and automatic; the acquired faculties being organized in the constitution of the sensori-motor ganglionic nuclei, the movements follow as reflex effects of an external stimulus. Another point especially deserving attention in connexion with these focal adjustments, is the combined precision and incessant variation required: so long as a person is awake, alterations in the distance between the retina and objects under observation must be taking place at every instant, necessitating corresponding alterations in the curvature of the lens; for it has been proved that, for correct vision, not only must the rays of light be brought to a focus on the retina, but they must be accurately focussed on its bacillary layer.

Focal adjustments.

Attributed to the ciliary muscle.

The highest authorities of the day hold, that the accommodation of the eye is effected by the action of the ciliary muscle. Donders says—"It therefore remains only to attribute to the musculus ciliaris the important quality of accommodation muscle. But the mechanism whereby the contraction of this little muscle alters the form of the lens, to however small a compass the question may now be reduced, is not yet satisfactorily or convincingly brought to light."*

In support of this idea we cannot overlook the fact that in those animals whose range of accommodation is highest, as birds, the ciliary muscle is largely developed; in those, as fishes, in which accommodation is almost *nil*, the ciliary muscle is hardly developed.

At one time it was supposed, that in the accommodation of the eye the action of the ciliary muscle was much assisted by the iris; but Von Graefe's case has settled this point; for in this instance, the whole of the iris was removed and yet the focus of accommodation remained perfect.

* "Accommodation and Refraction of the Eye," by Donders, p. 26 (New Sydenham Society).

CHAPTER II.

Methods employed in examining the Eye, and testing the patient's Vision — The Ophthalmoscope: its Principle and Use—Ophthalmoscopic Appearances of the Healthy Eye.

EXAMINATION OF THE EYE.

Examination of the Eye.

Light.

The first and most essential point to attend to in examining the eye is, that it should be illuminated by a clear, bright light. The patient may conveniently be seated before a window, the surgeon standing in such a position, that no part of his person intercepts the rays of light from falling directly on the patient's eye, and yet enabling him to examine the part thoroughly.

Manipulation.

The next thing to be done is to open the eyelids, the upper one with the thumb of one hand, and the lower with the other. This manipulation, though simple enough, requires care; even slight pressure on the diseased eyeball frequently causing pain and irritation, followed by a gush of tears from the eye, which for the moment prevents us from proceeding with our examination. The lids having been separated as far as possible, the condition of the cilia, puncta, conjunctiva, sclerotic, cornea, and iris should be carefully noticed.

The two eyes to be compared.

If one eye only is diseased we must compare its condition with the sound eye; slight alterations in the colour and brightness of the iris, which may nevertheless be very significant, are often thus distinguishable, and any abnormal prominence or flattening of one cornea will be made more apparent by contrast with the other. It is, moreover, by a comparative examination of this kind, that we ascertain the nature of the various derangements that are met with in connexion with the muscular apparatus and movements of the eyeball.

Measurement of strabismus.

The degree of diplopia, or squint, existing in any particular case may be obtained by directing the patient to look at a distant object in front of him, and then making a mark on the lid opposite to the centre of the pupil of the squinting eye; if now the working eye be closed, and the patient still directed to look at the distant object, the squinting eye will move outwards so as to fix the object under observation, and another mark must then be made on the lid below the pupil; the distance between the first and second dots will measure the angle of squinting.

Activity of the pupil.

Examination of the Iris.—It will frequently be necessary in examining the diseased eye, to ascertain if the iris responds to the stimulus of light, or in other words, if the pupil dilates and contracts freely. To determine this, the patient should be placed before a moderately strong light, which falls obliquely, from one side only, on the eye. The unaffected eye should be closed with a folded cloth or the hand, so that no light can reach it. The surgeon then places himself in such a position, that while he throws a very dark shadow on the uncovered eye with his hand, he keeps the pupil well in sight. Fixing his eye on the edge of the pupil he quickly removes his hand so as to allow a bright light to fall on the eye, and then the eye is again shaded, and so on. If the iris be healthy the pupils will have dilated while the light was shaded from the eye, but will contract again the instant that luminous rays reach the retina.

Value of its indications.

Any deviations from this rule should be carefully noticed, for, in the absence of synechia or other mechanical impediment to the motions of the iris, the character of its response to luminous impressions afford us valuable information in many disorders affecting the deep-seated structures of the eye. The retina may, however, be extensively diseased and yet the pupils dilate and contract on the stimulus of light, for as I have before remarked, light falling on the retina of a healthy eye will through reflex action cause the contraction of the iris in the other eye, although it be amaurotic; and, on the other hand, an inactive and dilated pupil does not by any means invariably indicate a diseased condition of the retina. In all doubtful cases it is advisable to apply a weak solution of atropine to the eye, the existence of synechia are demonstrated in this way, the affected pupil dilating in

Use of atropine.

an irregular manner. But supposing there are no such complications, the atropine will nevertheless be useful, enabling us the better to examine the deeper structures of the eye with the ophthalmoscope.

Examination of the lids.

Eyelids and Lachrymal Apparatus.—It is by no means an uncommon circumstance for foreign bodies to become lodged beneath the upper lid, and in order to see them it is necessary to evert the lid.

Mode of everting them.

A steel probe, or some such blunt instrument which will not easily bend, is laid against the skin of the lid along the upper border of the tarsal cartilage, or about half an inch from the free margin of the lid; the surgeon, with the other hand, takes hold of some of the most prominent cilia, and after gently drawing the lid forward, turns it backwards over the probe; if the patient be now directed to look downwards, the whole of the superior palpebral conjunctiva may be examined.

Lachrymal obstructions.

The condition of the passages by which the lachrymal secretion passes from the eye into the nose often requires investigation, for should they become occluded, it is evident that the tears will be unable to escape through their proper channel, and accumulating at the inner corner of the eye will overflow and run down the cheek.

Situation ascertained.

Under these circumstances an idea may be gained of the seat of the obstruction from the following considerations:—If the puncta and canaliculi are healthy, gentle pressure made over the lachrymal sac will cause a minute drop of fluid to ooze out through the puncta; but supposing these structures to be impervious, no such regurgitation of fluid can take place. If therefore constant lachrymation exists, and on making pressure below the tendon of the orbicularis, a drop of fluid oozes out through the puncta, we may conclude that the obstruction is in the nasal duct.

Displacement of the puncta.

There are, however, exceptions to this rule, for if the lachrymation depends on malposition of the puncta, either from chronic inflammation and thickening of the conjunctiva, from paralysis of the orbicularis, or any other cause slightly displacing the puncta, it is evident that only a portion of the tears can gain access to the sac, the remainder flowing over the cheek. Under these circumstances, the lachrymal sac being partly full, if pressure is made over it, a drop of fluid will ooze out through the puncta; but in such cases there can be no difficulty in ascertaining the cause of the overflow, the displacement of the puncta being readily detected by simple inspection.

Exploration by probe.

If we have reason to suppose that either the puncta or canaliculi are closed, we may explore the parts by introducing a fine probe into the punctum, and passing it along the canaliculus into the lachrymal sac. This is an easy matter if the parts are healthy, but if obstructed, we shall be unable to push the instrument beyond the point of stricture. In this operation the lid should be slightly everted, so as to expose the punctum, and a fine probe should be passed into it for about half a line in a perpendicular direction, the instrument being afterwards directed horizontally inwards towards the lachrymal sac. Care should be taken in passing the probe, as the mucous membrane lining the canal is a very delicate structure, which may readily be torn or injured, and a permanent stricture of the canal result.

Caution required.

Some slight resistance to the passage of the probe is often felt at one or both extremities of the canaliculus; this arises from the presence of two small valves, and the involuntary contraction of the sphincter muscle which surrounds the orifices of the duct. Gentle, but continued pressure with the probe, in the direction above indicated, will speedily overcome the spasm of these contractile fibres, and the instrument will then readily enter the sac, and its point may be pushed against the inner bony wall.

Tension of the eyeball.

Tension of the Eyeball.—The patient should be directed to close the lids of the eye under examination; the surgeon then places the tip of one forefinger on the outer part of the eyeball, exerting gentle pressure on the opposite side of the globe with the forefinger of the other hand; the amount of resistance offered indicates the degree of tension. In its healthy state the globe can be easily dimpled, but in chronic glaucoma it becomes of stony hardness. Mr. Bowman remarks:*—

Bowman's scale and register.

"I have found it possible and practically useful to distinguish nine degrees of tension, and for convenience and accuracy of note-taking have designated them by special signs. The degrees may be thus exhibited:

"T represents tension, T N tension normal; the interrogation (?) marks a doubt, which in such matters

* "British Medical Journal," 1862, vol, ii. p. 378.

we must often be content with; the numerals following the letter T on the same line, with or without the sign +, indicate the degree of increased tension; or if the letter T be followed by —, of diminished tension.

"It is also to be borne in mind that the normal tension has a certain range or variety in persons of different age, build, temperament, and according to varying temporary states of the system as regards emptiness and repletion."

Test types.

Test Types.—It has been found advantageous to have a fixed scale by which to test the acuteness of vision, and which may be used not only as a standard of comparison between one person and another, but also to ascertain whether a patient's sight be improving or otherwise under treatment. Snellen's test types are now commonly employed for this purpose.* A series of these types from No. I. to No. XX. are arranged according to the size of the letters, so that No. I. is seen by a normal eye at a distance of one foot at an angle of five minutes, and its letters cannot be distinctly made out beyond that distance. The letters of No. II. are seen at two feet distance at the same angle, and so on, up to No. XX.

Snellen's types.

Method of using them.

Supposing now a patient to be affected with a defect of vision, so that he cannot see No. I. type at a distance of twelve inches from his eyes, but can make out No. IV. type at this distance; evidently he requires to see the letters under a larger angle than that of five minutes, in order that he may gain a larger retinal image. We calculate the degree of acuteness of vision as follows:—

V = Acuteness of vision.
d = utmost distance at which the type is recognised.
D = distance at which type appears at an angle of five minutes.

$$\text{Then } V = \frac{d}{D}.$$

For instance, the individual who, having his eyes properly accommodated, distinguishes No. XX. test type

* Various forms of test types may be obtained from Messrs. Williams and Norgate, Henrietta Street, Covent Garden, London.

only at ten feet, instead of twenty feet, has diminished acuteness of vision,

$$V = \frac{10}{20} = \frac{1}{2}.$$

If he can only distinguish No. III. type at one foot, his acuteness of vision $V = \frac{1}{3}$, and so on.

Range of accommodation.

The range of accommodation for vision at different distances varies in different individuals and at different periods of life; in the normal or emmetropic eye, the nearest point of distinct vision is from three and a half to four inches, and the furthest point is at an infinite distance, being limited only by the loss of the rays of light, due to atmospherical or physical causes.

Visual field.

The Visual Field.—The visual powers may be almost perfect at the macula lutea, and yet beyond this spot the functions of the retina may be completely destroyed. It is often necessary, therefore, to ascertain the extent of the visual field—that is, of the integrity or otherwise of the whole of the sentient surface of the retina.

Limits ascertained.

The limitation of the visual field may be ascertained in the following manner. The patient is seated at a distance of a foot from a blackboard, or a frame in which has been placed a sheet of blue tissue or other paper. On the centre of this a small cross is marked with chalk or pencil, and the patient is directed to fix his eye upon this point, the other eye being closed. The crayon is now moved over the paper, being carried successively upwards, downwards, and to the right and left horizontally, marking in each direction the extreme limits at which the patient perceives it. The same plan is followed for all intermediate points, and the outline thus drawn upon the board or paper shows the limit of the field of visual perception. The other eye may then be tested in the same way.*

A good idea of the extent of the visual field may be obtained by directing the patient to close one eye, and with the other to look steadily at one of the observer's eyes. While the patient keeps his eye fixed in this way, the observer moves one of his hands in various directions over the patient's field of vision, ascertaining how far the hand can be seen from the optic axis

* "Recent Advances in Ophthalmic Surgery," by Dr. Williams of Boston, U.S., p. 30.

of the eye under observation. It is evident that under these circumstances, if the functions of any part of the retina external to the macula lutea is impaired, that the patient will be unable to see the observer's fingers when situated at the corresponding part of the visual field.

Another method.

If the patient's sight is so far impaired that he can no longer count fingers, it may yet be necessary to test the extent of the field of vision, which may be managed as follows. One eye being closed, a white disc may be moved over the surface of the blackboard, and the point at which the patient recognises the object should be marked on the board; or the uplifted hand may be held at a distance of a foot from the patient's face, and having directed him to look towards it, a lighted candle is to be held in different positions in the visual field, and the spots noted at which it can be seen.

THE OPHTHALMOSCOPE.

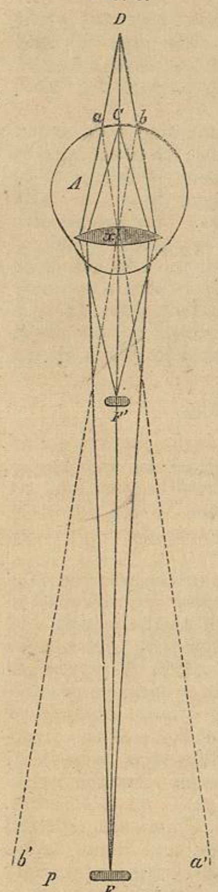
The Ophthalmoscope.

The ophthalmoscope is now in such constant use as a means of exploring the condition of the deeper structures of the eye, that I need not dilate on the advantages it offers in the investigation of affections of those parts, which were formerly very obscure.

Its principle and use.

Illumination of the Eye.—The reason why we cannot ordinarily see the interior of the eye without the aid of such an instrument, as well as the principle of its action, will both become intelligible by reference to the following figure (Fig. 3), in which A represents the eye under examination, accommodated to the distant point F, where the flame of a lamp is supposed to be situated. It is evident that some of the divergent rays, proceeding from the luminous body at F, will fall upon A's cornea, and being refracted by its dioptric media, they will meet at C on A's retina. Some of these rays are absorbed, others are reflected by the structures of the fundus, and these, before emerging from the eye, must pass through precisely the same media as they did on entering it; and in consequence of their pursuing this path, they will be brought to a focus at the point from which they started—namely, at F. Unless an observer's eye, therefore, can be made to take the place of the lumi-

FIG. 3.



Why the pupil appears black.

nous body at F, it is evident that none of the reflected light from A's retina can possibly reach the observer's. A's pupil, therefore, appears black to a person in the position *p*, or, in fact, at any other point than at F.* If, however, a mirror with a hole in its centre, through which light can pass, be substituted for the lamp, and the rays reflected from its surface be directed into the eye A, the light returning from A's retina can now enter the observer's eye, which, under these circumstances, may be made to occupy the position of the lamp, as represented in Fig. 3.

Illumination by a perforated mirror.

Again, suppose the luminous body is removed from the point F to F′ (the patient's eye being still accommodated for the distance A F), the divergent rays proceeding from it, and being refracted by the dioptric media of A, would intersect at D, were they not intercepted by the fundus of the eye; as it is, they form a circle of light extending from *a* to *b*. But since the eye A is adjusted for the far point F, and not for F′, it follows, that the rays reflected from any point in the circle *a b*, after emerging again from A, will be brought to a focus at the distance A F; and those from the extreme points *a* and *b* will converge respectively to *a′* and *b′* in lines prolonged from *a* and *b*

* "Manual of Instructions for the Guidance of Army Surgeons in Testing the Range and Quality of Vision." By Deputy Inspector-General J. Longmore, Professor of Military Surgery at the Army Medical School. Page 38.

through *x* the optical centre of A. Under these circumstances, an observer's eye at any point *p* will receive a few of the rays from A's retina, which will thus appear illuminated, even without the aid of a mirror.

If these considerations be applied to the ophthalmoscope, the principles upon which this instrument depends as a means of illumination, may be readily comprehended, it being essentially a mirror, constructed so as to allow the observer's eye to take the place of the flame of the lamp, as represented in Fig. 4. As, however, the deeper parts of the eye are only seen through its refracting media, we have still to explain the formation of images of those parts, which may be distinctly visible to the observer.

Formation of images.

Formation of Images.—There are two distinct modes of examining an eye with the ophthalmoscope, known as the direct and the indirect methods. By the former an erect geometrical image is perceived by the observer, and by the latter an inverted aerial image is produced.

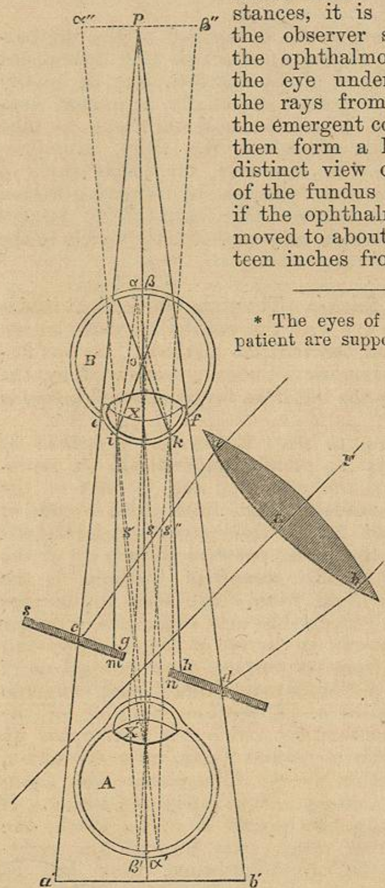
1. Direct method.

1. By referring to Fig. 4, the *direct method of examination* may be readily understood. A represents the eye of the observer, and B that of the patient, F the source of light, from which a cone of rays *a b* falls upon L, a double-convex lens interposed between F and the plane polished surface *c d* of the ophthalmoscope S. By means of the lens L the divergent rays of light from F are made to converge upon the mirror (which thus acts as a concave mirror in a position posterior to the eye of the observer), and after reflection from its surface, they proceed as if they came from *a′ b′* situated behind it, and converge towards some point *p*. A portion, however, of the rays included between *g i* and *h k* is intercepted by the dioptric media of B, and these, after refraction, intersect at O within the eye, from whence they again diverge to form a circle of light upon B's retina. If in this circle any two points *a*, *β*, be taken, the reflected rays from which pass through the sight-hole *m n* of the ophthalmoscope, they will be brought to a focus at *a′* and *β′* on A's retina, and a virtual, erect, and magnified image *a″ β″* of *a β*

Image erect, magnified.

will be seen by the observer, apparently projected beyond the patient's eye.*

Fig. 4.



(From Carter's translation of *Zander*.)

To obtain a clear view of the retina under these circumstances, it is necessary that the observer should advance the ophthalmoscope close to the eye under examination; the rays from the centre of the emergent cone of light will then form a large and very distinct view of minute parts of the fundus of the eye; but if the ophthalmoscope be removed to about twelve or fourteen inches from the patient's

* The eyes of both observer and patient are supposed to be emmetropic, that is, a clear and distinct image of an object is seen at ordinary visual distances. The magnification of the image in this case is so far a defect, that it loses in brightness and definition as it gains in size, and therefore contrasts unfavourably with the bright, sharp, beautiful image which the indirect method displays. Throughout the following work, *Coccius's* ophthalmoscope is supposed to be the instrument employed in making observations, unless, as in some few cases, special reference is made to another form of ophthalmoscope.

eye, the outer rays of the cone will pass through the sight-hole of the instrument together with the central ones, and the vessels or any other spot on the retina will appear indistinct.

Inconvenient proximity of surgeon and patient.

The inconvenience of the surgeon being obliged to keep his face within a few inches of that of his patient during a prolonged examination may be overcome by the interposition of a concave lens between the eye of the patient and the ophthalmoscope, the effect of which is to render the light, after emerging from the eye, divergent, and the outer rays of the cone will then fall on the surface of the mirror, in place of passing through the sight-hole of the instrument.

Corrected by a concave lens.

If then the direct method of examination be employed in the examination of an *emmetropic* eye, as in the instance we have supposed, an erect image of the retina may be clearly defined at a distance of three or four inches, but only a very imperfect one can be seen at fourteen or fifteen. The case, however, is different where the refracting power of the eye is abnormal; thus,

Available in myopia and hypermetropia.

In the *myopic* eye, an erect image cannot be seen at all, but at about fourteen inches a well-defined inverted figure may be observed.

In the *hypermetropic* eye an erect image of the retina may be seen at a distance of fourteen or fifteen inches.* (See Chapter XV.)

2. Indirect method.

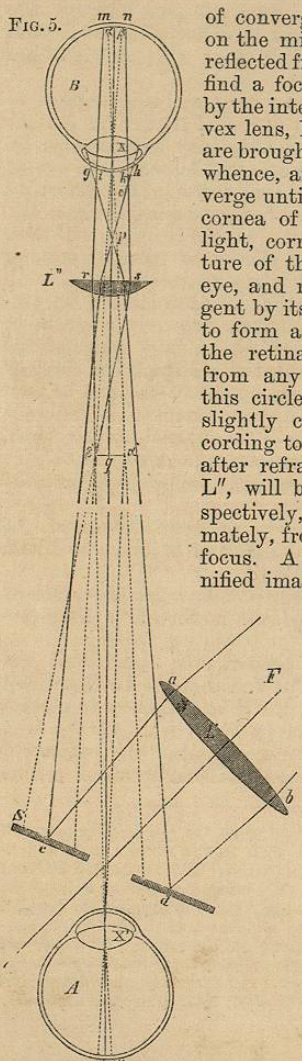
2. We may now proceed to make a few observations in explanation of the *indirect* method of ophthalmoscopic examination.

Using a convex lens.

The position of the patient, the lamp, and the ophthalmoscope should be the same as in the direct process, but, in addition, it will be necessary to place a convex lens in front of the patient's eye. In Fig. 5, A represents the observer's eye, B that of the patient, F the source of light, L′ a convex lens, by which a cone

* An eye is said to be *myopic* when the converging power of the dioptric media is greater than in the normal state, and in consequence the focal point of parallel rays is situated in front of the retina, diverging rays only being brought to a focus on the retina. *Hypermetropia* is the reverse of myopia, the parallel rays of light being brought to a focus behind the retina, convergent rays only being focussed on the retina. In these, and in all subsequent instances, it is supposed that the observer's eye is *emmetropic*, or that by means of suitable glasses both divergent and parallel rays of light are brought to a focus on his retina.

FIG. 5.



of converging rays is made to fall on the mirror S, and which, being reflected from its surface, *c d*, would find a focus at some point *o*; but by the interposition of a second convex lens, L″ (object lens), the rays are brought to an earlier focus at *p*, whence, after intersection, they diverge until intercepted by *g h*, the cornea of B. A portion of this light, corresponding to the aperture of the pupil *i k*, enters the eye, and rendered slightly convergent by its dioptric media, proceeds to form a circle of light *m n* on the retina. The rays, returning from any two points α and β in this circle will emerge parallel, or slightly convergent from B (according to its accommodation), and after refraction by the object lens L″, will be united at α' and β' respectively, at the distance, approximately, from L″ of *q* its principal focus. A real, inverted, and magnified image $\alpha' \beta'$, of $\alpha \beta$, will thus be formed; and this will be distinctly visible by A at a distance of twelve or fourteen inches, the rays diverging from α' being brought to a focus on the retina at α'', and those from β' at β''.

Image inverted.

Explanation.

Mr. Carter explains the phenomena of the inverted and aerial image, under these circumstances, as follows:—

"If you hold up your ophthalmoscope lens, at a distance of about eighteen inches from your eye, and look through it at any distant object, you will see an inverted image of that object. The image appears to you to be painted on the lens, but it is really suspended in the air, nearer to you than the lens by the focal length of the latter. You can test this by a simple experiment. Take a printed page, move it slowly towards one eye, the other being closed, until the letters begin to be indistinct. Measure the distance between the eye and the page at which this indistinctness commences, and let us suppose that it is eight inches. Then get the inverted image again, move the lens slowly towards the eye, and measure the distance between the two at which the image begins to be indistinct. This distance will be eight inches, *plus* the focal length of the lens. If it be a two-inch lens, the distance will be ten inches; if a three inch, eleven inches,—thus showing that the inverted image advances in front of the lens, and comes to within eight inches of the eye, while the lens is still at a greater distance away."

By the indirect method of examination—

More convenient.

1*st.*—A clear and distinct image of a vessel, or any other small object on the retina, may be seen at a distance of twelve or fourteen inches.

Field larger.

2*nd.*—Although the magnification is less than by the direct method, the field of view is larger, and a considerable portion of the fundus of the eye being visible at once, its several parts may be studied and compared in their relative positions at a glance.

Ophthalmoscope of Coccius.

Choice of Instruments.—With regard to the form of ophthalmoscope for ordinary purposes, the one invented by Coccius is a very useful one. It consists of a small metallic surface coated with silver; in its centre is a funnel-shaped hole about the one-sixteenth of an inch in diameter, and a plate of blackened metal is made to slide upon the grooved edge of the mirror, by means of which the illuminating power of the instrument may be lessened if necessary. Attached to the slide is a clamp, into which a lens may be fitted in order to concentrate the rays of light upon the mirror; or it may be turned behind the sight-hole of the ophthalmoscope. Various lenses are supplied in the case, to be used as object-glasses. This instrument