possible coincident cerebellar disease; and also to help in deciding to which side certain intra-cranial symptoms are due in cases of bilateral affections of the internal ear.

By "normal" reaction is meant, in this paper, those results which these tests are supposed to afford physiologically; namely, under the influence of an "excitant" affecting either labyrinth a "jerky" nystagmus is produced, composed of a quick movement of the eyes towards the same side, and a slow return in the opposite direction, whilst "depressants" produce a similar nystagmus, but "directed" to the opposite side.

The "excitants" include the application of hot water, the cathode of a galvanic battery, and rotation of the body and head in the opposite direction to the side tested.

The "depressants" are cold water, the application of the anode of a galvanic battery, and rotation in the same direction as the side in question.

AN EXAMINATION INTO THE CONDITION OF THE VESTIBULAR APPARATUS IN A SERIES OF CASES OF DEAFNESS OF NON-SUPPURATIVE ORIGIN.

By NORMAN H. PIKE, M.B., B.S.LOND.

Now that we have at our disposal definite clinical methods for examining the functions of the vestibular apparatus as distinct from the cochlear, this investigation has been undertaken with the object of inquiring into the condition of the vestibular apparatus in cases of deafness in which there has been no middle-ear suppuration.

I have been especially fortunate in having received instruction in this subject from Dr. Bárány, and I must take this opportunity to thank him for all his kindness and help.

My thanks are also due to Professor Urbantschitsch for allowing me to work in his clinic in Vienna and for the use of very valuable material. The explanation of the actions resulting from the clinical methods employed are those given in Bárány's book "Physiologie und Pathologie des Bogengang Apparates," and to him is due the credit of having made clear much that before was dark in this subject.

By the vestibular apparatus is meant the membranous parts of the semi-circular canals with the utricle and saccule and the contained endolymph.

I shall not go into the anatomy of these parts, but the following simple means employed by Bárány will quickly give the relative positions of the three semi-circular canals when the head is upright.

Lay the arms against the sides of your body, and then, bending the elbows at right angles palms upwards, bring the hands so that they meet in the middle line, the middle fingers touching and enclosing an angle of 90° . Now, if you wish to represent the canals of the right side you must leave the right hand in its position, and, bending the fingers of the left hand at right angles to the palm, place the hand thus bent on the right hand, so that the ulnar borders of the palms will lie together and the little finger of the left lays at right angles to the joints of the right hand.

Now, in this position the palm of the right hand will represent the plane of the right horizontal canal, the fingers of the left hand the plane of the anterior vertical canal, and the palm of the left hand the plane of the posterior vertical canal of the right side. The convexity of the three canals is turned towards the free borders of the hands, *i. e.* the horizontal outwards, the anterior vertical upwards, and the posterior vertical upwards and backwards. From this scheme it is clear also that neither the anterior or posterior vertical canals lie in the sagittal plane, the anterior enclosing an angle of 45° open anteriorly with the sagittal plane, the posterior a similar angle opening posteriorly. Also if you compare the relations of the positions of the canals of the right and left side you will at once notice the right anterior vertical and left posterior vertical canals lay in the same plane, while at right angles to them lie the left anterior vertical and right posterior vertical canals.

The ampullæ of the horizontal and anterior vertical canals will lie at the base of the first finger of the right hand. The ampulla of the posterior vertical canal will lie at the base of the metacarpal bone of the little finger of the left hand. It is obvious that the planes of the canals alter with each movement of the head; for instance, if the head is bent forward 90° the horizontal canals become vertical and so on.

The ampullæ contain the special nerve-endings of the vestibular portion of the eighth nerve with their special hair-cells and cupula. The cupula is a homogeneous mass and moves with each movement of the endolymph, and so draws the hair-cells and stimulates the nerve.

Whenever the cupula is moved reflex vestibular nystagmus is produced, provided the rest of the reflex path is intact.

Ewald, of Strassburg, showed this in 1892 by an experiment he did on the right horizontal canal of a pigeon. An opening was made in the bony canal some way from the ampulla, and in this a small piece of lead was pushed, thus completely blocking the canal. Another opening was bored between this point and the ampulla, to which the nozzle of a syringe was fixed by which compression or suction could be made. By compression the cupula would be pushed away from the canal, and in this case Ewald constantly found a slow horizontal movement of the head and eyes to the left. By suction, through the cupula being moved in the opposite direction there was a slow horizontal movement of head and eyes to the right.

When there is a slow horizontal movement of the eyes to the left there is a quick return to the right, and we speak of this as horizontal nystagmus to the right. So in the case of compression Ewald obtained horizontal nystagmus to the right when experimenting on the right horizontal canal.

It is mainly by observing the nystagmus after employing certain clinical methods that we judge of the condition of the vestibular apparatus.

There are two forms of nystagmus to be distinguished :

(1) In this form there is a quick undulating movement of the eyes, both movements following equally quickly and so one cannot distinguish a direction of the movement.

(2) In which there is a slow movement with a quick return. To this class nystagmus of vestibular origin always belongs.

Vestibular nystagmus has another peculiarity, it becomes most distinct when one looks in the direction of the quick movements, but becomes weakened or altogether stops when one looks in the opposite direction.

Nystagmus, Form (1), does not alter in this way. We always speak of the direction of the quick movement as the direction of the nystagmus, therefore horizontal nystagmus to the left is a nystagmus which strikes towards the left side of the patient and which becomes stronger on the patient's looking towards the left, weaker or stopped altogether if the patient looks to the right.

It is convenient to write the various forms of nystagmus as follows :

—→ *r* meaning horizontal nystagmus to the right on looking
to the right.
l ↺ meaning rotatory nystagmus to the left on looking
to the left.

The clinical methods employed have been :

(1) The turning reaction, *i. e.* an observation of the nystagmus produced after turning the patient and counting the duration of the same.

(2) The caloric reaction, *i. e.* the observation of the nystagmus produced by syringing the affected ear with cool water.

(1) *The Turning Reaction.*—This is elicited in the following manner : The patient is placed in a revolving chair to the back of which a vertical bar is fixed in order to facilitate turning. He sits with the head in the upright position and the eyes are covered with opaque spectacles. He is then turned ten times to the right, *i. e.* in the direction of the hands of a clock, and the duration of the nystagmus produced to the left, with the patient looking steadily into the opaque spectacles, is counted by means of a stop watch. He is then turned to the left in the same manner. The turning should always be done at a uniform rate and the stopping should be done suddenly.

The result is written as follows : $10 \times R = 25''$, meaning that turning to the right 10 times produced nystagmus to the left lasting 25 seconds.

The explanation of why turning ten times to the right should produce nystagmus to the left is as follows. If one turns a patient with the head in the upright position ten times to the right, at the beginning of the movement there will be a displacement of the endolymph in the right horizontal canal from the canal towards the ampulla (remember the ampulla lies at the anterior end of the horizontal canal), just the same as if you are standing on a tram which suddenly starts you tend to fall backwards, so at the beginning of turning the endolymph in the canal remains stationary for a moment, and does not at first participate in the turning movement. At the beginning, then, of turning to the right there will be a movement of the endolymph in the right horizontal canal from the smooth end towards the ampulla moving the cupula, and producing, as proved by Ewald's experiments, nystagmus of the eyes to the right. When we consider the smallness of the membranous canal and the greatness of the friction it is evident that this movement is only very slight.

The amount of this movement depends on the quickness of the beginning of the turning, and it is only possible to observe it with the aid of a revolving platform, on which the examiner also sits, as has been done recently by Bárány.

After the turning movement has been in progress a few

seconds the endolymph will move with the bony canals just as if it was frozen in, and only on suddenly stopping will there again be an independent movement of the endolymph. This movement will be in the opposite direction to that produced at the beginning of the turning. Whether this movement is greater or more continuous than that produced at the beginning of turning depends entirely on the suddenness of the stopping as compared with the beginning of the turning (just as in the example of the train, when the train suddenly stops you tend to fall forward). We see, then, that on suddenly stopping after turning ten times to the right there will be a movement of the endolymph in the left horizontal canal from the smooth end to the ampulla, moving the cupula and producing nystagmus to the left. At the same time in the right horizontal canal the endolymph will move from the ampulla to the smooth end of the canal. Both will act together in producing the nystagmus to the left, only the left takes the greater part (two thirds) of it, the right taking one third. Clinically, then, if we wish to examine into the irritability of the right vestibular apparatus we turn to the left and observe the nystagmus produced on suddenly stopping, and to examine the left vestibular apparatus we turn to the right.

On turning with the head in the upright position the disturbance of the endolymph will be chiefly in the horizontal canal. The magnitude of the disturbance of the endolymph diminishes with the size of the angle the canal makes with the horizontal plane. If the canal lies entirely in horizontal plane this disturbance will reach its maximum. If it is at right angles to the horizontal there will be practically no disturbance of the endolymph.

With the head, then, in the upright position and turning in the horizontal plane it is the horizontal canal which is affected, the anterior and posterior vertical canals being unaffected.

By bending the head 90° either forward, backward, or to the side the vertical canals will become in the horizontal plane and will be affected on turning.

It is a law that each canal produces an eye movement in its own plane. Practically several canals are called simultaneously into action, and we have either a rotatory or a horizontal eye movement.

The figure represents a scheme for horizontal nystagmus to the left from stimulation of the left labyrinth. The scheme shows the path of the slow and quick component of the nystagmus and why,

on stimulating the left Deiter's nucleus, you get the slow movement to the right and the quick movement to the left.

If you had a lesion at A, you will have all voluntary movements of the eye abolished, and by stimulating the left labyrinth (by turning) you will only have the slow component of the nystagmus, and so the eyes will be turned to the right and fixed there, *i. e.* away from the diseased side. If you had a lesion of the cortex, or anywhere between the cortex and A, you will have on turning both components of the nystagmus, but voluntary movements abolished. This scheme also shows why on looking away from the direction of

A. Supra-nuclear centre situated in the pons and associated eye movements. (From Bárány's "Physiologie des Bogengang-Apparates.")

the nystagmus, *i. e.* to the right, the nystagmus will be inhibited, as in this case the stimulation from the cortex will act in conjunction with the slow movement, whereas on looking in the direction of the nystagmus, *i. e.* to the left, the stimulation from the cortex will be antagonistic to the slow movement.

The effect of complete sudden removal of one labyrinth, say by operation, is to cause strong nystagmus to the opposite side. This after a time, generally in a few weeks, will lessen until it may entirely disappear.

In the cases of a central lesion, say a tumour or abscess in the

posterior fossa pressing on Deiter's nucleus, the nystagmus will be strong but does not weaken after a time. I do not place so much reliance on the turning reaction as on the caloric reaction. But in some cases, where for special reasons the caloric reaction could not be taken, sole reliance has been placed on the turning method. One infers that the vestibular irritability is normal when the nystagmus produced by turning to right and left has a duration of twenty-five seconds or over, *vide* Case 31. Here there was practically the same duration of the nystagmus after turning to the sound as to the affected side. The time since the accident was two years, and accommodation of the centre has taken place.

(2) *The Caloric Reaction.*—This can be produced with either hot or cold water. In all the cases in my tables it has been done with cold water producing nystagmus to the opposite side from the ear syringed. An attic cannula has been passed into the meatus, and this has been connected by means of a rubber tube with an ordinary air-inflation rubber Politzer balloon in which the cold water has been placed. The balloons hold approximately $\frac{3}{4}$ litre. The temperature of the water has been between 15–20°1. In most cases $\frac{1}{8}$ to $\frac{1}{4}$ of a balloon will produce a reaction. The strength of the reaction has been noted, and where you get—say with $\frac{1}{4}$ balloon of cold water—strong nystagmus in all directions of looking, *i.e.* on syringing the right ear nystagmus to the left on looking to the right, this has been noted as a strong reaction. In other cases where $\frac{1}{4}$ balloon has produced definite movements on looking in the direction of the nystagmus and also on looking straight forward, this has been called a normal reaction. A weak reaction has been where with a full balloon slight nystagmus has only been produced on extreme ocular abduction in the direction of the nystagmus. It has been found that it is not necessary to go beyond one balloon of water; if this does not produce a reaction no further amount of syringing will produce one.

In the tables, then, $\frac{1}{4}$ balloon, R. normal, will mean that by syringing in the right ear with $\frac{1}{4}$ balloon of cold water, nystagmus to the left is produced of a normal strength. To explain this reaction we must consider that the labyrinth is filled with a fluid at the body temperature. The cold water acting through the bony wall will cool this fluid and a current will be produced, as the fluid cooled will sink to the bottom and hence the cupula will be moved. In the upright position of the head this will chiefly affect the anterior vertical canal, but it is obvious that in different positions of the head the different canals will be affected, and that by using

hot water an exactly opposite effect will be produced. This reaction can also be produced by cold air or ether vapour. One can be quite certain that where no reaction is produced there is no irritability of the vestibular apparatus of the ear syringed.

Where an erosion of the bony wall has produced a fistula into the labyrinth and the labyrinth is still irritable, you can produce nystagmus by increasing the pressure in the tympanic cavity by means of an air balloon connected with the ear by means of an olive and a rubber tube. This increased pressure will cause a movement of the cupula in just the same way as that produced by Ewald's experiments.

It is best to make the patient gaze steadily at you, and then on pressing the balloon the nystagmus will be observed; the direction is not constant but it is most often towards the ill side.

This reaction, the so-called "fistula reaction," is of great practical value in diagnosing a fistula into the labyrinth.

In all cases, before doing the turning or caloric reaction, careful observation has been made of any spontaneous nystagmus produced by simply looking to the extreme right or left. Any error from this in the case of the turning reaction is obviated by using the opaque spectacles into which the patient looks.

Any subjective symptoms such as vertigo, nausea or vomiting must be noted. These vary with the individual. The rule is that objects will move in the direction of the nystagmus and patients will tend to fall in the contrary direction. The quick movement of the nystagmus causes no optical impression, it is only the slow movement. If one lays the first finger on the side of the eye and moves the globe laterally, it will be seen that objects looked at apparently move in the opposite direction to the movement of the globe. Hence objects apparently move in the opposite direction to the slow movement of the nystagmus, *i e.* in the direction of the quick movement.

In those cases in which one or both vestibular apparatuses were not functioning it was found that there was no disturbance of equilibrium, and that the patients could perform all Romberg's tests normally. Indeed, the semi-circular canals seem to have in man a very slight influence, if any at all, on the equilibrium in the normal state. It is probably different in animals.

Bárány has shown that the counter rolling movements of the eyes which occur when you bend your head to the side are probably partly dependent on the vestibular apparatus. By means of a very ingenious apparatus he has measured this movement and has shown that there is very little in the case of a deaf-mute with

destruction of the labyrinth, whereas in patients with vertiginous attacks there is a very marked movement.

Patients have also been tested in the usual way for conversation and whispered voice, also for Weber, Rinne and bone-conduction. For low tones C_1 and for high tones C_4 has been used.

The cases are all of a high degree of deafness in one or both ears, and in the cases of unilateral deafness, to demonstrate whether there was any perception of hearing by the bad ear, I have made use of an apparatus devised by Bárány. This consists of a hollow metalcone through which a stream of water is conducted by one fine tube and led off by another; by means of a third tube air is blown into the cone by a rubber balloon. The cone is covered by fine rubber to prevent the patient's ear getting wet, and is inserted into the patient's sound ear. By means of this instrument a very great noise is produced in the patient's ear, and with two of these, one in either ear, no sound at all can be heard. If, then, the patient hears with one of these in the good ear it is certain that he is hearing with the affected ear. This examination has been mentioned under the "Remarks" column under the term "Air and water syringing."

This instrument has been improved lately, the noise being made by clock-work enclosed in a small box. This is made by F. Reiner and Co., Vienna.

The galvanic reaction, not being of such practical importance, has not been taken, but this and a more complete description of the other methods can be found in Bárány's "Physiologie und Pathologie des Bogengang Apparates," Leipzig und Wien. Franz Deuticke, 1907.

To consider first generally the result of the examination of the seventy-four cases in the tables, we find the following figures with regard to the condition of the irritability of the vestibular apparatus:

Normal irritability or +.	Diminished irritability.		Very much diminished.		No irritability or -.	
	One side.	Both sides.	One side.	Both sides.	One side.	Both sides.
39 cases, or 52.7 per cent.	2 cases, or 2.7 per cent.	1 case, or 1.3 per cent.	5 cases, or 6.7 per cent.	2 cases, or 2.7 per cent.	21 cases, or 28.3 per cent.	4 cases, or 5.4 per cent.

39 cases, or 52.7 per cent.

35 cases, or 47.3 per cent. impaired or not functioning.

This is undoubtedly a high percentage of cases with an impaired or not functioning vestibular apparatus, but in explanation of this I must state that of the 74 cases 36 have been very kindly supplied to me by Dr. Bárány from his private notes on cases extending over the last three years. These comprise most of the cases of tumour and trauma, and are marked B in the tables. The other 38 cases have been examined by myself during the past three months as they attended the clinic, and from these 38 I find that in 24, or 63·2 per cent., the vestibular apparatus was normal; in 14, or 36·8 per cent, the vestibular apparatus was impaired or not functioning. Even then 36·8 per cent. is probably a higher percentage than is generally supposed.

The cases, as far as possible, have been classified according to their ætiology, and we will now consider the groups more in detail.

I. (Cases 1 and 2.) Congenital deformity of the external ear. In both the vestibule was + (+ meaning here irritable to the caloric or turning reaction.)

In Case 1 a probe could be passed for about one and a half inches, and by employing one and a half balloons of cold water I was enabled to obtain a weak but definite caloric reaction.

Case 2 was operated on, and during the operation the prominence of the external semi-circular canal could be seen. Later the caloric reaction was tried and was found to be normal.

II. (Cases 3-5.) Occupation deafness.

Case 3 had been deaf eighteen years and the irritability of the vestibule on the deaf side was diminished.

Case 5 was combined with trauma, and in this case also the irritability of the vestibule was diminished on the one side.

III. (Case 6.) ? Smallpox. The vestibular apparatus was +.

IV. (Case 7.) ? Diphtheria. The irritability of the right vestibule was greater than of the left.

V. (Case 8.) ? Influenza and ? otitis externa. This case had very severe vertigo attacks with nystagmus to the ill side. A week after the onset he became perfectly deaf in the left ear, but still the irritability of the left vestibular apparatus remained normal.

VI. (Two cases, 9 and 60.) In which a rheumatic affection of the vestibular nerve was probable.

In Case 9 there was facial paralysis which healed within three weeks. The vestibular irritability was normal.

In Case 60 after a fortnight's observation the hearing was very much improved, although the attacks of vertigo were still strong.

VII. (Fifteen cases, 10-24.) Oto-sclerosis.

The diagnosis of pure oto-sclerosis has been made in cases with normal drums, free Eustachian tubes, negative Rinne and lengthened bone-conduction. A diagnosis of oto-sclerosis combined with lesion of the internal ear, where, with normal drums, free Eustachian tubes and negative Rinne, the bone-conduction has been normal or shortened.

In the first group there are six cases, in the second nine. Case 24 showed a very much diminished irritability of the left vestibule, but in this case there was shortened bone-conduction and the possibility of syphilis could not be excluded. In Case 20 also there was impaired irritability of the right vestibule.

In the remaining thirteen cases the irritability of the vestibule was +, and, indeed, it was noticeable that with the caloric reaction a strong nystagmus was very quickly produced, and was usually accompanied by strong vertigo, nausea or even vomiting. Seven cases (10, 14, 19, 20, 21, 22, 24) suffered from attacks of vertigo.

VIII. (Ten cases, 25-33 and 70.) Trauma.

In four cases the vestibule irritability was +.

In two cases very much diminished on one side; in two cases was - on the one side and impaired on the other; in one case was - on the one side and normal on the other. Case 31 has been commented on previously.

IX. (Ten cases, 34-43.) Brain tumour.

In all these without exception there was negative irritability of the vestibule on the diseased side. The spontaneous nystagmus is interesting in these cases. In six it was stronger to the side of the tumour, in one it was stronger to the opposite side, and in three it was equal both sides. All suffered from attacks of vertigo.

X. (Three cases, 44-46.) Arterio-sclerosis. In two cases the vestibular reaction was normal, in one case it was negative on the one side. All the cases suffered from attacks of vertigo.

XI. (Five cases, 47-51.) Acquired syphilis.

In three of these cases the vestibular irritability was normal. In Case 47 one year ago with conversation voice heard at 6 metres there was practically no vestibular irritation. Now the irritability to caloric irritation is returning and more nearly approaches the normal.

In Case 49 with negative irritability on the one side there was luetic meningitis of the base.

XII. (Seven cases, 52-58.) Congenital syphilis. In all these

cases, without exception, there was diminution or absence of the vestibular irritability. In three cases there was negative irritability on both sides; in one case (58) there was negative irritability on the one side and very much diminished on the other. In two cases there was much diminished irritability on both sides. In one case there was negative irritability on the one side and probably normal on the other, but this case (54) was complicated by strong ocular nystagmus which made the examination difficult. In none of the cases was there any discomfort or vertigo produced by the syringing with cold water, nor was there any disturbance of equilibrium. The results in these cases of congenital syphilis is important and interesting. That there was such a constant obliteration of the labyrinth was up till now not known.

XIII. (One case, 61.) The diagnosis of chronic adhesive process with lesion of the internal ear was made. In this case the vestibular irritability was +.

XIV. (Fourteen cases, 61-69, 71-75.) Cases with the character of a lesion of the internal ear without discoverable cause. Of these cases :

9	had the vestibular irritability normal.
3	„ „ „ negative on one side.
1	„ „ „ negative both sides.

ANTRAL DISEASE IN RELATION TO SPECIAL AND GENERAL SURGERY.¹

BY HERBERT TILLEY, M.D.LOND., F.R.C.S.ENG.,
Surgeon, Ear and Throat Department, University College Hospital.

THE diseases of the maxillary antrum appeal to the general as well as the special surgeon, and the latter comprise the rhinologist or surgeon with special knowledge of nasal diseases, and the dental surgeon whose studies have been focussed on pathological conditions of the teeth. Speaking generally, it may be said that the general surgeon will be more familiar with those diseases which cause obvious external swelling or deformity of the upper jaw or of the adjacent soft parts, and so he will be consulted for large alveolar abscesses, dental cysts, malignant disease of the antrum, and necrosis of the upper jaw. Since these affections are

¹ Read in the Section of Dental Surgery of the British Medical Association, by kind permission of the Editors.