only, whose hearts were allowed to remain unopened from twelve to twenty-four hours after death, the temperature varying from 75° to 90° Fahr., the blood when removed from the cardiac cavities in such a way as to avoid all contamination, and carefully examined with a high power, exhibited cells corresponding perfectly to those described by Prof. Halford; yet that these so-called "peculiar cells" were always mingled not only with white blood corpuscles in their ordinary "pearly and opaque" condition, but also with those in various stages of enlargement and alteration, such as may be at any time produced in the white globules of normal blood simply by diluting the liquor sanguinis with water; and further, that in the case of the goat, when a majority of the "peculiar cells" presented the unusual character of being multinucleated, the white blood globules, if distended by water, exhibited the same peculiarity. We may, therefore, I think, fairly conclude that the abnormal corpuscles in these particular instances were in reality only white blood globules which had undergone an alteration similar to that caused by reducing the specific gravity of the blood, and so establish a strong presumption (whose correctness Prof. Halford can alone decide) that the "peculiar cells" described by him as resulting from the poison of snake bites are precisely analogous in their character.

In regard to the "thinning" of the blood I hope to have an opportunity of deciding as to its amount at some future time by taking the sp. gr. of that fluid at intervals after death by means of a hydrometer. To do this, however, one of the larger animals, as a horse, for example, will be required.

ART. III.—*Determination of the Optical Condition of the Eye by the Ophthalmoscope, with a new Modification of the Instrument for that purpose.* By EDWARD G. LORING, M. D., Surgeon to the Manhattan Eye and Ear Hospital, N. Y., and the Brooklyn Eye and Ear Hospital, Long Island. (With eleven figures.)

IF the ophthalmoscope was one of the most brilliant inventions ever known to medical science, it was certainly also one of the most complete, for the very method first proposed by Helmholtz still remains, by far the most beautiful, comprehensive, and truthful of all the means yet in our possession for the exploration of the bottom of the eye.

From the difficulties which this method is supposed to offer—difficulties which are rather imaginary than real—its use has never attained, even among oculists themselves, that prevalence which its merits deserve. Thanks, however, to the untiring perseverance of Jaeger as an observer, and his unequalled skill as a delineator, as well as to the written precept of his disciple Mauthner, examinations by the upright image are being pursued with a zeal which cannot fail to contribute largely to our knowledge of intraocular conditions, both normal and pathological.

There is, however, one particular advantage which this method offers above all others to the explanation of which the following remarks will exclusively apply, and that is, as Helmholtz himself pointed out, "the ability to determine the optical condition of the eye independent of its visual power, and the statements of the person examined."

Since Helmholtz first pointed out this fact in 1851, both Ed. Jaeger and Donders have written upon the subject, but it is to Mauthner, in his recent admirable work on the ophthalmoscope, that we are indebted for the most exhaustive treatise which exists on this important branch of ophthalmoscopy, and we sincerely regret that no translation of this text-book, which is by far the best which has ever appeared, has not yet been made into English.

Before passing to a detailed consideration of the methods of determining the various errors of refraction, there are some practical points common to the examination of all to which it may be well to call attention.

In regard to the kind of ophthalmoscope, any instrument which is provided with an apparatus at the back for holding the necessary glasses may be used. The kind of mirror too is rather a matter of preference than necessity; some observers preferring a plane, others a concave silvered one. For the simple determination of errors of refraction, I must say that I have a decided preference for the latter wherever it is not directly contraindicated by a dread of light on the part of the patient. There are, it is true, cases where the iris is unusually responsive to light, where it is necessary to use the weak illumination, and even here the difficulty can be usually met by reducing the volume of light employed.

If Jaeger's instrument is used, then the lamp which is the source of light can be at a distance laterally from the head of the person examined, which is somewhat of an advantage as a matter of comfort both to the observed and observer. If, however, an instrument is used like Liebreich's common ophthalmoscope, where the mirror is not set at an angle, then the light should be placed more on a line with the patient's head, so that the incident rays may strike the mirror at a reduced angle.

The position of the patient and examiner is not without importance. The observer should sit well to the side of the patient and on the side of course of the eye to be examined. If the right eye is to be examined, the patient should be directed to look slightly towards the right; if the left eye, then towards the left. This throws the optic axis away from the median line, places the optic nerve just opposite the pupil, and allows the observer to approach very near the observed eye without bending too much over the person examined.

The observer must learn to use either eye and either hand as occasion may require, so as to be able to examine the patient's right eye with his right and the left with his left, holding the ophthalmoscope in the right or left hand, as the case may be.

As the very word refraction implies the true optical value of an eye independent of its accommodation, it follows that this condition can only be ascertained when the eye examined is in a state of rest. Further, that it is indispensable that the observer should be aware of the exact state of refraction and accommodation of his own eye, before he can estimate that of another.

Perfect relaxation of the accommodation in the observed eye can of course be obtained by atropia, no matter what the nature of the refraction is. But usually, sufficient relaxation can be obtained in emmetropia by causing the patient to look into the distance, and as much as possible into vacancy, which is induced somewhat by having the walls of the ophthalmoscopic room painted black. For a myope it will only be necessary that he should look at some object which is at a greater distance than his far point. The ability and disability which hypermetropes have in relaxing their accommodation will better be considered a little later under its special heading.

As far as the observer is concerned, it can be laid down as a rule, at least for beginners, that the nearer the refraction of his eye approaches emmetropia and the more completely he can relax his accommodation, the better. This ability to relax the accommodation varies with different people, some acquiring the power completely, others only partially. Practice here, as everywhere else, increases the ability. If the observer is emmetropic, one of the best methods of acquiring this control over the accommodation is to take a convex glass of a moderate power, say $\frac{1}{8}$, and ascertain the farthest point at which fine type can be read with perfect distinctness through the glass, the other eye being closed, or better still, opened but excluded from the visual act by a screen, as under this condition there is a tendency for the visual axes to assume a parallel position, and with it that perfect state of rest usual to them when looking at the most distant objects. If the object can be moved in this case to a distance of eight inches, it is proof positive that the accommodation is entirely relaxed, since, as the object viewed is situated at the principal focus of the glass, only parallel rays can enter the eye, and such rays can only be brought to a focus on the retina of an emmetropic eye when it is in a state of perfect rest. This experiment should be repeated with glasses of various strengths till the ability is acquired of always seeing the test object at the focal distance of the glass used. This once acquired, a little further practice with the ophthalmoscope will also enable the observer to relax his accommodation during the examination.

If, however, the object viewed cannot be removed from the eye to a distance equal to the focal length of the glass, then it is evident that the accommodation is not entirely relaxed. If, for example, convex $\frac{1}{8}$ be used, and the object, instead of being seen distinctly at eight inches, can only be so seen at six, then it is evident that some accommodation is still going on, and the exact amount of this will be equal to the difference between $\frac{1}{6}$ and $\frac{1}{8} = \frac{1}{24}$. Continued practice may soon enable the observer to overcome this involuntary contraction of the accommodation. Sometimes, however, in spite of all his efforts, it still remains, but he soon finds that the amount used is always the same. This then represents the optical condition of his eye. If, for example, he finds that the amount of accommodation which he still uses is $\frac{1}{16}$ or $\frac{1}{12}$, his eye is then, practically speaking, no longer emmetropic, but myopic, equal in fact to $\frac{1}{16}$ or $\frac{1}{12}$, as the case may be. Consequently, he must use a concave $\frac{1}{16}$ or $\frac{1}{12}$, in order to see clearly a near object, the rays from which, however, enter his eye as parallel. Having thus ascertained the optical condition of his eye in its greatest state of rest he should, having selected some one whose eye has been proved to be emmetropic, practise with the ophthalmoscope through the glass which he has previously found neutralizes the amount of accommodation which he involuntarily employs.

As a rule, then, the weakest concave glass through which the fundus of an emmetropic eye can be distinctly seen, should be taken as the criterion on which the emmetropic observer, who cannot entirely relax his accommodation, should base his estimates of refraction.

If the observer is ametropic, the simplest way for him is to reduce his ametropia by the suitable glass. More, however, in regard to this matter, will be found under its appropriate heading.

It is of course very essential, for an accurate determination of the refraction, to have some object point in the eye examined which shall be fine enough, not only to let us judge when we see, but when we are seeing with the most perfect sharpness.

The most conspicuous object, and one for which we at first instinctively look, is the papilla, but this should never be chosen, as it very frequently is however, as an object on which to found our observations, for the disk often protrudes, sometimes to an enormous degree, above the general plane of the rest of the retina,[1] and would thus frequently lead to the supposition that an eye was hypermetropic, sometimes markedly so, which was in reality emmetropic or even myopic. An eye lately examined by the writer was, for example, hypermetropic one-fortieth at the disk, but myopic one-eighteenth in the region of the macula. The general trunks of the central artery, besides being often on an advanced plane, at the nerve entrance, are in themselves seen under too great an enlargement to admit of nice discrimination in focal adjustment. There are, however, some very fine vessels which always leave the edge of the nerve, running out horizontally on both sides. These are admirably adapted for the purpose, when viewed at a little distance from the disk, especially towards the inner side; the best of all objects, however, at least for those who are skilful in this kind of examination, is the choroidal epithelium in the neighborhood of the

[1] Compare Schweigger's Vorlesungen, Taf 1, figs. 1, 2.

macula, though the advantages which this region offers are more than counterbalanced by the difficulties which attend its examination.

The observer having found out the exact optical condition of his own eye, what remains for him to do is, first to ascertain the nature of the refraction of the eye under examination, and then, if ametropic, to determine the exact degree of the anomaly.

If the observer is emmetropic, and relaxes his accommodation entirely, he knows that his eye is adjusted for parallel rays only. Now the only kind of eye from which rays emerge parallel, is an emmetropic eye, consequently, if the fundus of the eye examined is focussed sharply on the observer's retina, the rays which enter his eye must be parallel, and the eye observed must be emmetropic.

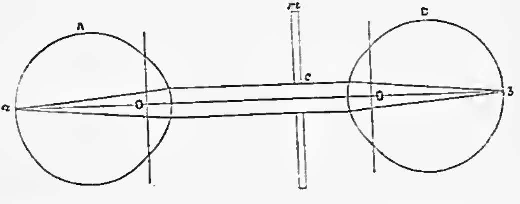
If, in a given case, the observer finds that he does not gain a clear view of the eye examined, when his own eye is in a state of rest, but that it becomes clear by using his accommodation, he then knows that the observed eye must be hypermetropic, since his own eye under tension of the accommodation is no longer adjusted for parallel, but for divergent rays, and there is no eye but a hypermetropic eye from which divergent rays can possibly come.

If the observer finds, however, that he can get no clear view of the fundus, either by relaxing or calling forth his accommodation, he knows that the rays coming from the observed eye cannot be either parallel or divergent, consequently they must be convergent, and the eye examined myopic.

Having thus ascertained, in a general way, the *nature* of the optical condition present, the next step is to determine the exact degree of the refraction. The method for doing this will be embodied, for the sake of convenience and brevity, in the following propositions, it being presupposed in all cases that the examined eye is in a state of rest.

PROPOSITION I. *For an emmetropic eye to determine that the observed eye is emmetropic.*—Let A (Fig. 1) be the observed eye illuminated by the

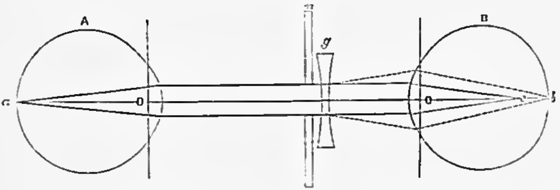
Fig. 1.



ophthalmoscopic mirror m. Since the eye is emmetropic, and in a state of rest, rays radiating from an illuminated point a on the retina must leave the eye as parallel, and, as such, pass through the hole of the mirror c. If now the observer's eye is placed behind the mirror, the rays which strike his cornea, being parallel, will, since his own eye is emmetropic and in a state of rest, just come to a focus on his retina at the point *b*. A distinct image of the fundus will therefore be obtained, as what is true of one point is of all. As his eye is adjusted for parallel rays, and for no others, he knows the eye examined must be emmetropic; consequently, the fundus of an emmetropic eye can be distinctly seen by another emmetropic eye, without the aid of any correcting glass; providing, however, that the observer's eye is also in a state of rest.

If, however, the observer is unable to relax his accommodation entirely, it is evident that the parallel rays entering his eye must come to a focus in front of the retina, that is to say, rays coming from the point *a* (Fig. 1) will no longer come to a focus at *b*, but will unite in front of it at *e* (Fig. 2). Circles of dispersion will consequently be formed on *B's* retina, and an indistinct image of *A's* fundus will be the result.

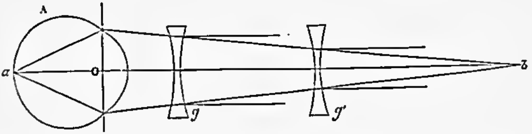
Fig. 2.



The reason of this is that *B's* eye—as has been formerly explained—though emmetropic while looking at distant objects, is, as far as ophthalmoscopic examinations are concerned—since he cannot relax his accommodation—virtually myopic, and a concave glass (*g*) must be used behind the ophthalmoscope, to bring parallel rays to a focus on his retina. The weakest concave glass that will do this will then be just the amount that *B's* accommodation cannot be relaxed, and with it his eye will be just adapted for parallel rays; consequently, when the fundus of an eye can only be seen clearly through this glass, the eye must be emmetropic.

PROPOSITION II. *The observer being emmetropic to determine the amount of myopia in the observed eye.*—As the observed eye is myopic, rays of light emerging from it are convergent, and will meet at a point in front of the eye, at a distance just equal to the amount of the myopia. If, for example, the myopia equals $\frac{1}{6}$ then the rays will meet at six inches in front of the nodal point. As the observer's eye, however, is emmetropic, and in a state of rest, it is accommodated, not for convergent but parallel rays, so that before the convergent rays coming from a myopic eye can be focussed on the observer's retina, they must be made parallel. This will be made clear by the following diagram (Fig. 3).

Fig. 3.



Let *A* be an eye myopic $\frac{1}{6}$; rays of light leaving its retina will emerge convergent, and come to a focus six inches in front of the nodal point o, at the point *b*. If we could place a concave lens $\frac{1}{6}$ at the nodal point, we should neutralize the myopia, and the rays would then leave the eye as parallel, since the glass would then be just six inches from the point *b*, which would then represent the virtual focus of the glass. But as we cannot put the glass at the nodal point of the observed eye, we place it as near as the conditions of an ophthalmoscopic examination will permit. This distance is generally assumed to be about two inches. As the glass (*g*) is then two inches in front of the nodal point, the distance between it and the point *b* will be only four inches; consequently, it will require a concave $\frac{1}{4}$, to render the rays parallel at two inches from the eye, while it only required $\frac{1}{6}$ at the nodal point. If the glass (*g'*) is at three inches from the nodal point, then it will be only three inches from the point *b*, and it will require a glass of $\frac{1}{3}$ to reduce the rays to parallel; consequently, $\frac{1}{3}$ three inches from the nodal point is equal to $\frac{1}{6}$ at it. That is to say, the glass required is just as much too strong as it is distant from the nodal point. We must therefore reduce it by this quantity. In the above cases it will be $\frac{1}{4+2}=\frac{1}{6}$. $\frac{1}{3+3}=\frac{1}{6}$. From which we deduce—

For an emmetropic observer whose eye is at rest, the myopia in a given case will equal the weakest concave glass through which the fundus is seen distinctly, plus the distance of the glass from the nodal point of the observed eye.

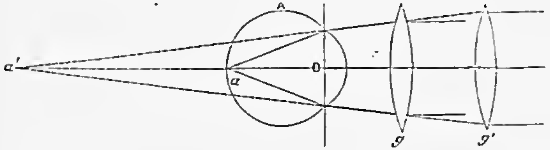
This will give the exact amount of the myopia present, but inasmuch as we usually measure degrees of ametropia by that glass which brings parallel rays to a focus on the retina, placed, not at the nodal point, but half an inch in front of it, we may for ordinary calculations omit this half inch. For example, we say a man is myopic $\frac{1}{6}$, when a concave $\frac{1}{6}$ placed one-half inch in front of his nodal point, brings parallel rays to a focus on the retina; he is really, however, myopic only $\frac{1}{6\frac{1}{2}}$. So, too, with the ophthalmoscope we may neglect this half inch, and then the result will give the amount of ametropia, as it is usually expressed, in glasses.

We have taken the distance between the glass and nodal point as two inches, simply as a matter of convenience and because it represents about the distance common to those who are not adepts in this kind of examinations, especially if they use Jaeger's ophthalmoscope. With a little practice the observer can reduce this distance to one inch instead of two, and if he uses an ophthalmoscope, the mirror of which lies in the same plane with the handle, he can with a little skill approach so near the eye, as to place the glass he looks through nearly in the position which the patient would in wearing his glasses. In this case the glass used would represent the amount of ametropia without further addition of the distance.

If the observer is unable to relax his accommodation when using the ophthalmoscope he is, as has already been explained, no longer emmetropic but virtually myopic to the amount of accommodation that he involuntarily calls forth. He has then to simply reduce his own eye to the condition of an emmetropic one by adding the suitable glass and then proceed as above.

Proposition III. *The observer being emmetropic to estimate the degree of hypermetropia in a given case.*—As the observed eye is hypermetropic, rays emerging from it will have a direction as if they came from a point situated behind the eye observed, equal to the degree of the hypermetropia. Thus the rays coming from an eye hypermetropic $\frac{1}{8}$ will emerge from it as if they came from a point eight inches behind the nodal point. For example, let *A* (Fig. 4) be hypermetropic $\frac{1}{8}$, then the rays, coming from the point *a* on the retina, will after they leave the eye diverge as if they came from *a′* eight inches behind the eye. As the observer's eye is emmetropic and at rest, we must render these rays parallel before they

Fig. 4.



can come to a focus on his retina. If we could place a convex glass at the nodal point of *A*, it would require just $\frac{1}{8}$ to make the rays parallel, inasmuch as *a′*, which may be considered as the principal focus, is just eight inches distant, and this glass then would just equal the amount of *H*. If, however, we place the glass (*g*) behind the ophthalmoscope two inches in front of the observed eye *A*, then, as *a′* is ten inches from the glass it will only require $\frac{1}{10}$ to render the rays parallel. If the glass (*g′*) is at four inches from the eye, then *a′* will be twelve inches from the glass, and it will only require $\frac{1}{12}$. Consequently the glass used is as much weaker than the hypermetropia is, as it is distant from the nodal point; we must therefore make it so much stronger, before it can represent the true degree of H in the observed eye. In the above case, $H = \frac{1}{10-2} = \frac{1}{8}$, $H = \frac{1}{12-4} = \frac{1}{8}$.

The hypermetropia in the observed eye is therefore for an emmetropic observer always equal to the glass used, minus the distance of the glass from the nodal point of the examined eye.

As the accommodation is equivalent to a convex glass of different focal lengths, it is evident that the observer may substitute his own accommodation for the glass, provided he knows just how much he is using, and how far his nodal point is from that of the examined eye. For example, if the observer sees an eye distinctly, while he is conscious that he is accommodating for ten inches, he knows that the H in the observed eye must be equal to one-tenth minus the distance between the nodal points of his own and the observed eye. If this is two inches, then $H = \frac{1}{10-2} = \frac{1}{8}$.

The ability to judge of refraction by the degree of tension required of the accommodation, can only of course be brought into play in one condition, that is, where the observed eye is hypermetropic, and even here it is rather a *tour de force* than an essential advantage. We can all of us by a little practice get an approximate idea as to the amount of hypermetropia in a given case, by the amount of tension required of our accommodation in getting a clear view of the fundus, but very few even with any amount of practice ever approximate that precision which can be obtained with infinitely less trouble by means of glasses.

As in the above cases the rays of light passing through the hole of the mirror are parallel, and will continue so if uninterrupted to infinity, it makes no difference in the result whether the observer's eye is close against the instrument or a little removed from it. The only calculation necessary is the distance between the glass and nodal point of the examined eye.

The above directions, which are sufficient for an emmetropic observer whose eye is in a state of rest to determine any condition of refraction, may be summed up in this general rule :—

The ametropia in a given case is equal to the glass used plus the distance between it and the nodal point if the eye examined be myopic, minus the distance if it be hypermetropic.

If, however, the observer is so unfortunate as to be ametropic, then the simplest way for him is to reduce his eye to a condition of emmetropia, that is to say to that condition of refraction that parallel rays unite on his retina; considering that portion of the accommodation which cannot be relaxed as part and parcel of the refraction.

If the ametropic observer does this, then of course the preceding directions will be all that he will have to bear in mind. Should he not wish, however, to pursue this course he will find in the appendix at the end of this paper the methods which he must follow.

Such being the theoretical rules, it remains to be seen how far they are applicable to the wants of the practitioner. The advantages offered by this method may be summed up as follows:—

(1). In the ability to tell the optical condition of the eye examined independent of the statements of the patient, or amount of vision of the eye.

(2). In measuring the amount of elevation or depression of given parts of the fundus.

Under the first heading the point which, without doubt, is the most important in a practical point of view, is the determination of the degree of latent hypermetropia.

The use of atropin and the trial by glasses is, and must remain in the vast majority of cases, the most certain test possible, still its use is attended with more or less inconvenience to all, and to some, with so much, that its employment is often impossible. Consequently, any means of diagnosticating the amount of total hypermetropia, which is on the one hand accurate, and on the other free from inconvenience to the patient, cannot fail of being of the greatest value to the practitioner. The only question is, can the ophthalmoscope do this?

From the result of a series of trials with the ophthalmoscope, both before and after the use of atropia, Mauthner does not hesitate to answer this question in the affirmative; laying it down as a law that "*In examinations with the ophthalmoscope* (by the upright image) *the total hypermetropia is revealed.*"[1] This opinion is supported by the citation of the following remarkable case:—

A boy of twelve years presented the usual symptoms of asthenopia. Both concave and convex glasses were declined for distant vision. Even convex $\frac{1}{30}$ was obstinately rejected. The ophthalmoscopic examination brought to light a hypermetropia of $\frac{1}{6}$. The eye was then paralyzed with atropia, and the total H was found to be by glasses $\frac{1}{6}$.

Inasmuch as I have never seen a case of total H of so high a grade as $\frac{1}{6}$ where there was no manifest at all, I am unable to corroborate the above case with a precisely similar one from my own practice. I could, however, cite many where the degree of the manifest was very trifling in proportion to the total revealed by the ophthalmoscope, and where the latter obtained by this means differed but slightly from what was subsequently obtained by the use of atropia and glasses. For example, $\frac{1}{36}$ with glasses, $\frac{1}{12}$ with the ophthalmoscope; $\frac{1}{24}$ with glasses, $\frac{1}{8}$ with the ophthalmoscope, $\frac{1}{8}$ with atropia; $\frac{1}{18}$ with glasses, $\frac{1}{8}$ with the ophthalmoscope, $\frac{1}{6\frac{1}{2}}$ with atropia; $\frac{1}{17}$ with glasses, $\frac{1}{4\frac{1}{2}}$ with the ophthalmoscope; $\frac{1}{12}$

[1] Mauthner, ab. 1, p. 174.

with glasses, $\frac{1}{6}$ with the ophthalmoscope, $\frac{1}{6}$ with atropia, etc. etc. Such glittering results as these certainly need but little comment, and their practical application but little explanation, the only wonder being that examinations of this kind are not as universal as the use of the ophthalmoscope itself.

There is one point which at first appears curious, and that is, that we get the most exact and certainly by far the most brilliant results just where we should expect them least; that is, with the highest grades of hypermetropia, at least such has been the writer's experience; so much so that he feels convinced that it is very difficult, sometimes impossible, with young people to tell the lighter degrees of H (above one-fortieth) with the ophthalmoscope, unless indeed atropia has been used. This he believes to be owing to the fact that hypermetropes of a high degree often relax their accommodation entirely while looking inattentively into the distance, making no effort to call forth their accommodation till their attention is aroused; when, however, their attention is called to some particular object, they instinctively call forth that amount, or very near it, which is demanded for parallel rays. Consequently, under glasses where particular attention is required of them in deciphering the smaller letters of the test board, they refuse to relax their accommodation except to a trifling degree. But when placed in a dimly-lighted room and told to look at a wall which offers a blank and diffused surface, and which will appear to them but a little less distinct even when seen in circles of dispersion, they have no difficulty in relaxing their accommodation. But young persons who have say $H\ \frac{1}{40}$ or less, see clearly in the distance with so little effort, that they probably never relax their accommodation, preferring to make slight demands on their ciliary muscle to seeing in circles of dispersion. Their condition is practically emmetropic, and in the ophthalmoscopic room they relax their A no more than they are accustomed to, accommodating for the plane of the wall which they see distinctly, or at most for parallel rays. We may, however, lay it down as a rule even in these cases, that where but little or no H can be detected either by glasses or the ophthalmoscope, little or none exists.

Without being able to accept then, unreservedly, Mauthner's general statement, that the total H can be invariably determined with the ophthalmoscope, we nevertheless believe that a very close approximation to it can almost invariably be obtained.

So much for the ophthalmoscope where atropia has not been used, but there are cases in which it is even superior to the test by atropia and glasses, where the latter indeed utterly fail in giving an idea of the amount of hypermetropia, as the following case will show:—

A bright little girl was brought to me for the purpose of having the exact optical condition of the eyes determined. With a convex one-twenty-fourth vision was decidedly improved; amounting, however, even with the glass, only to $\frac{1}{5}$ in the right eye, $\frac{1}{10}$ in the left. The same result was obtained under atropia. Glasses of various strengths from $\frac{1}{24}$ to $\frac{1}{12}$ were tried, and still the vision remained about the same. Recourse was now had to the ophthalmoscope, when a total *H* of $\frac{1}{7}$ was found in the right, $\frac{1}{6}$ in the left eye. The discrepancy between the glass selected by the child and the amount of *H* as given by the ophthalmoscope was so great, that an independent examination was made by another oculist with precisely the same result in each eye. There was evidently a large amount of congenital amblyopia, the only hope of relieving which, certainly lay in careful and systematic exercise through that glass which would produce sharply defined images upon the retina, and this glass could only be ascertained through the ophthalmoscope. Previous experience had already taught me that wonderful results could be obtained in this manner, and I ventured to give an encouraging prognosis.

So, too, in strabismus in children, it is often impossible, from their inability to read, or the irrelevancy of their answers, to get an adequate idea as to the condition of the refraction, even where atropia has been used. And yet the whole question in regard to operative interference may turn on the presence or non presence of *H* and its degree. With the ophthalmoscope, however, with a little care and with a dilated pupil, the exact amount, or what approximates to it very closely, can, as a rule, be ascertained, even with children in arms.

So, too, in any disease in which amblyopia is an element.

One of the most interesting attributes of the upright image is the means which it affords us for determining the various planes which different parts of the fundus often occupy. For, inasmuch as a certain amount of refraction corresponds to a given length of the axis of the eye, we have only to know the refraction of a certain point to know its exact antero-posterior position, and the difference of refraction between two given points must represent their difference of level. We are thus enabled to measure numerically, for example, the amount of excavation of the optic nerve or its projection above the level of the retina; the projection of the choroid or retina from underlying effusion; the height of tumours and their rate of increase; the amount of swelling in the retina; the situations of membranes in the vitreous, etc.

Taking the emmetropic eye as a standard, calculations have been made by various authors to determine what amount of increase or decrease in the length of the optic axis corresponds to a given degree of hypermetropia or myopia. I have calculated for the easy reference of the reader, from the formulas given by Mauthner, p. 67, 226, ab. 1, the two following tables, the first representing the amount of decrease in length of the axis due to *H*, and the second the increase due to *M*.

TABLE I.

$H\ \frac{1}{2}$	equals a shortening of	3.96 Mm.	$H\ \frac{1}{12}$	equals a shortening of	0.85 Mm.
" $\frac{1}{3}$	" " "	2.9 "	" $\frac{1}{14}$	" " "	0.74 "
" $\frac{1}{4}$	" " "	2.3 "	" $\frac{1}{16}$	" " "	0.65 "
" $\frac{1}{5}$	" " "	1.89 "	" $\frac{1}{18}$	" " "	0.58 "
" $\frac{1}{6}$	" " "	1.6 "	" $\frac{1}{20}$	" " "	0.52 "
" $\frac{1}{7}$	" " "	1.4 "	" $\frac{1}{24}$	" " "	0.45 "
" $\frac{1}{8}$	" " "	1.25 "	" $\frac{1}{30}$	" " "	0.35 "
" $\frac{1}{9}$	" " "	1.12 "	" $\frac{1}{40}$	" " "	0.26 "
" $\frac{1}{10}$	" " "	1. "	" $\frac{1}{50}$	" " "	0.21 "
" $\frac{1}{11}$	" " "	0.92 "			

TABLE II.

$M\ \frac{1}{2}$	equals an increase of	8.6 Mm.	$M\ \frac{1}{12}$	equals an increase of	0.97 Mm.
" $\frac{1}{3}$	" " "	4.81 "	" $\frac{1}{14}$	" " "	0.82 "
" $\frac{1}{4}$	" " "	3.34 "	" $\frac{1}{16}$	" " "	0.71 "
" $\frac{1}{5}$	" " "	2.56 "	" $\frac{1}{18}$	" " "	0.63 "
" $\frac{1}{6}$	" " "	2.07 "	" $\frac{1}{20}$	" " "	0.56 "
" $\frac{1}{7}$	" " "	1.97 "	" $\frac{1}{24}$	" " "	0.46 "
" $\frac{1}{8}$	" " "	1.5 "	" $\frac{1}{30}$	" " "	0.37 "
" $\frac{1}{9}$	" " "	1.31 "	" $\frac{1}{40}$	" " "	0.27 "
" $\frac{1}{10}$	" " "	1.17 "	" $\frac{1}{50}$	" " "	0.22 "
" $\frac{1}{11}$	" " "	1.62 "			

The application of the above tables will perhaps be made clearer by some examples.

In a case of glaucoma the edge of the nerve is emmetropic, while the bottom of the excavation is myopic $\frac{1}{8}$. As myopia $\frac{1}{8}$ signifies a lengthening of the axis equal to 1.5 Mm. (see Table II.), the depth of the excavations must be, since the edge of the nerve is emmetropic, equal to 1.5 Mm. In a second case the border of the nerve and general fundus is myopic $\frac{1}{24}$, the bottom of the excavation is myopic $\frac{1}{8}$; the true extent of the excavation will then be equal to $\frac{1}{8} - \frac{1}{24} = \frac{1}{12}\ M\ \frac{1}{12} = 0.97$ Mm. In a third case the edge of the nerve is $H\ \frac{1}{30}$; the bottom of the excavation is still myopic $\frac{1}{8}$. As $H\ \frac{1}{30}$ represents a shortening of the axis 0.35 Mm. and $M\ \frac{1}{8}$ an increase of 1.5, the true extent of the excavation will be $1.5 + 0.35 = 1.85$ Mm.

In a case of neuritis, following sunstroke, the centre of the nerve to which the disease was almost entirely confined was hypermetropic $\frac{1}{11}$, the neighbouring region was emmetropic. As $H\ \frac{1}{11}$ represents a shortening of the axis $= 0.92$ Mm., the protrusion of the nerve was 0.92 Mm.

In another case of violent neuro-retinitis in the left eye the centre of the nerve was $H\ \frac{1}{6}$; a little further onward, $H\ \frac{1}{10}$; a little further still, $H\ \frac{1}{16}$; and at the furthest extremity of the field, towards the ora serrata, $H\ \frac{1}{30}$. In the other eye in which the process has just commenced, the general refraction was $H = \frac{1}{40}$. Assuming then that the refraction of the eyes when in a state of health was emmetropic, and it could not have been far from this, a plan might easily be drawn (as indeed was done) representing the amount of swelling due to the morbid process. This might be subsequently compared with the future progress and recession of the disease, under atrophy, etc., and some interesting results obtained. It is of course very difficult to follow these cases of retinal swelling, such as are common to Bright's disease, from their beginning to their end; still such opportunities do occur, even where the cause is renal, and it appears to me many interesting facts might be obtained from such investigations.

In a certain case a well-marked tumour was observed, situated exactly above the optic nerve, the upper edge of which it overhung. As the media were perfectly clear, a distinct view of the growth in all its detail was obtained. The crest of the tumour was, at the first examination, hypermetropic $\frac{1}{6}$. The lower half of the nerve and all the surrounding fundus was emmetropic; the protrusion of the growth was then 1.6 Mm. A subsequent examination was made and the crest of the tumour was found to be $H\,\frac{1}{4}$, the protrusion was then 2.3 mm., and the increase between the two examinations was 2.3—1.6 mm = 0.7 mm.

In another case a membrane in the vitreous appeared clearly defined when $+\frac{1}{3}$ was used, one inch from the nodal point of the examined eye; consequently there would have been, if the retina had occupied the plane of the membrane $H = \frac{1}{3-1} = \frac{1}{2}$. The fundus was in fact emmetropic; the membrane was, therefore, in front of the retina to a degree equal to $H\,\frac{1}{2} = 3.96$ Mm.

The determination of Astigmatism.—The determination of astigmatism by means of the ophthalmoscope has always been considered one of the most difficult, and from its want of accuracy one of the least satisfactory applications of the instrument, and there is no doubt that this is, to a great extent, true. Still, the difficulty in ascertaining the existence of astigmatism, and the uncertainty in establishing its degree, are, I think, due in a great measure to the method adopted, which has usually depended on the fact, first pointed out by Schweigger, that in astigmatism the disk was seen elongated in one direction with the upright image, and in the opposite by the inverted. The effect involved in this fact is due to the following causes:—

If we look through a convex lens at an object which is placed within its principal focus, we see it magnified to a certain degree, according to the power of the lens.

If we make, for example, a small cross, the arms of which are of equal length, and view it through a common convex glass, say of three inches focal distance, it appears enlarged, but equally in both directions, as the magnifying power is the same for each arm. If we now add, however, a convex cylindric glass $\frac{1}{6}$ to the spherical, we increase the magnifying power in one principal direction without altering it in the other. The lens is, therefore, equal in one direction to $\frac{1}{3}$, but in the other to $\frac{1}{3} + \frac{1}{6} = \frac{1}{2}$. If we now turn the glass in such a way that the strongest magnifying power shall correspond with the vertical arm of the cross, this will be more enlarged than the horizontal, which is seen through a weaker power, and will consequently appear longer. If we now draw a circle round the arms of the cross in such a way that these shall be the radii, the effect will still be the same, and the circle will appear elongated in the vertical direction because it is more magnified in that direction, consequently it will appear no longer a circle, but an oval.

If, however, we now take a second lens and hold it in the other hand at a certain distance in front of the first lens, just as we do in the indirect method with the ophthalmoscope, then we get an inverted image of the cross, and circle round it, elongated no longer in the vertical but in the horizontal position. The reason of this is that the rays passing through the first lens, whose principal meridians are of different focal power, are refracted unequally, those passing through the vertical meridian where the lens is of two inches focal power more than those passing through the horizontal where it is only three inches. As the rays passing through the vertical meridian are more refracted by the first lens, they will, after passing through the second, come to a focus sooner behind it, and the nearer the rays meet behind a lens the smaller is the image, consequently the vertical line of the cross will now appear smaller than the horizontal, and the circle will now be elongated horizontally.

Applying this principal to the eye, Schweigger deduced the fact that with the upright image the disk in astigmatism is seen elongated in the direction of the meridian of greatest refraction, with the inverted image in the meridian of the least refraction. This gives us at once the directions of the principal meridians, and we have only to find the glass which reduces the distortion to know the kind and amount of astigmatism.

It will be seen at once that an examination must be made by *both* methods, for it may happen that the disk may be elongated anatomically in a vertical, horizontal, or oblique direction, the effect of which might be so counteracted by astigmatism as to make the disk appear round when the ophthalmoscopic examination was made by only one method, but never when both are employed.

Simple and true as all this is on paper, its application to practical wants is limited from the fact that the distortion under the degrees of astigmatism which usually occur in the human eye, is not sufficient to form a basis for accurate calculation. It may be well to state, however, that the effect is always increased by the observer's alternately withdrawing from, and approaching the eye examined, watching as he does so the change in the contour of the nerve.

From the uncertainty and want of delicacy attending this method of examination, it is evident that, in order to make the ophthalmoscope of practical use in astigmatism, we must look for some more sensitive test to act either as a supplement or a substitute to the above, and this we have in the vessels.

If we consider the optic disk as the centre of a circle, and all the vessels large and small radiating from it as so many straight lines, we have in the fundus of the eye itself a representation of Dr. Green's test for astigmatism, in which the principal branches of the central artery and veins represent the vertical lines, and the small vessels leaving the edge of the disk the horizontal and oblique. It may be said that the principal trunks of the central artery and veins do not always run exactly vertical. This is true, but such is their general tendency, and the fact that the vessels do not continue in their original vertical course is of itself an assistance to the diagnosis.

The practical application of this is as follows: If we look with the ophthalmoscope through the cornea of an astigmatic eye to the retina beyond, the effect is precisely the same as if we were looking through an astigmatic glass, and the vessels radiating from the optic nerve will then appear just as the radiating lines do in the common test when seen through a cylindric glass, *most distinct in the meridian of greatest ametropia.* This gives us at once the direction of one of the principal meridians, and we know that the direction of the other must be at right angles to it. Having thus found out the direction of the principal meridians, we have then only to determine the refraction of each meridian separately, and the difference between the two will be the amount of astigmatism. If, for example, in a certain case the vertical vessels appear perfectly distinct, and are only rendered less so by glasses, one of the principal meridians of the eye must be emmetropic. If, however, the fine horizontal vessels are only made distinct by a concave $\frac{1}{24}$, then the second principal meridian must be myopic $\frac{1}{24}$, and inasmuch as the first was emmetropic, the amount of astigmatism present must be one-twenty-fourth.

It is a little puzzling for those who are not much accustomed to the determination of astigmatism, to understand how it is that the vessels, as do radiating lines, always appear most distinct to an emmetropic eye, in the meridian of the greatest ametropia, instead of, as would appear more rational, in that of the least. It would, for example, seem more natural, that inasmuch as the vertical vessels were seen in the above case most distinctly, that the vertical meridian should be the one which deviated least from the normal. But it must be borne in mind that the rays which form the vertical boundary of these vessels are, in fact, horizontal rays, and as such pass through, not the vertical, but the horizontal meridian, and as this is emmetropic they are readily focussed in the observer's retina. On the other hand, the rays which form the boundary of the horizontal vessels are vertical rays, and pass through the vertical meridian, which is myopic, and consequently the horizontal vessels are indistinct, although this meridian is, in fact, emmetropic.

This, of course, holds good for all kinds and degrees of astigmatism.

The writer readily admits that this method is also, though by no means in the same degree, wanting in accuracy, and is not to be looked upon at all as a substitute for the trial by glasses, but is to be used in co-operation with it. When so employed, the ophthalmoscope often renders important service in revealing to us at a single glance, as it were, the nature of the anomaly and the general direction of the principal meridians, when to have obtained them by glasses would have been an affair of hours. In cases of mixed astigmatism this holds true in a marked degree, and I cannot forbear, for the sake of their practical bearing, from citing the two following cases :—

A young lad was examined by me, who, it was alleged by his parents, was nearly "blind" in one eye. On testing the eyes, the left was found to have a trifling degree of hypermetropia ($\frac{1}{36}$) with vision one. In the right eye, however, vision was reduced to $\frac{1}{20}$, that is, Snellen C. could only be read in five feet. A few trials were made with glasses with no material improvement in vision. In looking into the eye with the ophthalmoscope the nerve appeared distorted and drawn out vertically, while at the same time its outline was indistinct in all directions, as were also all the vessels. On using the accommodation, however, the vertical edge of the nerve became well defined, as did all the vessels, so long as they ran in a vertical direction, but as soon as they deviated from this they at once became indistinct, and in proportion to the amount of the deviation. This was very apparent at a certain place where one of the larger vessels divided, sending off a branch almost at right angles to the original direction of the vessel. The branch which continued in the vertical direction remained perfectly distinct, and the double contour of its walls clearly defined, while that running at right angles to it, that is, horizontally, was indistinct and evidently much out of focus, as were, in fact, all the vessels, large and small, running in this direction, and no amount of tension or relaxation of the accommodation made them clearly defined.

It was manifest that astigmatism was present, and that the directions of the principal meridians were vertical and horizontal. It was evident, too, that as it required the action of the accommodation to make the vertical vessels distinct, that there must be hypermetropia in the horizontal meridian. In determining the degree, it was found that the strongest glass through which a certain fine vertical vessel remained distinct at two inches distance was a convex $\frac{1}{16}$, the hypermetropia in the horizontal meridian was therefore equal to $\frac{1}{16-2}=\frac{1}{14}$.

As the horizontal edge of the nerve and all the vessels running horizontally remained indistinct, even when the observer's accommodation was perfectly relaxed, it was evident that the rays which formed the horizontal boundary of the nerve and vessels must leave the eye as convergent, and as these rays are vertical rays, the eye must be myopic in the vertical meridian. It was found that the weakest glass under which the horizontal boundary of the nerve and vessels became sharply defined was $-\frac{1}{10}$, the vertical meridian was therefore myopic equal to $-\frac{1}{10+2}=\frac{1}{12}$.

The case was therefore one of mixed astigmatism, in which the vertical meridian was myopic $\frac{1}{12}$, and the horizontal hypermetropic $\frac{1}{14}$, and the discrepancy between the two meridians was $\frac{1}{12}+\frac{1}{14}=\frac{1}{6\frac{1}{2}}$. With a bicylindric glass $-\frac{1}{12}$ and $+\frac{1}{14}$ vision at once rose from $\frac{1}{20}$ to $\frac{8}{20}$. It was in fact increased eightfold. It was subsequently found from a care ful examination that $-\frac{1}{13}$e and $+\frac{1}{13}$e was preferred. With this glass, vision became one-half.

In another case, where the patient suffered a great deal from asthenopic symptoms, vision was found to be only one-fifth in either eye. Reading was performed at six inches, while in sewing the patient declared that she had to exercise great care to keep from wounding her nose with the needle. As in the former case, spherical glasses were tried with but little improvement of vision. On looking into the eye, here too neither the nerve nor any of the vessels appeared distinctly defined. On accommodating, however, it was seen that although the vertical and horizontal vessels still remained comparatively indistinct, those that originally ran, and those which later in their course assumed an oblique direction upwards and inwards and downwards and outwards (about $+ 30°$ Green) suddenly came sharply into view, while those which ran at right angles became the most indistinct of all. The same effect was noticed all over the fundus, especially in following along the course of a vessel, some of whose branches appeared perfectly distinct, while those running at right angles were much out of focus. This meridian was found to be myopic $\frac{1}{20}$, the opposite hypermetropic $\frac{1}{11}$. With these glasses properly arranged, vision rose from one-fifth to two-thirds, and the patient could read Jaeger No. 4 at ten inches, and sew with ease at twelve. The left eye was $\frac{1}{18}$e $\Gamma - \frac{1}{20}$e $V = \frac{1}{2} +$.

One of the principal causes which have retarded the more general use of the upright image in ophthalmoscopy is the necessity for a constant change of the glass behind the mirror and consequent loss of time and inconvenience. To avoid this, and to expedite the determination of errors of refraction, the writer has adopted the following modification of the ophthalmoscope,[1] the principal feature of which is the substitution of detachable cylinders for the fixed Rekoss disk, now common to a number of ophthalmoscopes. In the present case but three cylinders are employed, though these might be multiplied indefinitely were there any occasion for so doing. Each cylinder is pierced for eight glasses, forming in the aggregate the following series:—

$$\text{Convex} \ldots\ldots\ldots 0, \frac{1}{48}, \frac{1}{24}, \frac{1}{16}, \frac{1}{12}, \frac{1}{10}, \frac{1}{8}, \frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}.$$

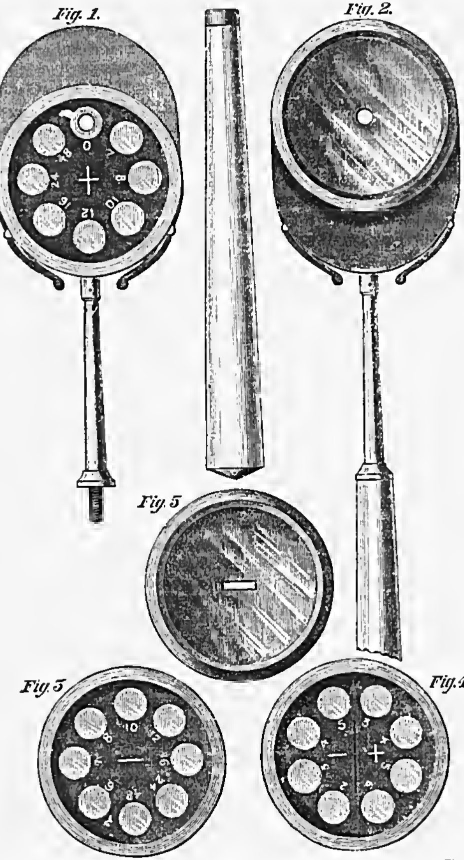
$$\text{Concave} \ldots\ldots\ldots \frac{1}{48}, \frac{1}{24}, \frac{1}{16}, \frac{1}{12}, \frac{1}{10}, \frac{1}{8}, \frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2},$$

Thus we have a series of glasses extending, with but comparatively slight differences in focal value, from convex $\frac{1}{48}$ to $\frac{1}{3}$ and from concave $\frac{1}{48}$ to $\frac{1}{2}$.

The manner in which the glasses are divided among the cylinders will

[1] This instrument was exhibited to the American Ophthalmological Association at its meeting in July last, and a description of it is inserted in their Transactions, but as that publication is not accessible to most of our readers, a few copies only having been printed, and as the description is essential to the completion of this paper, we reproduce it here.

be readily understood from the accompanying figures. The first cylinder is made up entirely of convex glasses, by means of which all ordinary de-



Explanation of Figures.—Fig. 1. Back of instrument with cylinder in position. Fig 2. Front view of instrument. Figs. 3 and 4. Remaining cylinders detached. Fig. 5. Astigmatic optometer and mirror.

grees of hypermetropia can with sufficient exactness be determined. One hole (0) is left vacant to represent emmetropia, without the necessity of removing the cylinder, and for examination by the inverted image without an eye-piece; should, however, the latter be desired, the observer has a large selection at his command. The second cylinder contains the concaves of moderate focal power, and the third is composed of the high numbers, both positive and negative. These strong numbers are designed for the determination of the highest degrees of errors of refraction and for the measurement of the inequalities of the fundus, such as excavations and elevations of the optic nerve, projections of tumours, retinal detachments, membranes in the vitreous, etc. With the stronger convex, such as $\frac{1}{3}$, opacities of the cornea and lens can be viewed under considerable enlargement.

The cylinders fit into a cell at the back of the instrument and are held firmly in their place by means of the two small springs shown in the engraving, which projecting into a groove in the side of the cylinders, prevent these from falling out, yet do not interfere with their rotation. In turning, the centre of the glass comes opposite the centre of the hole in the mirror.

Great care was taken to have the mirror, which is concave, seven inches' focal distance, ground exceedingly thin—as thin almost as a metal mirror —while the surrounding brass work is so bevelled away that as little impediment as possible is offered to the passage of the rays, thus rendering the image perfectly distinct, and I think unusually brilliant.

The mirror being contained in a separate case of its own is made detachable from the rest of the instrument, which can then be used as an optometer, the patient himself revolving the cylinder till the suitable glass is obtained. As the perforation through which the patient looks when the mirror is removed is equal to the diameter of the glass (three lines), and is much larger than the normal pupil, the peripheral rays are not cut off, which is usually a source of error when smaller diaphrams are used.

The handle of the instrument has purposely been made unusually long, so that the observer's hand shall not interfere with an easy and close proximity to the observed eye, which is a great advantage in examination by the upright image.

The instrument, the three cylinders, and a convex two and one-half inch lens for examination by the inverted image, are all contained in a small pocket-case, measuring four and three-quarter inches by two and one-half square by three-quarters thick.

Besides the common concave mirror which comes with the instrument, I have had two others constructed which may not be unworthy of mention. The first is intended for examination by the "weak illumination," and is precisely similar to the common concave 7″ mirror, silvered on the back, only it is made from London smoke instead of colorless glass.

As it is the property of London smoke glass to simply reduce the quantity of the transmitted light without sensibly altering its colour, it occurred to me that any degree of illumination might be obtained by using various shades of the glass, without sensibly changing the appearance of the fundus. I have made many experiments with these mirrors and have finally settled upon two as the most serviceable. One is even weaker than the three plates of plane glass—so weak indeed that the patient is hardly aware that any light is thrown into his eye. The other is made from a much lighter shade, and gives a reflection intermediate in brilliancy between the ordinary weak and strong reflectors. By its means a much more brilliant picture is obtained than with the plane glass mirror, while at the same time with much less glare to the patient than with the ordinary silvered one. The advantages of these mirrors are that the quantity of light can be varied and that they can be so easily kept clean.

The common weak mirror, consisting of three plates of plane glass, could however be easily fitted to the instrument should it be desired.

The remaining mirror mentioned above was originally designed for a stenopæic slit to be used with the instrument when employed as an optometer for the determination of astigmatism. It consisted of a thin plate with a slit in it, whose length was equal to the diameter of the perforations in the cylinder. This was mounted like the mirror, and made to fit in the mirror cell in which it revolved, so as to allow the slit to correspond with any given meridian of the cornea. The meridian once determined, the patient turned the cylinder till the suitable glass was obtained. This plate was subsequently made with a polished surface in front, and then was made to serve also as a mirror for determining, by means of the ophthalmoscope, the amount of astigmatism in the principal meridians of the eye.

I would take this opportunity of informing those who are desirous of obtaining this instrument that it can be had of its maker, H. W. Hunter, Optician, 1132 Broadway, N. Y. City.

APPENDIX.

Directions to be Observed in Case the Observer is Ametropic.

The observer being myopic.

PROPOSITION I. *For a myope to examine an emmetropic eye.*—It is very evident that as the rays which leave an emmetropic eye are parallel, that the myopic observer, provided he can relax his accommodation, will simply have to use the glass behind the mirror, which neutralizes his myopia, that is to say, which brings parallel rays to a focus on his retina. If a concave $\frac{1}{8}$ does this, then $\frac{1}{8}$ will be the glass employed, and whenever he sees an eye distinctly with this glass, he knows that the rays which leave it must be parallel and consequently it must be emmetropic.

But it may happen that the myopic observer like the emmetropic cannot relax his accommodation, while using the ophthalmoscope. This will make him just so much more myopic, and instead of using, say $\frac{1}{8}$, which fully neutralizes his myopia, he will with the ophthalmoscope have to use, in order to bring parallel rays to a focus in his retina, $\frac{1}{6}$ or $\frac{1}{5}$. Under these conditions his eye is equivalent to a myope's of $\frac{1}{6}$ or $\frac{1}{5}$, whose accommodation is entirely relaxed. The observer will then know that when the eye under examination is seen clearly with this glass it must be emmetropic.

As the rays leaving the emmetropic eye will always strike upon the glass used as parallel, it is evident that the distance between the two eyes need not be here taken into account, and that, consequently, the observer may be one or more inches from the observed eye, as he pleases.

PROPOSITION II. *For a myope to determine the degree of myopia in the observed eye.*—If the observer does not wish to wear a correcting glass, which is often inconvenient and clumsy, the simplest way for him is to proceed with the examination just as an emmetrope would, and find by trial with what glass he sees the fundus most distinctly, his accommodation being of course relaxed, and then to take into account the amount of his error in refraction; saying, for example, a myope of $\frac{1}{6}$ finds that he sees the fundus of the examined eye with concave $\frac{1}{3}$, what is the amount of M present?

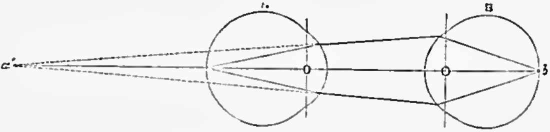
The observer knows that a part of this glass $= \frac{1}{6}$ is employed in neutralizing his own myopia; consequently to get the true glass through which the fundus would be seen independent of his error of refraction, he must substract this $\frac{1}{6}$ from $\frac{1}{3}$ used, $\frac{1}{3} - \frac{1}{6} = \frac{1}{6}$. Now assuming the distance to be two inches, we have $\frac{1}{6+2} = \frac{1}{8}$. The amount of myopia in the examined eye is therefore equal to $\frac{1}{8}$, and a myope of $\frac{1}{6}$ will have to use $-\frac{1}{3}$ at two inches, in order to see the fundus clearly.

From this it will be seen that the myope of even a medium degree will have to use very strong glasses to see the fundus of an eye which is only moderately myopic. Now as ophthalmoscopic cases do not usually contain these strong glasses, it follows that the myopic observer must renounce in many cases examinations by the upright image.

By far the best way of avoiding this difficulty, is to have a small movable slide containing the proper glass fitted to the back of the instrument. This will not interfere with the use of the glasses ordinarily placed in the clip. There is no real disadvantage in seeing through two concave glasses; on the contrary, according to Maunther, an actual advantage over one very strong glass, inasmuch as the image by the use of the two weaker glasses is more aplanatic than where one strong glass is employed. The lessening in illumination is so small as to be of no consequence at all.

PROPOSITION III. *For a myopic eye to determine the degree of hypermetropia in a given case.*—Let A represent a hypermetropic eye of $\frac{1}{8}$; rays coming from the fundus of such an eye will diverge as if they came from a point eight inches behind the nodal point at a'. If now a myope of $\frac{1}{10}$ (B), places his eye two inches in front of the observed eye, then the rays which enter his eye will diverge as if they came from a point ten inches in front of his nodal point,

Fig. 6.



that is to say, his far point, and as his eye is just adapted for such rays, they will come to a focus on his retina, and he will get a clear view of the fundus without the use of any glass.

If the observer's eye is at four inches from the observed eye, then the rays which enter his eye will diverge as if they came from a point twelve inches in front of his nodal point, the observer will only have to be myopic $\frac{1}{12}$ to bring such rays to a focus. The hypermetropia in the observed eye is then always greater than the observer's myopia by as much as the observer's eye is distant from the observed. In the above case $H = \frac{1}{10-2} = \frac{1}{8}$. $H = \frac{1}{12-4} = \frac{1}{8}$.

If the hypermetropia in the observed eye is greater than the observer's myopia (the distance between the two eyes being taken into consideration), it is evident that the rays will emerge so divergent that they will no longer meet upon the observer's retina, but behind it. In order to bring such rays to a focus he must make himself so much more myopic. This he does by a convex glass which he finds by trial just as an emmetrope would. For example, a myope of one-eighteenth finds that he needs a *convex* $\frac{1}{18}$ to see the fundus distinctly. If he adds this glass he is no longer myopic $\frac{1}{18}$, but $\frac{1}{18}+\frac{1}{18}=\frac{1}{9}$. Now we have just found that the H equalled the M minus the distance, and as the $M=\frac{1}{9}$th, we get $H=\frac{1}{9-2}=\frac{1}{7}$.

The observer may in this case use his A instead of a lens, providing he can estimate the amount.

If, however, the hypermetropia in the observed eye is less than the myopia of the observer (the distance between the eyes being taken into account), it is evident that the rays emerging from the eye will be so little divergent, that the stronger myopia of the observer will cause them to meet in front of his retina. The observer must make himself less myopic in order to bring such rays to a focus on his retina; this he does by means of a *concave* glass. For example, a myope of $\frac{1}{6}$ can only see the fundus in a given case with $-\frac{1}{18}$, what is the H of the observed eye? By placing the concave glass before his eye, he has reduced his myopia so that he has no longer $M=\frac{1}{6}$, but $\frac{1}{6}-\frac{1}{18}=\frac{1}{9}$. As we have previously found that $H=M$ minus the distance, we have $H=\frac{1}{9-2}=\frac{1}{7}$.

The observer being hypermetropic.

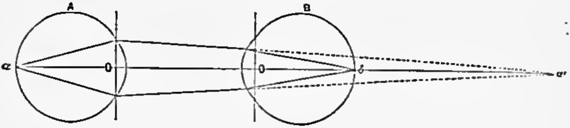
PROPOSITION IV. *For a hypermetropic observer to see an emmetropic eye.*— Inasmuch as the rays leaving an emmetropic eye are parallel, the observer, in order to bring such rays to a focus on his retina, will simply have to neutralize his manifest hypermetropia. If he is $H\ \frac{1}{12}$, then he will simply have to place a convex $\frac{1}{12}$ behind the mirror.

He may find, however, that with the ophthalmoscope he does not relax his accommodation. His hypermetropia, consequently, will be reduced by just the amount of accommodation which he is using. And he may find that instead of using say a convex of $\frac{1}{12}$, which fully neutralizes his manifest H, he will, with the ophthalmoscope, require only $\frac{1}{24}$ to bring parallel rays to a focus. Under these conditions his eye is in fact equal to a hypermetrope's of $\frac{1}{24}$, who can entirely relax his accommodation, and the observer will then know that an eye seen distinctly through this glass must be emmetropic. It may happen in this way that a person who is slightly hypermetropic for the distance, becomes for the ophthalmoscope emmetropic, and so has to use no glass at all; or even myopic, and then will have to use a slightly concave glass. For example, a hypermetrope of $\frac{1}{36}$ may find on account of his inability to relax his accommodation, that in order to see an emmetropic eye he needs a concave $\frac{1}{36}$. The amount of accommodation which he uses would then only be $\frac{1}{18}$ and many inexperienced observers use $\frac{1}{12}$. In this case the observer is virtually myopic, and must proceed as such.

The observer may of course use his accommodation in all cases instead of a convex-glass, that is to say, the lens in his own eye instead of one behind the mirror. He would, however, in this case have to know just what amount of tension of his ciliary muscle corresponds to a given glass.

PROPOSITION V. *For a hypermetropic observer to determine the amount of myopia in the observed eye.*—Let A be myopic $\frac{1}{8}$; rays of light coming from a will meet eight inches in front of A's nodal point at b. If B, who is hypermetropic $\frac{1}{6}$, places his eye two inches from A, then rays from A would meet, if uninterrupted, at a point just six inches behind B's nodal point. Now as B's

Fig. 7.



eye being hypermetropic $\frac{1}{6}$ is adapted for such rays, they will be brought to a focus on the retina. Consequently A's myopia must be equal to B's hypermetropia plus the distance, $M = \frac{1}{6+2} = \frac{1}{8}$. From this it follows that a hypermetrope of a certain degree can see the fundus of a myope of a certain degree without any glass.

If, however, the myopia of the observed eye is greater than the observer's hypermetropia, it is evident that the rays emerging from the eye examined will be so convergent that they will meet in front of the observer's retina; to bring them to a focus he must make himself more hypermetropic. This he does by means of a concave glass, which he finds just as an emmetrope does by trial. For example, a hypermetrope of $\frac{1}{18}$ finds that he, with his accommodation relaxed, sees the fundus distinctly in a given case with concave $\frac{1}{9}$, what is the myopia in the observed eye?

By putting the concave $\frac{1}{9}$ before his eye, the observer has made himself just so much more hypermetropic. He is consequently no longer hypermetropic one-eighteenth, but $\frac{1}{18} + \frac{1}{9} = \frac{1}{6}$. Now as the myopia in the observed eye is equal to the observer's hypermetropia plus the distance, we get $M = \frac{1}{6+2} = \frac{1}{8}$.

If, however, the myopia in the observed eye is less than the observer's hypermetropia (the distance between the two eyes also taken into consideration), rays emerging from the observed eye will not be convergent enough to meet on the retina, but behind it. To make such rays meet on his retina he must make himself less hypermetropic. This he does by a convex glass which he finds by trial. For example, a hypermetrope of $\frac{1}{9}$ sees in a given case with a convex $\frac{1}{18}$, what is the degree of myopia present in the examined eye? By adding the convex $\frac{1}{18}$ to his eye, the observer has reduced his hypermetropia, making himself no longer hypermetropic $\frac{1}{9}$, but $\frac{1}{9} - \frac{1}{18} = \frac{1}{18}$. Now as the myopia equals the hypermetropia plus the distance, we get $M = \frac{1}{18+2} = \frac{1}{20}$. Thus we see that a hypermetrope may, according to circumstances, in estimating myopia, use no glass at all, or a concave, or a convex one.

PROPOSITION VI. *For an hypermetropic observer to estimate the amount of hypermetropia in the examined eye.*—The best way in this case is for the observer to find by trial with what glass he sees the fundus most distinctly, and then to take his own error of refraction into consideration. For example, a hypermetrope of $\frac{1}{18}$ sees the examined eye with convex $\frac{1}{6}$, what is the hypermetropia present? The observer knows that a part of this, equal to one-eighteenth, is employed in neutralizing his hypermetropia, consequently to get at the true glass which would be used independently of his error in refraction he must subtract this $\frac{1}{18}$. $\frac{1}{8} - \frac{1}{18} = \frac{1}{18}$. As the observer has thus neutralized his hypermetropia, he is virtually emmetropic, and knows that the H present must be equal to the glass used minus the distance. $H = \frac{1}{18-2} = \frac{1}{16}$.

ART. IV.—*Cases of Nerve-Irritation, cured by Surgical Operations.* By JOHN H. PACKARD, M.D., of Philadelphia.

THE following cases, which occurred to me in the summer of 1869, seem to be of sufficient interest to warrant me in laying them before the readers of the Journal. I propose first to narrate them, and then to offer a few brief comments upon them.

In one of these cases there was irritation of the terminal filaments of the median nerve at the side of the last phalanx of the thumb; in the second, the trunk of the infrao-rbital was the seat of trouble; in the third, the cerebrum itself was pressed upon. In all, the operations resorted to gave complete relief.

CASE I.—Miss E. N., æt. 11 years, was brought to my office on April 12th, 1869, with a very large splinter of wood under her right thumb-nail, at the ulnar side, which had been three days previously forced in while she was driving her hoop. A neighbouring physician had advised poulticing, to draw it out; but it was firmly imbedded, and pus had formed at the root of the nail, while the tension of the tissues gave rise to exquisite pain. She was suffering so much that her parents took her to Dr. F. G. Smith, their regular attendant, who sent her to me.

I at once sent her home, as soon as possible etherized her, and removed the splinter; making also an incision in the pulp of the thumb, where pus was beginning to form, which afforded very great relief. The wounds healed kindly, although the swelling was slow in subsiding.

In July the child was again brought to me, suffering from very grave general symptoms of nervous irritation. She had choreic movements of the whole body, of all the limbs, and of the jaw; the right half of her person being somewhat more affected than the left. She had lost flesh and strength, was peevish, irritable, and unable to fix her attention on anything. Her appetite was very poor. Locally, there was sensitiveness of the affected thumb, which she could not use in grasping; thus she could not use her right hand at the table, or in writing or sewing.

By Dr. Smith's direction, she was using iron, quinia, and arsenic, and was soon to be taken to the sea-shore at Cape May. I advised also the constant protection of the thumb by a plaster containing the extracts of opium and belladonna.

On her return from the sea-shore she was somewhat improved in general health, but the irregular movements still continued, and with undiminished intensity. After she had been at home a few weeks, she began again to lose condition; and as there seemed to be one point of special sensitive-