to have a good number of each of the sizes of the broken circles printed on the card, the break in the successive members of the same line being put at different angles; either that or to make each of the broken circles to rotate so that the angle at which the break occurs may be varied. I beg respectfully to suggest that the Board of Trade be urged to adopt the principle of Landolt's types and to scrap those in ordinary letters because of the irregularity in each line of the latter.

The investigation of the light sense is a matter which I fear is too much neglected. I think its proper examination would often be most helpful to physicians and to neurologists. Probably it is the first function of the optic nerve to become affected in impending diseases of that structure. I am also of opinion that its examination would frequently reveal such diseases as sclerosis and locomotor ataxy in the early stages; but, so far as I am aware at the moment, it is almost entirely neglected in clinical work in medical wards. In a previous part of this communication I have distinguished between what I call macular vision and field vision, and I think it might be of great utility if apparatus were devised to enable the light sense of both macular vision and field vision to be thoroughly investigated separately. At present there seems to be little hope of any such thing being done in the United Kingdom. I am not aware of there being anywhere a thoroughly equipped laboratory for the ophthalmic investigation of disease.

The examination of the light sense should be considered under two headings: first, the examination of the minimum light sense; secondly, the examination of the light difference sense; for both of these functions are important as regards the eyesight of seamen. Recently, considerable light has been thrown on this subject by Mr. Percival of Newcastle-on-Tyne, and he has invented apparatus which is probably the best for testing these important functions. Many years ago I devoted some attention to the testing of the light sense. For the testing of the minimum light sense I used what was to all intents and purposes a Foerster's light sense box, and for testing the light difference sense I used a spot of light seen double through a rhomb of Iceland spar. The double spot was examined by means of a Nicol's prism, which was arranged to rotate about its long axis, the amount of rotation being indicated in ordinary degrees on a scale. The difficulty of course was to determine the zero with such an apparatus—in other words, the place at which both spots appeared equally bright. This was done by adjusting the apparatus so that they seemed to have the same luminosity; the Nicol's prism was then turned in one direction till the spots appeared to differ very slightly in luminosity, and the point at which that occurred was carefully noted on the scale; the prism was then turned in the opposite direction till again a difference was observed, and the spot at which this occurred was also noted; the point on the scale midway between these two positions was taken to be the zero.

I have no hesitation, however, in saying that Mr. Percival's test is a very admirable one. It is much more easily arranged than the somewhat complicated one I have described, and I think ought to be used by the Board of Trade in the testing of seamen's eyesight. The value of such an examination is perhaps best illustrated by the following incident which occurred in my own experience. Once coming in from the Western Ocean, making for the Clyde, several officers of a steamboat were busy trying on a misty day to see one of the islands lying off the west coast of Ireland. Some of them were quite certain that they had seen it, others altogether failed to see it; that I think was probably due to the light difference sense of the officers who failed to see it being defective. On dark nights in narrow waters where the shore lighting is defective the light difference sense is of the first importance. A person with defective light difference sense on such a night is likely to have great difficulty in determining where the water ends and the land begins. So also it is to be observed that such impediments to safe navigation as icebergs and waterlogged derelicts do not carry lights; a man with a defective light sense will not see these dangers as easily as a man with good light sense. I cannot but regard the matter as being one of extreme importance.

Visual acuteness in the strict sense of the term is of importance in navigation. Thus an officer will not be able to read charts or tide tables or the various instruments used in navigation unless he has good macular vision, nor will the ordinary steersman be able to read a compass card unless he also has good macular vision. It is therefore of great

importance in these respects. The picking up of objects at a distance, such as other vessels or buoys or a land fall, is not necessarily a function of macular vision at all, but is chiefly a function of field vision, and very especially of the light difference sense. The images of most objects seen at sea are not, of course, primarily formed on the macula but on some peripheral point of the retina—in other words, the appeal first comes to the field vision and not to the macular. No doubt in a very large proportion of cases, when a new object appears on the horizon line, and by the field vision the officer becomes aware that it is there, he instinctively looks directly at it to see what it is and thus brings the object into the macular field. If, however, the light difference sense be defective there is a very much increased chance that the new object will not be seen at all, and danger may ensue therefrom. Long years ago I advocated strongly that the light sense of all men entrusted with the duties of an officer of the watch should be carefully tested, but up till now, so far as I am aware, no steps have been taken to bring about this desirable change. At that time the apparatus available was not very suitable, but the circles introduced by Mr. Percival seem to me to leave nothing to be desired.

One other question remains to be mentioned, although I am sorry to say that I am not in a position to give any answer—it is as to the effect of errors of refraction on what I now call field vision. I have already pointed out that very high degrees of myopia do not hinder a man from working, and that satisfactorily, at coal-mining. Navigation, except for the reading of charts and other documents and the necessary instruments of navigation, does not involve, or hardly at all, macular vision, but does involve field vision. The question then arises, Can a man with a moderate degree of myopia safely navigate? I am not prepared to give a dogmatic answer to this important question. At the same time if the myopia be high I think it would form an insuperable barrier to his being put in charge of a vessel. Personally I have provided myself with convex glasses of 3 diopters when at sea, and certainly the artificial myopia induced thereby would have rendered me quite incapable of performing navigational duties. Still it must be remembered that that is an artificial myopia, and that I had not been in the habit of subconsciously interpreting blurred images. On the other hand, I have known a master mariner who commanded a ship, for some years, and who had a myopia of about 2 diopters in each eye, a condition which presumably had been with him for most of his life. It is just within the range of the possible that a man who has had for most of his life a fair amount of myopia, and who has been interpreting the consequent blurred images, may be quite fit for navigational duties. The work of a man on the look-out is not a function of macular vision, it is a function of field vision, and although I have no data to go upon, except the case of the master mariner just mentioned, I think it is quite possible that even with a fair amount of myopia the field vision is sufficiently good to render a man safe when on the look-out.

The two points which I desire to emphasize in this paper are: first, that for navigation the light sense should be tested as carefully as the colour sense; and secondly, that most manual work does not depend on macular vision at all, but on what I have called field vision, and that therefore it is idle to attempt to evaluate manual efficiency in terms of visual acuteness as above defined.

THE MECHANISM OF HEARING.

BY

SIR W. M. BAYLISS, F.R.S.

ALTHOUGH from time to time objections have been made to the theory put forward by Helmholtz that the basilar membrane of the cochlea acts as a series of resonators and that by its means analysis of compound sounds is performed in the peripheral receptor organ, it has to be admitted that rival theories present at least as many difficulties. Theories in which this membrane acts as a whole, like a telephone diaphragm, or by "pressure patterns," are inconsistent with the newer knowledge of the conducting properties of nerve fibres. For these reasons the views put forward by Rutherford, Waller, Wrightson, and Ewald cannot be accepted.

In a recent paper Mr. George Wilkinson, F.R.C.S., of Sheffield, also points out that those of Meyer and of Ter

Kuile, if applied to a series of impulses, really amount to sympathetic resonance. In the paper referred to¹ Mr. Wilkinson describes the construction and properties of a model made with careful adherence to the proportions and nature of the cochlear mechanism. It is by far the most important recent contribution to the knowledge of the problem. Very little attention had previously been given to the experimental investigation of the physics of resonant vibrators immersed in liquid. Professor McKendrick had shown that a series of metallic reeds immersed in water was capable of sympathetic resonance, but the system was apparently thought too far removed from the actual structure of the basilar membrane to throw very much light on the behaviour of the latter. Mr. Wilkinson's model is a great advance. It was shown to the Physiological Society in December, 1921, and to the British Association in September, 1922. Details of the mode of construction, in which various difficulties were successfully overcome, must be read in the paper. The mechanician of Professor Leathes's laboratory, Mr. C. E. Stewart, is to be congratulated on the result. It consists essentially of a series of strips of very fine phosphor-bronze stretched across a gap in a brass plate and soldered to this at both ends. The gap is wider at one end than at the other, in order to give a graduated series of different lengths. The strips were first soldered at one end, then stretched by a series of weights, and while under tension soldered at the other end. The whole was then coated with gelatin to form a continuous membrane, leaving a gap at one end (the "helicotrema"). This structure was made to form the division between two closed chambers of water (the "scalae") into which the two "windows," closed with india-rubber, opened. On one of these a little wooden rod ("stapes") was cemented. The top of the upper chamber was formed by a glass plate. Finely powdered blue enamel was distributed over the membrane to indicate the region of vibration when tuning-forks of various period were applied to the "stapes." The lengths and tensions of the strips, as also the dimensions of the chambers, were carefully calculated, but the vibration rates turned out to be higher than those expected. This is, of course, partly due to difficulties in construction and probably also to the omission of some unknown factors which complicate the formula.

It will be remembered that the rate of vibration of a string depends on three factors. It is directly proportional to the square root of the tension, inversely proportional to the length and to the square root of the mass. As regards the first of these factors, it was early recognized that the difference in length between the fibres at the two ends of the basilar membrane was insufficient to account for the range of pitch perceived, but it was sometimes overlooked that, as Dr. A. A. Gray has shown, there is also a difference in tension, such that the shorter fibres in the membrane are more tightly stretched and the range hereby increased. The mass of the vibrating element was mentioned incidentally by Helmholtz in referring to the membrane being weighted by the liquid in which it lies. But the real importance of this factor was first pointed out by Mr. Wilkinson. He shows that each element of the membrane is to be considered as consisting, not only of the fibre itself and the cells covering it, but also of two columns of water reaching from each element to each window, one on each side. This mass of water vibrates with the fibre, greatly increasing its mass and lowering its rate of vibration. Since the shorter columns are nearer the windows and the shorter fibres of the membrane are at this end of the cochlea, the range of response is further increased, and the reason why the basilar membrane is narrower at the base than at the apex of the cochlea is clear. It is further clear why the membrane must be a continuous one, because, if the fibres had gaps between them, no regular loading of the fibres would be possible.

Passing to the behaviour of this model, it was found that when the "stapes" was touched lightly with a vibrating tuning-fork of 32 D.V. the membrane responded only at one extreme end. Sixty-four D.V. gave a fairly local response about one-third of the way along. To 200 D.V. there was a response at about the middle, below the calculated position, with a partial response at the position for 100 D.V. To 400 D.V. the reaction was close to the calculated point, with a well-marked partial vibration at the 200 D.V. position and a less marked one at that for 100 D.V.

¹ Analysis of Sound by Resonance, *Journ. of Laryngol. and Otol.*, September, 1922. Also a brief account in *Proc. Physiol. Soc. in Journ. of Physiol.*, vol. lvi, p. ii (February, 1922).

The model is probably capable of further improvement, but it appears that many important investigations might be made in its present form. The degree of damping and the extent of spread of resonance may be mentioned. It may be pointed out that some degree of resonance of adjoining elements is not contradictory to the theory of Helmholtz. The amplitude of vibration of these is probably too small to stimulate the nerve endings. Gray has shown that a similar cutting out of the smaller stimuli occurs in the localization of a point of pressure in the skin.

One fact of interest may be referred to in conclusion. The model responds also to a tuning-fork held in contact with the brass case, just as does the cochlea to conduction through the bone. This indicates that the impulses given by the movements of the stapes are of the same nature as those of sound waves directly transmitted to the water, as would be expected from theoretical considerations.

LUMINAL IN MIGRAINE.

BY

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PAROXYSMAL recurrent headaches of hemicranial type are so common, and hitherto have been so difficult to diminish either in severity or frequency, that the apparent success of a new remedy which I have been using in this distressing complaint for the past year is, I think, sufficient justification for putting my results before the profession in order that others may test its value, I hope with similar good effect.

The close relationship of true migraine to epilepsy, as one of the paroxysmal neuroses, resembling epilepsy in being preceded often by an aura and succeeded by violent headache, suggested originally the treatment of migraine by prolonged administration of bromides in various forms and combinations. In my hands bromide has practically proved a failure in the treatment of migraine, though in a few cases aspirin, and in others cachets of pyramidon (gr. vii) with cannabin tannate (gr. ii), have notably cut short the duration of the headache if taken immediately after the attack is recognized. Migraine subjects almost invariably visit the oculist before the neurologist, and glasses are often ordered, though very rarely is true migraine improved thereby. Dieting of various kinds, reasonable and unreasonable, is also usually tried, the attacks being spoken of as liverishness, dyspepsia, or bilious headaches. A diet of milk and nuts alone has occasionally been said to cure a tendency to frequently recurring headaches.

Some headaches, doubtless, are of intestinal toxic origin, such as a chronic appendicitis; others, as we know, may be due to errors of refraction, nasal obstruction, pyorrhoea, etc., and may yield to the appropriate treatment. Such headaches must, however, be differentiated from migraine, which in its more characteristic type is notably hereditary, frequently unilateral (hemicrania), and often preceded for twenty to thirty minutes by a visual aura known as a scintillating scotoma, with temporary marked diminution of visual acuity. Nausea and vomiting usually follow the headache, sometimes occurring early, often delayed for hours, when the vomiting appears to relieve the headache.

Migraine may alternate with epilepsy in the same patient or in different members of a family, and I have known the same visual aura of scintillating scotoma herald both the epileptic and migraine attacks to which a boy of 13 was subject, whose mother was also a sufferer from migraine. The striking success of luminal in a considerable number of epileptics, who might justly be labelled "bromide failures," is now beginning to be common knowledge, through the writings of Golla and others, though at the same time a few cases, especially in children or young adults, seem to do definitely worse on luminal than on bromide, having more frequent attacks and greater mental torpor. In my experience I have found that it is the epilepsies in children, associated with some organic cerebral lesion, such as an infantile hemiplegia or congenital mental defect, without any family history of epilepsy, that are especially likely not to be benefited by luminal.

In analogy, therefore, with the successful treatment of some of the "bromide failure" epileptics with luminal, it occurred to me to try the effect of this drug in obstinate and frequently recurring migrainous attacks. I may say at