For, in addition to shielding the delicate cochlea from the destructive action of loud noise, the meatal plug also protects the brain against the exhausting effects of an incessant series of excessive auditory stimuli, the wasting influence of which upon the reserve stores of nerve-energy may be suitably compared with the neurasthenia-producing effect of severe, persistent pain.

Physiologically speaking, of course, loud, unpleasant noise is equivalent to pain.

REPORTS FOR THE YEAR 1914 FROM THE EAR AND THROAT DEPARTMENT OF THE ROYAL INFIRMARY, EDINBURGH.

Under the care of A. Logan Turner, M.D., F.R.C.S.E., F.R.S.E.

PART I.

NOISE-DEAFNESS: A REVIEW OF RECENT EXPERIMENTAL WORK, AND A CLINICAL INVESTIGATION INTO THE EFFECT OF LOUD NOISE UPON THE LABYRINTH IN BOILER-MAKERS.

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The deafness induced in the workers in certain trades and callings by the prevalence of unusually loud noises has generally been designated "occupational deafness," but it has been very properly pointed out by Dan McKenzie that this term includes also such conditions of very diverse ætiology as Caisson-deafness and the deafness associated with lead-poisoning. I have, therefore, adhered to the more restricted term "noise-deafness."

Although the incidence of noise-deafness, as affecting blacksmiths, boiler-makers, railway and factory employés, engineers, and others has been long recognised both by the profession and by laymen, no systematic investigation of the subject seems to have been conducted until Dr. Thomas Barr in 1886 read before the Philosophical Society of Glasgow a paper entitled "An Inquiry into the Effects of Loud Sounds upon the Hearing of Boiler-makers and others who work amid noisy surroundings." Since that time, as far as I have been able to gather, no further contribution of any extent has been made in the English language. On the Continent, however, the subject has been widely canvassed in recent

years. Habermann, of Prague, had indeed in 1890 (1) published the clinical records of 30 cases without apparently arousing much interest in the subject, but when sixteen years later he contributed reports on a further 107 cases (2) with the pathological findings of the *post-mortem* examination of the inner ears of 5 cases, laboratory workers particularly saw that these results offered them an interesting field of study. In the following year, Wittmaack, of Jena (3), published his experimental work on guinea-pigs, and although his technique seems to have been faulty in some respects and some of his conclusions weakly supported by his arguments, to him must be accorded the honour of having been the first to elucidate the subject of noise-injuries by experimentation, and incidentally to point out that on some similar experimental basis must rest the ultimate proof or disproof of Helmholtz's theory of perception of sound. A year later, Yoshii, of Japan (4), working in Siebenmann's laboratory at Basle, set out to extend Wittmaack's experiments along certain lines and found occasion to revise some of the conclusions assumed by the latter. Von Eicken (5) and Hoessle (6) followed suit, and, besides adding a considerable amount of new material, confirmed on the whole Yoshii's views of the points in dispute.

Wittmaack's series of animals were divided into four groups:

(1) Six guinea-pigs were exposed to the continuous sound of an electric bell placed in the animals' wooden cage. After continued treatment the animals were killed at intervals varying from five to sixty days, when the petrous portion of the temporal bone was fixed by a method he describes in detail, and sections examined microscopically. No change was noticed in the physical condition of the animals during life and no pathological change of any kind was noted on microscopic examination.

(2) The next six animals were exposed to similar sounds conveyed this time by both bone-conduction and air-conduction, the cages being made of metal and the vibrations being conveyed to the metal floor. This time the animals showed rapid wasting, and whereas the intention had been to kill them at similar intervals to those of Group 1, only the earlier ones required such interference, as all were dead within sixteen days. The two last survivors were found sitting on the dead bodies of their companions, in a vain endeavour to escape the vibrations conveyed through the floor of the cage. On examination after fixing as before, no change was found in the middle ear, but in the inner ear was seen a commencing degeneration in the nerve cells of the cochlear ganglia and of the nerve fibres of the ramus cochlearis and a commencing decay of Corti's organ. No change was found in the vestibular nerve or its end-apparatus.

(3) Thinking that the absence of intermission of the vibrations might explain the severe constitutional signs, it was determined to approximate the next experiment to the conditions obtaining in actual occupations, and the noise was intermitted at night, the animals being exposed to the noise during the day-time only. It was now found that there was no loss of weight—indeed, most of them put on

weight, feeding well at night. Killed at intervals of 3 to 250 days afterwards they showed the same changes as described above (2).

(4) Experiments were next instituted with noises of short duration but intensive. Of these there were two sub-groups:

(*a*) Animals exposed to short intense noises oft-repeated. A shrill whistle was employed, a full blast being applied over a glass funnel at the animal's ear. As a rule the animal sank immediately unconscious, and remained so for some seconds, with complete relaxation of muscles and inhibition of sensation, but recovery was always speedy. This procedure was repeated daily or every second day, and the animals were killed from 3 to 30 days after the first exposure. On examination, no changes were found in the middle ear, not even rupture of the membrane. In the inner ear, no hæmorrhage or tears of the delicate membranes or any such gross changes were seen, but definite changes similar to those already described were found in the cochlear ganglia and nerves and in Corti's organ, varying in degree according to the date at which the animal had been killed. The degenerative process reached its highest degree in the lower part of the lowest turn of the cochlea, and in this region, in the case of the animals longest exposed, not even a spur of Corti's organ remained.

(*b*) In the second sub-group, the animals were killed at intervals of 1 to 60 days after a single exposure to the blast of the whistle. The same results as above were noted, but very much slighter in degree, and passing off gradually according to the length of time the animals were allowed to live after exposure.

We might summarise in the following manner the minute changes found by Wittmaack in Groups 2, 3 and 4:

(1) In the ganglion cells of the spiral lamina, disappearance of Nissl's granules, vacuole-formation, the presence of bodies like "asthma-crystals," changes in the nucleus, which had taken on an irregular contour and become homogeneous in structure. In the more severe cases the vacuoles were very large and the protoplasm shrunken.

(2) In the nerve-fibres in the spiral lamina very marked changes were also seen. Individual fibres had lost their regularly uniform calibre, showing alternate swelling and narrowing. Actual segmentation was seen in the more severe cases, and in most cases proliferation of interstitial cells had occurred.

(3) In Corti's organ the changes ranged, according to the severity of the pathological process, from slight swelling of the hair-cells and their supporting cells to such an extensive atrophy of the whole end-organ that nothing of it remained beyond the merest fringe of flattened epithelium. Cases of moderate severity showed vacuole-formation in the hair-cells and rod-cells; the latter had lost their upright position, and the tunnel-space was consequently contracted. Deiter's and Hensen's cells had lost their characteristic structure, and in their place was found a heap of cubical and cylindrical cells becoming gradually more and more flattened.

(4) Other changes within the scala media were not well noted by Wittmaack, but Yoshii, who agreed essentially as regards the observations just detailed, found the membrana tectoria in lighter cases occupying a more or less erect position, while in severe cases it was fibrillated or even torn, with its remains resting on the atrophied Corti's organ. Wittmaack described tearing of Reisner's membrane with glueing of the external portion to the stria vascularis. Yoshii declares that such an appearance could only be due to an artefact, and describes the pathological change seen in this structure as consisting of thickening and infiltration of its outer part. He found also similar cell infiltration in the stria vascularis and in the basilar membrane.

But the chief point on which Yoshii found it necessary to join issue with the earlier observer was the condition of the cochlea after exposure to sounds conveyed by air-conduction without the aid of bone-conduction. Wittmaack had discovered no change in such cases, but Yoshii with more careful methods was able to demonstrate all the above-mentioned changes after experiments on similar lines. This question, of course, as far as the relationship of the experimentation to occupational deafness is concerned, is the crux of the subject from the point of view of utility at least. If Wittmaack is right in holding that the injury does not reach the ear by the *via physiologica* (air-conduction), but only through the bone, the customary advice to people exposed to such dangers, to protect the ears by some form of obstruction in the meatus, is of no avail. Besides being able to demonstrate the presence of the lesions after exposure of the animals to purely air-conducted sounds, Yoshii proved his point in other ways. One of his animals had developed a middle-ear condition, and after being treated like the others it was found that the cochlea on that side had escaped the pathological process, which on the other side presented the usual marked appearances. Further, in the case of the last animal of his series, on which he experimented with detonations from a revolver, he describes the following result: "When the shot was fired (at a distance of 20 c.m.), the animal was greatly frightened, lost his liveliness, and became very slow in his movements. A few moments later it scarcely reacted at all to hand-clapping, but became more sprightly in five minutes. It showed, however, neither nystagmus nor disturbance of equilibrium. At the end of five minutes it was killed. On examination the right ear showed a large perforation in the lower part of the drumhead. The mucous membrane of the tympanic cavity was hyperæmic, especially in the

region of the promontory and at the tympanic ring. In the latter place there was also a small amount of free blood. Examination of the inner ear, however, revealed no change—Corti's organ was normal in every part. Tectorial membrane and Reisner's membrane showed no change: no bleeding or exudate was seen anywhere. Saccule, utricle, ampullæ, and canals were normal. On the left side, however, quite a different picture presented itself. Drumhead and middle ear were quite normal—no hæmorrhage or hyperæmia were seen. In the inner ear, however, a distinct degree of change was noticeable quite in consonance with the alterations already described. Corti's organ showed the boundaries of the hair cells and Deiter's cells somewhat obliterated, Hensen's cells flattened, and the pillar-cells pressed in. In this case it was apparent that the membrane on the right side having given way before the violence of the sound-waves, such a dissipation of the air pressure occurred as prevented the end-organs on that side from receiving such a shock as was conveyed to the cochlea of the other side by the intact conducting media. Yoshii, in my opinion, rightly claims this as supporting his contention that the injury is conveyed to the inner ear by the ordinary conducting media, but seems to be on less sure ground when he explains that with a ruptured membrana tympani the flaccid membrane of the round window receives the vibrations and transmits them through the cochlea canal in the reverse direction to the normal. He holds that this flaccidity of the membrane of the round window depreciates the energy of the vibration and prevents the over-excitation which would produce the pathological condition in the inner ear. This reverse current may, perhaps, be accepted as a fairly satisfactory explanation of the remarkable amount of hearing sometimes present with large perforations of the drumhead, and at the same time loss of one or more ossicles. It seems much more simple to explain the case in question, however, by supposing that the vibrations were still transmitted by the ordinary route through the oval window, but that the rupture of the membrana tympani impaired its function, and caused too much loss of energy for over-excitation to take place in such degree as is required for the production of pathological changes after a single exposure. Von Eicken followed with a series of animals in which the incus on one side had been removed, and in every case he found that on that side the inner ear had escaped injury, while the other showed the typical changes already described. Hoessli also more recently removed the incus with the same result, and also experimented with an animal, the subject of middle-ear disease on one

side, finding, as did Yoshii, that this side escaped injury to the cochlea. He further made experiments with animals insulated, as far as bone-conduction was concerned, by a matting of felt placed on the floor of the cage, as suggested by Wittmaack, and found that this had no effect in preventing the onset of the disease process. Habermann also includes in his five *post-mortem* reports on men who had been the subjects of occupational deafness one who had unilateral middle-ear disease. He found the inner ear intact on the side of the middle-ear lesion. It may thus be taken as conclusively established that it is by the way of the chain of ossicles and the oval window that the excessive impulses reach the inner ear in this form of deafness.

Another assumption by Wittmaack which, like the one first dealt with, probably did a good deal to arouse the interest taken in his work and also to stimulate the later experimenters, was that, contrary to what had hitherto been supposed, the degenerative change consisted primarily in an atrophy of the ganglia of the spiral lamina with secondary degeneration of the end-organ, instead of a primary atrophy of Corti's organ with an ascending degenerative change involving the nerve-fibres and ganglion cells. He supports his contention by very indifferent arguments, and even makes the fatal admission that in one of his animals killed immediately after exposure he detected changes in Corti's organ without being able to demonstrate any change in the corresponding nerve-fibres and ganglia. Yoshii's results led him to the opposite conclusion, and Habermann, whose *post-mortem* observations on the human subject had been published before Wittmaack's work appeared, had no doubt that the disease was primarily one of Corti's organ with ascending degeneration in the nerve, because, as he says:

"While Corti's organ was markedly involved, particularly as regards the sense cells, and while the nerve-fibres also showed marked degeneration, the ganglion cells only in some instances were affected, and in such cases only the distal cells were involved."

Yoshii also found himself at variance with Wittmaack as regards his assertion of the complete immunity of the vestibular apparatus. While his experiments with whistles and syrens, like those of Wittmaack with the electric bell, produced no change here, it was not so when the animals were exposed to repeated revolver shots. This observation was supported by clinical signs, as in one of the animals marked disturbance of equilibrium was noted.

"After the first shot in front of the right ear as usual nothing striking happened, but shortly after the second shot was fired close to the left ear, the animal drew

his head to the left and at the same time executed rhythmic pendulum movements to the same side in a horizontal direction. Both eyes were markedly deviated to the left and at the same time an undoubted nystagmus developed. The animal swung itself for a long time to the same side and several times fell down, apparently in consequence of an inco-ordination of the hind legs. The condition passed off in about an hour.

The minute examination revealed in addition to such cochlear changes as have been already described,

"blood corpuscles sparsely strewn in saccule and utricle; in the vestibular nerve varicose formation of fibres, but not so marked as in the cochlear nerve; the epithelium of the macula sacculi and macula utriculi and of the cristæ ampullares swollen; in the canals themselves nothing abnormal."

In concluding this *resumé* of recent experimental work on the Continent, I would refer briefly to Yoshii's further experiments with sounds of varying pitch for the purpose of testing, as suggested by Wittmaack, the accuracy of the Helmholtz theory of the perception of sound. With a whistle producing a note = C^5 (about 4096 double vibrations per second) he found the maximum amount of atrophy consistently located in the upper half of the basal coil of the cochlea; one producing a note = A^2 (about 838 double vibrations) gave changes in the middle and upper part of the second lowest coil; while one producing a note = G (about 192 double vibrations) gave rise to changes half a coil higher. It was found that, no matter how pure the note was, the pathological change had quite a measurable distribution, being most marked in the centre of the area involved and tapering off above and below. He accordingly assumes that Helmholtz's theory is essentially correct, although the parts of the sound-perceiving end-organ are not so definitely isolated in their action as the parts of the keyboard of a musical instrument.

Such a wealth of laboratory results having thus recently been placed at our disposal, there is room for further clinical investigation, to extend the observations of Barr and Habermann already referred to, and I now propose to submit some notes on the examination of forty-eight cases of occupation deafness. Of these, four were seen in Dr. Logan Turner's clinic, two being blacksmiths, one an engineer, and one a brass-finisher. The remaining forty-four were boiler-makers and rivetters, who were seen, not as patients, but for the purpose of the investigation. Care was taken to secure a proper proportion of the younger men, so that the condition might be studied in relation to the length of time the trade had been engaged in. The accompanying scheme of examination

was followed, but the caloric tests were naturally somewhat unpopular, and only fifteen submitted to them.

SCHEME.

Name. Occupation.
Age. Date.
Address.
History: How long at trade?
Is deafness present? Duration?
Noises in ears?
Paracusis Willisii?
Any previous ear trouble?
Any family history of deafness?
Objective examination: R. M. T. L. M. T.
R. nasal fossa. L. nasal fossa.
Lip-reading present?

Functional examination:	R.	L.
(1) Conversation voice.		
(2) Whispered voice.		
(3) Weber.		
(4) Schwabach.		
(5) Rinne.		
(6) Tuning fork 32 (duration).		
(7) „ 419 „		
(8) „ 512 „		
(9) „ 2048 „		
(10) Upper tone limit (monochord).		
(11) Cold caloric test.		

I introduced forks A^1 (419 double vibrations) and C^2 (512 double vibrations) into the scheme because, after repeated testing in the different parts of the boiler-shops and rivetting yards while the men were at work, and after having my observations confirmed by a person with a good musical ear and training, I found that the predominant sounds ranged between G^1 and C^2. Barr and Habermann both refer to the "shrill" noises to which these workmen are exposed, and others have followed their example, but probably the only subjects of occupation deafness who are exposed to shrill sounds are engine-drivers and other railway employés.

I shall deal later with the question of the marked deterioration in the hearing of sounds of high pitch as found in cases of long standing, but the explanation is, I think, not to be found in the predominance of noises of such high pitch in the workshop.

The method employed to determine the duration of hearing was to note the number of seconds during which the examinée heard the sound and then to transfer the fork to my own ear, recording his time as the numerator and mine as denominator. It

is true that there is a slight fallacy in such a course, as the examinée's ear receiving the earlier and louder part of the sound undergoes a certain amount of exhaustion to the particular note in question, but after going into the matter carefully with persons of normal hearing I arrived at the conclusion that the difference is so small as to have no appreciable effect on my statistics. To determine the upper tone limit I used the Schulze-Struycken monochord as being more accurate than the whistle. We are still in need of some extended observations to determine what should be looked upon as the average limit of hearing for high tones, but after examining twenty persons with normal hearing I am of the opinion that it does not exceed 17,000 to 18,000 double vibrations up to twenty-five years of age (although, of course, individual cases reach 20,000 or higher), while between forty and fifty years of age the average is probably as low as 14,000.

Of the ninety-six ears thus examined, otorrhœa was found to be present in four, one bilateral case, and two unilateral. These six cases gave lengthened Schwabach and negative Rinne. On another ear the radical mastoid operation had been performed, leaving lengthened Schwabach and negative Rinne, but no hearing for any tuning fork by air-conduction. One other ear with a dry perforation gave similar results to the Schwabach and Rinne tests, whereas other two with dry perforations, as well as three others with a history of otorrhœa of very short duration, gave shortened Schwabach and positive Rinne. I shall refer to these later, but have eliminated them all from the statistics following, which thus have reference only to inner-ear deafness, uncomplicated by any middle-ear condition, past or present.

I have divided the cases into three categories according to the length of time they had been employed.

I.—Of twenty men who had been less than ten years at work, eight declared at the outset of their examination that they were not deaf at all. In every case, however, depreciation of hearing was demonstrated, sometimes only for the medium tuning forks, but generally for all the forks, with more marked deterioration for the medium. In all cases, both in this group and in the others, the deafness was combined with shortened Schwabach and positive Rinne. In the whole of this group, raising the figures to percentages for the sake of easier comparison, I found that with

32 D.V. 4 per cent. equalled my own duration of hearing.
16 per cent. had $\frac{2}{3}$.
80 per cent. had less than $\frac{2}{3}$.

419 D.V. None equalled
44 per cent. had $\frac{2}{3}$.
56 per cent. had less than $\frac{2}{3}$.
512 D.V. None equalled.
41 per cent. had $\frac{2}{3}$.
59 per cent. had less than $\frac{2}{3}$.
2048 D.V. 10 per cent. equalled.
53 per cent. had $\frac{2}{3}$.
37 per cent. had less than $\frac{2}{3}$.

As regards the upper tone limit, 77 per cent. could hear 16,000 double vibrations, and only 3 per cent. came below 15,000. One ear could appreciate 20,000, although the hearing for the medium forks was reduced to $\frac{2}{3}$, while three could hear 19,000 with hearing for medium forks reduced to $\frac{3}{4}$.

II.—Of those from ten to thirty years at work (thirteen men):

For 32 D.V. None equalled examiner's duration.
62 per cent. had $\frac{2}{3}$.
38 per cent. had less than $\frac{2}{3}$.
„ 419 D.V. None equalled.
38 per cent. had $\frac{2}{3}$.
62 per cent. had less than $\frac{2}{3}$.
„ 512 D.V. None equalled.
13 per cent. had $\frac{2}{3}$.
87 per cent. had less than $\frac{2}{3}$.
„ 2048 D.V. None equalled.
14 per cent. had $\frac{2}{3}$.
86 per cent. had less than $\frac{2}{3}$.

Sixteen per cent. of these attained an upper tone limit of 16,000, while another 20 per cent. reached 14,000; 12 per cent. did not hear 2000, the remaining 52 per cent. hearing from 9000 to 11,000.

III.—Fifteen men had been over thirty years employed, but it should be stated that only two of these had reached the age of sixty, so that the incidence of any appreciable degree of senile deafness may be discounted.

For 32 D.V. None equalled.
18 per cent. had $\frac{2}{3}$.
82 per cent. had less than $\frac{2}{3}$.
„ 419 D.V. None equalled.
23 per cent. had $\frac{2}{3}$.
77 per cent. had less than $\frac{2}{3}$.
„ 512 D.V. None equalled.
25 per cent. had $\frac{2}{3}$.
75 per cent. had less than $\frac{2}{3}$.
„ 2048 D.V. None equalled.
12 per cent. had $\frac{2}{3}$.
88 per cent had less than $\frac{2}{3}$.

As regard the upper tone limit 9 per cent. of these heard 13,000, 30 per cent. could not hear 2000, while the remainder ranged between 9000 and 11,000.

From a consideration of these figures it is apparent that in the earlier stages, at least, the condition of noise-deafness does not affect principally the perception of high tones as has been hitherto generally accepted. In Group I we find the upper tone limit scarcely affected, although there is marked loss of hearing for tuning forks corresponding to the predominant noises. Doubtless the explanation of the marked loss of hearing for very low tones in these cases lies in the prevalence of the low rumbling noises of machinery. It is only when we come to Groups II and III that we find a clinical picture such as has hitherto been accepted as typical of the condition, with marked loss of hearing for high notes. Probably this is sufficiently explained by the fact that cases seen as patients are always more or less in an advanced stage, whereas out of the whole of Group I of my cases not one had sought advice for the condition, which had not proved a serious inconvenience.

It is apparent that the pathological condition involved is an exhaustion atrophy from over-excitation, affecting primarily the parts of the cochlear duct corresponding to the prevailing sounds, and doubtless a *post-mortem* examination on an early case would reveal such well-defined areas of change as were found after experiments on animals by the observers already referred to. Conversely it is more than probable that had these experiments been carried into years instead of days the pathological picture would have shown, as in Habermann's examination of the ear of an old boiler-maker, a preponderance of the atrophy in the lowest part of the cochlea. Habermann, while not avoiding the pitfall of assuming, as others have done, that the prevailing sounds are of high pitch, admits that this cannot explain fully the excessive involvement of that area, and suggests that there is probably a poorer blood-supply and consequently defective nourishment there, citing, in support of this hypothesis, the fact that in arterio-sclerosis and in the other forms of nerve-deafness this same area is first and particularly involved. On the other hand, it may be that the predilection of the disease for this area, alike in noise-deafness and in those other conditions, is to be simply explained by the well-established law of pathology that the most delicate and highly-developed part of any organ is always the most vulnerable.

In railwaymen, however, exposed to the shrill notes of the

engine whistle, Putelli, of Venice (7), has found direct injury to that part of the cochlea concerned in the perception of high notes. His results are in all respects in accord with the foregoing deductions. In every case he found Schwabach shortened and Rinne positive. Hearing for low and medium tones was normal, while there was marked depreciation for tuning forks C_4 and C_5.

With regard to *subjective noises*, 56 per cent. gave a history of this symptom. Barr found this in 34 per cent. of his cases, and I agree with him that it is in the early days of their occupation that men suffer from it. Most of the apprentices said they had noises after leaving their work at night, and many of the older men, who at first replied in the negative to the question, admitted, when more closely questioned, that in their earlier years they had suffered from such noises. These were most frequently of the nature of a ringing of bells; sometimes of buzzing, humming, hammering, whistling, or blowing.

Vestibular Apparatus: Giddiness.—I obtained a history of this in 10 per cent. of cases. Barr found it in 14 per cent., and Habermann in 16 per cent. Neither of these observers attributed much importance to the phenomenon as an integral part of the symptom-complex, but in the light of the most recent work on the vestibular function there is some reason for our looking upon this symptom as an indication of slight concomitant disturbance of the vestibular apparatus. Yoshii, as already stated, found that one of his animals gave marked signs of disturbance of equilibrium during his detonation experiments, and examination of one ear after death showed, in addition to the usual cochlear changes, similar though slight changes in the vestibular apparatus. Such vestibular changes were not found in any of the other experiments, no matter how loud the sound, nor how high or low its pitch, detonation being evidently the determining element. Now, when we consider how much the sounds of hammering on metal partake of the character of a repeated detonation, we cannot express surprise if we find among many of these workmen signs of an affection of the vestibule, and, as has been already mentioned, Habermann, although noting no clinical manifestations of such a condition, actually found, *post mortem* in the victims of noise-deafness, increased pigmentation in the ampullæ and hyperplasia of the conical ridges. On applying the cold caloric test to both ears of fifteen cases, I obtained an average induction period of 45 seconds for the nystagmus (33 seconds in Group I, 44 seconds in Group II, and 50 seconds in Group III). As the average in normal ears does not exceed 25 or

30 seconds, it will be seen that even in the early cases there is slightly diminished sensibility of the vestibular apparatus, while in the established cases this is quite marked.

Dan McKenzie (8) also, in the paper in which he first brought to the notice of otologists the use of the induction period, states that in the series of cases examined for the purpose of his article he included a number of cases of noise-deafness, and found the reaction delayed. It therefore seems justifiable to assume, from the history of giddiness on the one hand, and the obtaining of a delayed caloric reaction on the other, that, contrary to the hitherto accepted belief, the vestibular apparatus does not entirely escape, in the form of deafness under consideration.

To return to the eleven ears excluded on account of middle-ear disease, past or present, these do not at first sight seem to give unqualified support to the contention that the presence of such disease obviates the onset of the inner-ear condition, inasmuch as five of them gave shortened Schwabach and positive Rinne. It will be noted, however, that of these five three presented a history of otorrhœa of very short duration (two were accounted for by a case of bilateral otorrhœa lasting for a very short time after acute pneumonia, and the third had discharge on two occasions lasting only two weeks), while the remaining two had dry perforations. Now, middle-ear disease could obviously only act as a protection to the inner ear against the effect of injurious noises in proportion to the amount of interference it caused to the sound-conducting apparatus, and it is well known that otorrhœa of very short duration may leave the hearing practically unaffected. Hence, we might assume that the middle-ear condition in these cases had been too slight or too short-lived to produce marked permanent interference with sound conduction.

To deal lastly with the question of prophylaxis, Wittmaack's advocacy of a rubber mat does not merit consideration, founded, as it was, on the assumption that the injury reached the inner ear by bone-conduction, and directly disproved, as it has been, by Hoessli's experiments with it. All hope of any prevention or mitigation of the condition must be based on some means of occluding the external auditory meatus, and so obstructing in some measure the injurious waves of sound. Different materials have been recommended—plugs of rubber, celluloid, or cotton-wool, the last named made up with jeweller's wax or simply smeared with vaseline, but the great difficulty is to get the workmen to take the trouble to use them regularly. It is customary for them to insert

"cotton-waste" in their ears when engaged at "caulking" or "holding on," at which work they are standing or sitting inside a boiler, with several men hammering on the outside, but otherwise they, as a rule, take no precautions, the opinion being apparently a fixed one among them that nothing will prevent the deafness. In recent years it has been made one of the duties of gunners in the British Navy to see that their crews are supplied with cotton-wool for their ears during gun practice, and I had recently an opportunity of noting the beneficial effect in the case of a gunner of ten years' standing. In this case the left ear had normal hearing while the right ear (which is nearer to the gun) showed a depreciation of only $\frac{1}{4}$ for tuning forks up to 2048 double vibrations, while the upper tone limit was 16,000 in each ear.

If civil employers could be induced to make similar provision for their workmen and to make it incumbent on their foremen to see that the preventive measures were regularly made use of, there is every reason to expect that extreme cases of noise-deafness would rarely be met with.

The following conclusions seem to be justified :

(1) That loss of hearing for high notes is not, as hitherto taught, the outstanding feature of noise-deafness.

(2) That the predominant noises to which the patient has been exposed determine the site of the initial lesion in the inner ear, and that for a considerable time the depreciation of hearing is mainly for sounds of a pitch corresponding to these noises.

(3) That later, the unusual vulnerability of the lowest part of the cochlear canal gives rise to marked loss of hearing for high tones.

(4) That the vestibular apparatus in such occupations as boiler-making, where loud hammering is being carried on, is also affected, although in less degree than the cochlear apparatus.

(5) That the condition of noise-deafness could be to a very large extent obviated by the use of suitable ear-plugs.

I wish, in concluding, to express my indebtedness to Drs. A. Logan Turner and J. S. Fraser for helpful suggestions and facilities given me, also to the managers of Leith Hospital for accommodation for the examination of patients, and the firm of Messrs. Hawthorn and Morton, shipbuilders, Leith, for access to their works and employés.

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(4) YOSHII.—*Zeit. f. Ohrenheilk.*, Bd. 58, 1909.
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(6) HOESSLI.—*Monats. f. Ohrenheilk.*, Year 47, No. 7.
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SOME CONSIDERATIONS WHICH DETERMINE THE EXTENT OF AN OPERATION IN SEPTIC INVASION OF THE LATERAL SINUS.[1]

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I DO not commence an operation with the fixed idea that the venous channel must be obliterated, its lumen exposed, and, as far as possible, its walls excised from the torcular Herophili to the junction of the jugular vein with the innominate; nor, on the other hand, do I say to myself, "all that is necessary is to plug the sinus for an inch or two after removing the clot." The conditions found are so varied that the maximum operation may in one case be as futile as the minimum, in another the minor as successful as would have been the major, while in a third the maximum operation would appear to give the best, if not the only, chance of recovery. For this reason also it seems to me that collected statistics are particularly baffling and of little value as a general guide to the extent of the operation required in an individual case. My own experience, contrary, I fear, to the expectation of the gentlemen who have honoured me by asking me to read a paper on this subject, is comparatively small,[2] but, if small, it has been fairly varied, therefore I do not propose to analyse figures, but to give my thoughts and conclusions as to the best methods of dealing with such conditions as it has been my fortune to recognise. I have also, in answer to set questions, obtained from twenty-five British otologists, practising outside London, expressions of opinion based on their own experience on varied points of interest. These answers have been tabulated and analysed. I propose to give you the result of this analysis and to print with my paper, if the editors permit, the actual replies or the substance of the replies received. Many of these replies are of great interest, and I take this opportunity of

[1] Read at the Clinical Congress of Surgeons, London, July, 1914.
[2] About 30 cases.