pan " and extraneous noises are entirely cut out if the instrument is made to suit the Company's electric current.

Now the whole point of buying one of these mains instruments ought to be to put it to its best use. That *best* use is undoubtedly not to carry it about, for certain reasons. It may suit one company's electric supply and not another, quite apart from one being direct current and another alternating. It is made as a " Portable " but it needs an electric-light-point or a plug for the insertion of the wire to energize its valves, and the wire to that plug or point necessarily hampers the movement of the user. It can, of course, be used as a portable instrument if these matters are realized and allowed for.

With it working properly the deaf person (as above) can hear general conversation (not too low or in whispers) as ordinary-toned talk. Thus he can join in and enjoy life totally oblivious, to some large degree, of his deafness. He can hear every announcement on the wireless, merely by setting the microphone nearby. The microphone need not be close, indeed it is far better not to have it close to the speaker. Therefore if the owner of the instrument can arrange his own " atmosphere " he can sit in his chair at office or home and, save for the headband which carries the receiver, do all his business with client or messenger as if he could hear well in the natural manner. The valves, like those on the wireless take some moments to warm up and he must be prepared for that. Special volume-control, just as in the wireless instrument when you turn the knob, enables the deaf to amplify the speaker's voice enormously. Nerve-deaf people have in this way ample power for the vibration-receiver (see p. 99) which is held to the mastoid bone.

Remember again, the smaller the instrument the worse for wear. There is no reason in having the Mains instrument unduly small since, unlike the battery-energized valve-machine it is not truly adapted or adaptable for moving about. The makers of course claim that it is. Very well. Let them not charge for it double what you can buy a thoroughly good wireless instrument at, for it is a fact that :

1 crystal microphone
3 midget valves
1 rectifier
2 transformers
1 condenser
1 magnet-receiver and wiring

packed into a three-ply box, should not cost £25, as charged. If makers of these instruments halved their prices and enabled two good instruments to be obtained for the one as now, they would sell more and really help the deaf public ; and make as much money.

The remedy lies with institutions and societies which are paying out to makers public subscription-funds given for the aid of the deaf without themselves making real research into the intrinsic cost of these appliances. We understand from the National Institute for the Deaf that this point has by no means escaped their attention. Manchester University is, we learn, also doing valuable research work in this matter.

What could, for example, be better work for the deaf rendered deaf by the war, as so many were in 1914-18, and so many more will be in this war, than to put together valve-amplifying instruments for themselves and the deaf public ?

Life is difficult enough for deaf people. They need help and in many ways these institutions are giving it. Let them extend their benefices and their usefulness economically with modern means.

The deaf owe so much to your courtesy that I am a little aware of some discourtesy in drawing attention to what the deaf have done for you. Yet I must recall your attention to Edison who gave you your electric light and your gramophone ; and, as Mr. Way already has stated, to Graham Bell who gave you the telephone ; to Ambrose Fleming who made your wireless possible ; and to Beethoven who gave you immortal music. All were nearly stone deaf.

When you want to speak to the deaf make life a little

easier for them by drawing their attention by a light touch on arm or shoulder, so that they may be aware you are addressing them. If you can give them a key-word to the subject—what it is about—they will grasp your meaning more quickly. It is quite likely that you will not have much to raise your tones.

The deaf are often difficult, just as you are when you do not quite grasp what is wanted of you. But it is a common mistake to think the deaf unintelligent.

We have known some people with good hearing write larger than usual to deaf friends; so that they could understand the subject better! The deaf certainly have much to undergo, to suffer with humour.

But on the other hand it is far better for them now than it was and it would be still better for them if there was not an ignorant deaf public who expect makers of hearing aids to put a reliable electric valve-amplifying instrument into the size of a spectacle case, and are prepared to pay highly for it.

It is true that battery-makers in the U.S.A. are far more efficient at producing long-life batteries than they are over here and they would *seem* to produce, therefore, a *better* small instrument. But there is little in that. No one will hear long with a toy instrument and I hope the examination and analysis made in this volume will put an end to what is really the wrong outlook and demand better hearing for the deaf.

I have examined very many makes of instruments and I am of opinion that those made in Great Britain can stand comparison with any. Some of the small valve-instruments are very good indeed. But it is a poor and unworthy policy to exploit the deaf by untrue and exaggerated claims as, unfortunately, some do. The best way to prevent it is for the deaf, and their relatives, better to understand their own problems; to which understanding I hope this book will contribute.

THE END

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