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THE

OPHTHALMOSCOPE

HARTRIDGE

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OPHTHALMOSCOPE

A MANUAL FOR STUDENTS

BY

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WITH SIXTY-THREE ILLUSTRATIONS

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1891

PREFACE

THE subject of this volume is one that has made great progress during the last few years, not only in the mechanism of the instrument, but also in the methods of using it to the best advantage. In the present day the ophthalmoscope is almost as necessary to the physician as it is to the ophthalmic surgeon, since many serious general diseases may first be detected by changes taking place in the fundus, frequently without any subjective symptoms; thus the importance and usefulness of the instrument is greatly extended.

In introducing this small work to the profession, I do so in the hope that it may be found useful not only to the ophthalmic students who, in London and other large medical schools, have the advantage of practical demonstrations on the subject, but also to the large class of practitioners whose opportunities of seeing cases are few and far between, and who may desire to learn the use of the ophthalmoscope when practical instruction is out of their reach.

While hoping that the description given will be found sufficiently clear and elementary to enable the most inexperienced to understand it; I trust that even the advanced student may here find some help and instruction.

The arrangement of the book is simple and systematic, and an endeavour has been made to keep it small, so that it may be conveniently carried in the pocket for reference in the out-patient room; and this, perhaps, constitutes one of its chief advantages. The work is profusely illustrated with woodcuts, a matter of some importance, as it is almost impossible to make the subject clear without them, especially to those of my readers who may not have access to an instructor; illustrations, although in many instances conveying only a somewhat imperfect idea, certainly impress the subject on the student's mind. A slight knowledge of optics is essential, and therefore the first chapter from my work on the 'Refraction of the Eye' is reproduced, and several of the woodcuts from that book are doing duty again.

G. H.

65, Green Street, Park Lane, W.;
August, 1891.

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CHAPTER I

OPTICAL PRINCIPLES INVOLVED IN THE USE OF THE OPHTHALMOSCOPE

Light is propagated from a luminous point in every plane and in every direction in straight lines; these lines of direction are called *rays*. Rays travel with the same rapidity so long as they remain in the same medium.

The denser the medium the less rapidly does the ray of light pass through it.

Rays of light diverge, and the amount of divergence is proportionate to the distance of the point from which they come; the nearer the source of the rays the more they diverge.

When rays proceed from a distant point such as the sun, it is impossible to show that they are not parallel, and in dealing with rays which enter the eye, it will be sufficiently accurate to assume them to be parallel when they proceed from a point at a greater distance than 6 mètres.

A ray of light meeting with a body, may be *absorbed, reflected,* or if it is able to pass through this body, it may be *refracted.*

Reflection

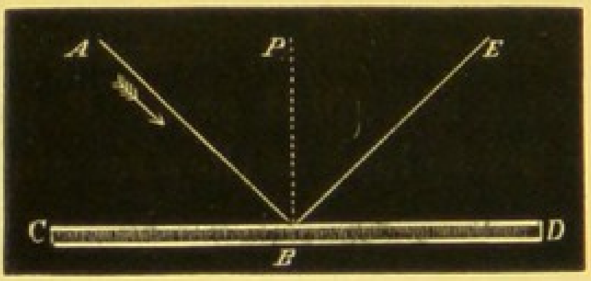
Reflection by a Plane Surface

Reflection takes place from any polished surface and according to two laws.

1st.—The angle of reflection is equal to the angle of incidence.

2nd.—The reflected and incident rays are both in the same plane, which is perpendicular to the reflecting surface.

Fig. 1.

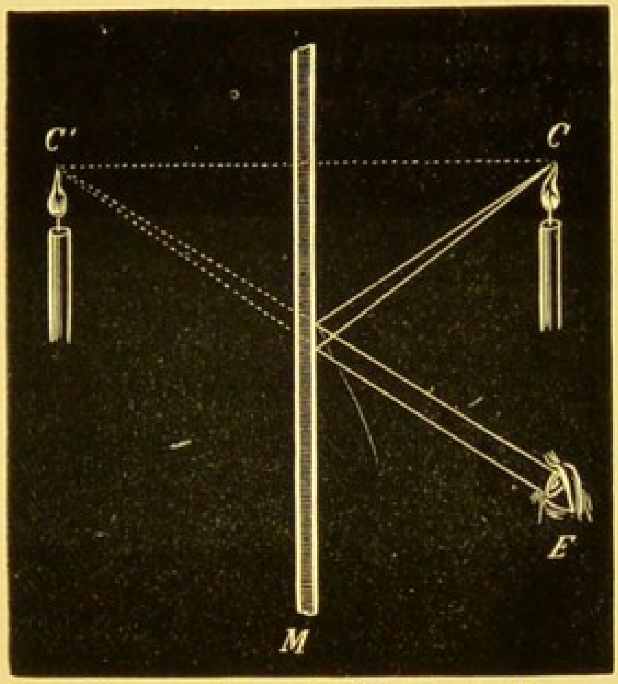


Thus, if A B be the ray incident at B, on the mirror C D, and B E the ray reflected, the perpendicular P B, will divide the angle A B E into two equal parts, the angle A B P is equal to the angle P B E; and A B, P B and E B lie in the same plane.

When reflection takes place from a plane surface, the image is projected backwards to a distance behind the mirror, equal to the distance of the object in front of it, the image being of the same size as the object.

Thus in Fig. 2 the image of the candle C, is formed behind the mirror M, at C′, a distance behind the mirror, equal to the distance of the candle in front of it, and an observer's eye placed at E, would receive the rays from C as if they came from C′.

FIG. 2.



M. The mirror. C. The candle. C′. The virtual image of the candle. E. The eye of the observer receiving rays from mirror.

The image of the candle so formed by a plane mirror is called a *virtual image*.

Reflection by a Concave Surface

A concave surface may be looked upon as made up of a number of planes inclined to each other.

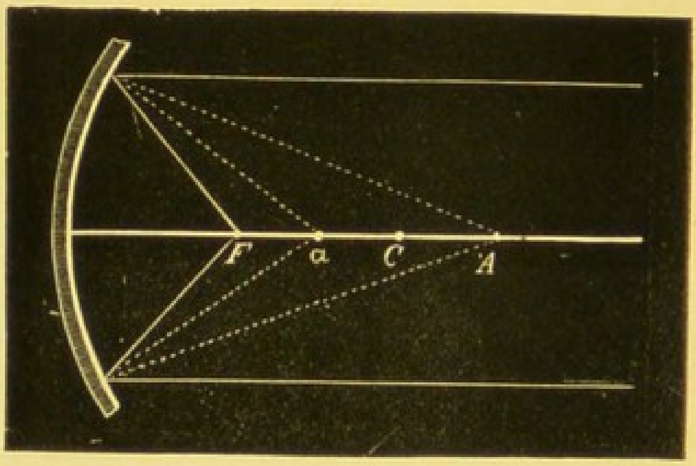
Parallel rays falling on a concave mirror are reflected as convergent rays, which meet on the axis at a point (F, Fig. 3) called the *principal focus*, about equally distant from the mirror and its centre C. The distance of the principal focus from the mirror is called the focal length of the mirror.

If the luminous point be situated at F, then the diverging rays would be reflected as parallel to each other and to the axis.

If the point is at the centre of the concavity of the mirror (C), the rays return along the same lines, so that the point is its own image.

If the point be at A the focus will be at *a*, and it will be obvious that if the point be moved to *a*, its focus will be at A; these two points therefore, A and *a*, bear a reciprocal relation to each other and are called *conjugate foci*.

FIG. 3.

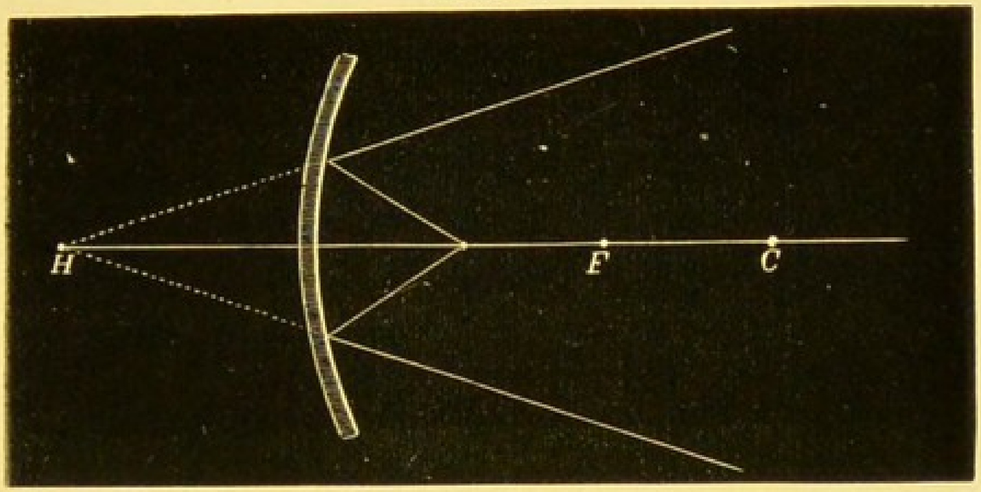


If the luminous point is beyond the centre, its conjugate focus is between the principal focus and the centre.

If the luminous point is between the principal focus and the centre, then its conjugate is beyond the centre; so that the nearer the luminous point approaches the principal focus, the greater is the distance at which the reflected rays meet.

If the point be nearer the mirror than (F) the principal focus, the rays will be reflected as divergent and will therefore never meet; if, however, we continue these diverging rays backwards, they will unite at a point (H) behind the mirror; this point is called the *virtual*

FIG. 4.



focus, and an observer situated in the path of reflected rays will receive them as if they came from this point.

Thus it follows that—

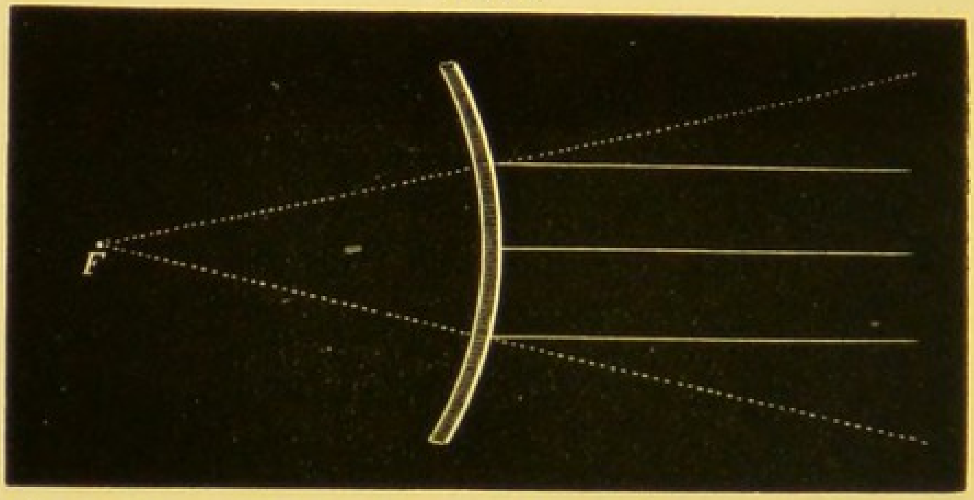
Concave mirrors produce two kinds of images or none at all, according to the distance of the object, as may be seen by looking at oneself in a concave mirror; at a certain distance one sees a small and inverted image, at a less distance the image is confused and disappears when at the focus; still nearer, the image is erect and larger, being then a virtual image.

Reflection by a Convex Surface

Parallel rays falling on such a surface become divergent, hence never meet, but if the diverging rays thus formed are carried backwards by lines, then an imaginary image is formed which is called *negative*, and at a point called the *principal focus* (F).

Foci of convex mirrors are virtual; and the image, whatever the position of the object, is always virtual, erect, and smaller than the object.

FIG. 5.



The radius of the mirror is double the principal focus.

Refraction

Refraction by a Plane Surface

A ray of light passing through a transparent medium into another of a different density is refracted, unless the ray fall perpendicular to the surface separating the two media, when it continues its course without undergoing any refraction (Fig. 6, H K).

A ray is called *incident* before passing into the second medium, *emergent* after it has penetrated it.

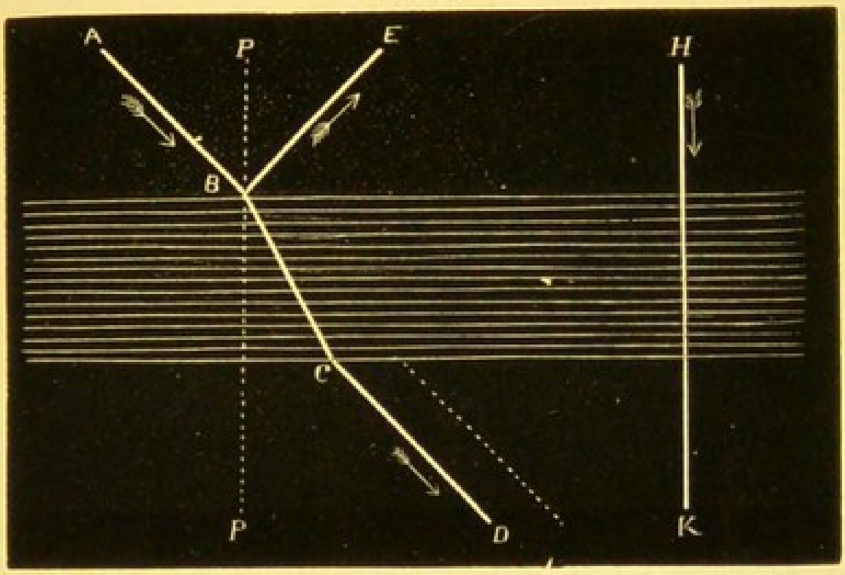
A ray passing from a rarer to a denser medium is refracted towards the perpendicular; as shown in Fig. 6, the ray A B is refracted at B, towards the perpendicular P P.

In passing from the denser to the rarer medium the ray is refracted from the perpendicular, B D is refracted at C from P P (Fig. 6).

Reflection accompanies refraction, the ray dividing itself at the point of incidence into a refracted portion (B C) and a reflected portion (B E).

The amount of refraction is the same for any medium at the same obliquity and is called the index of refraction; air is taken as the standard and is called 1; the index of refraction of water is 1·3, that of glass 1·5. The diamond has almost the highest refractive power of any transparent substance, and has an index of refraction of 2·4. The cornea has an index of refraction of 1·3 and the lens 1·4.

Fig. 6.



The refractive power of a transparent substance is not always in proportion to its density.

If the sides of the medium are parallel, then all rays except those perpendicular to the surface which pass through without altering their course, are refracted twice, as at B and C (Fig.6), and continue in the same direction after passing through the medium, as they had before entering it.

If the two sides of the refracting medium are not parallel, as in a prism, the rays cannot be perpendicular to more than one surface at a time.

Therefore every ray falling on a prism must undergo refraction, and the deviation is always towards the base of the prism.

The relative direction of the rays is unaltered (Fig.7).

FIG. 7.

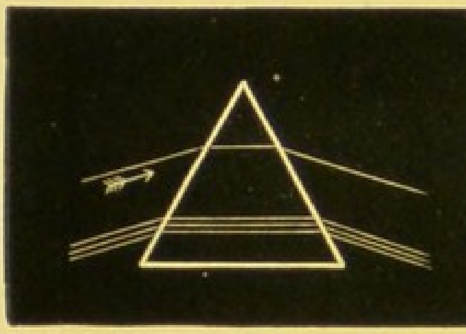
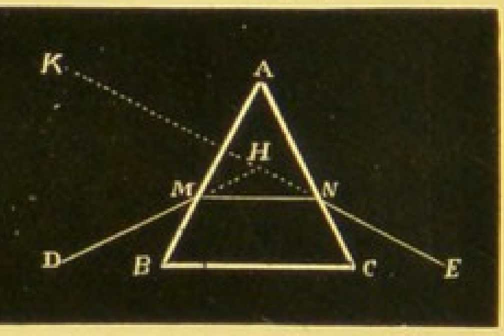


FIG. 8.



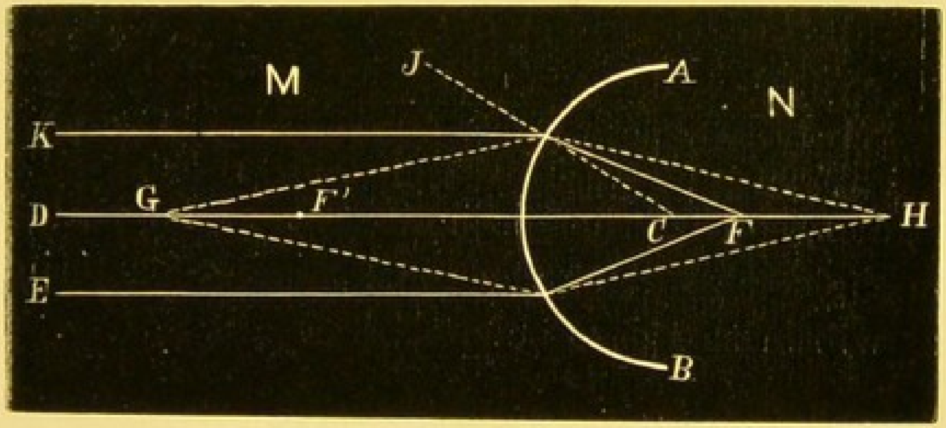
If D M (Fig. 8) be a ray falling on a prism (A B C) at M, it is bent towards the base of the prism, assuming the direction M N; on emergence it is again bent at N, an observer placed at E would receive the ray as if it came from K; the angle K H D formed by the two lines at H is called the *angle of deviation*, and is about half the size of the *principal angle* formed at A by the two sides of the prism.

Refraction by a Spherical Surface

Parallel rays passing through such a surface separating media of different density, do not continue parallel, but are refracted, so that they meet at a point called the principal focus.

If parallel rays K, D, E, fall on A B, a spherical surface separating the media M and N of which N is the denser, ray D, which strikes the surface of A B at right angles, passes through without refraction and is called the *principal axis;* ray K will strike the surface at an angle and will therefore be refracted towards the perpendicular C J, meeting the ray D at F; so also with ray E, and all rays parallel in medium M. The point F where these rays meet is the *principal focus,* and the distance between the principal focus and the curved surface is spoken of as the *principal focal distance.*

FIG. 9.



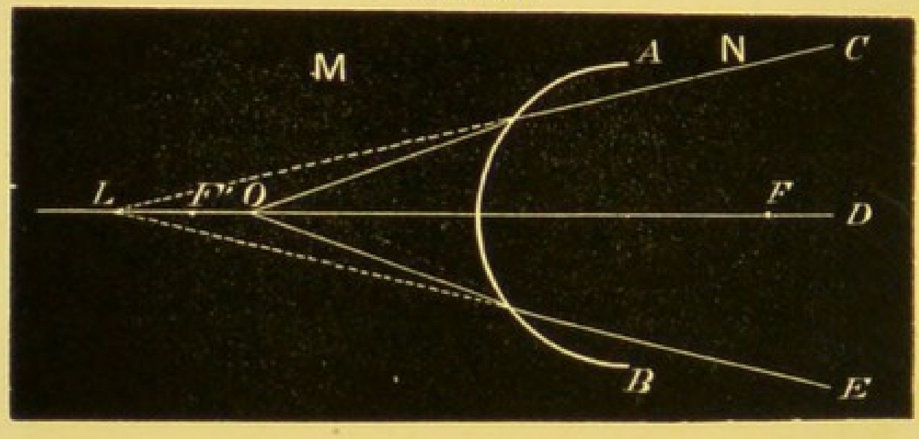
Rays proceeding from F will be parallel in M after passing through the refracting surface. Rays parallel in medium N will focus at F′, which is called the *anterior focus.*

Had the rays in medium M been more or less divergent, they would focus on the principal axis at a greater distance than the principal focus say at H, and conversely rays coming from H would focus at G; these two points are then *conjugate foci.*

When the divergent rays focus at a point on the axis twice the distance of the principal focus, then its conjugate will be at an equal distance on the other side of the curved surface.

If rays proceed from a point O, nearer the surface than its principal focus, they will still be divergent after passing through A B, and will therefore never meet; by continuing these rays backwards they will meet at L, so that the conjugate focus of O will be at L, on the same side as the focus; and the conjugate focus will in this case be spoken of as *negative*.

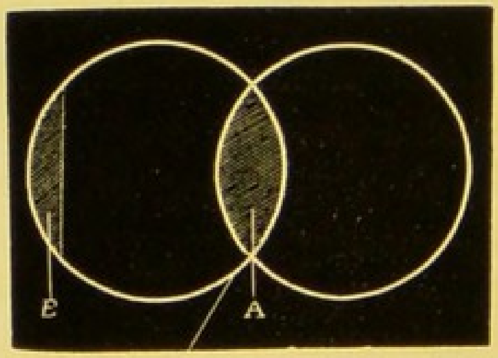
FIG. 10.



Refraction by Lenses

Refraction by lenses is somewhat more complicated. A lens is an optical contrivance usually made of glass, and consists of a refracting medium with two

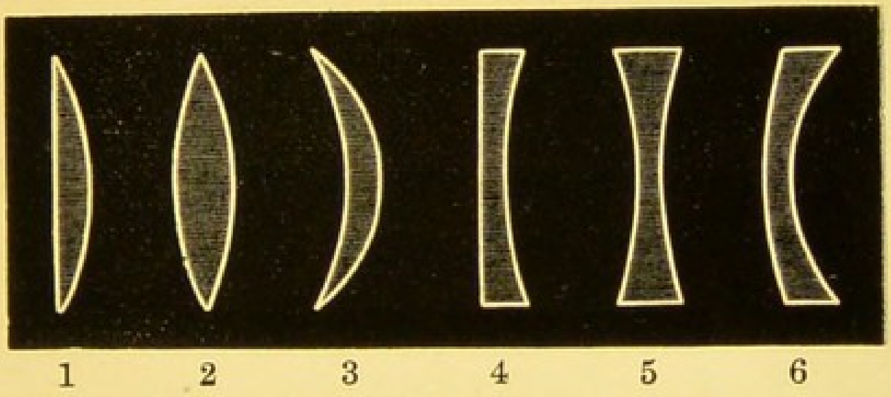
FIG. 11.



opposite surfaces, one or both of which may be segments of a sphere; they are then called spherical lenses, of which there are six varieties.

1. Plano-convex, the segment of one sphere (Fig. 11, B).
2. Biconvex, segments of two spheres (Fig. 11, A).
3. Converging concavo-convex, also called a converging meniscus.
4. Plano-concave.
5. Biconcave.
6. Diverging concavo-convex, called also a diverging meniscus.

FIG. 12.



Lenses may be looked upon as made up of a number of prisms with different refracting angles—convex lenses, of prisms placed with their bases together; concave lenses, of prisms with their edges together.

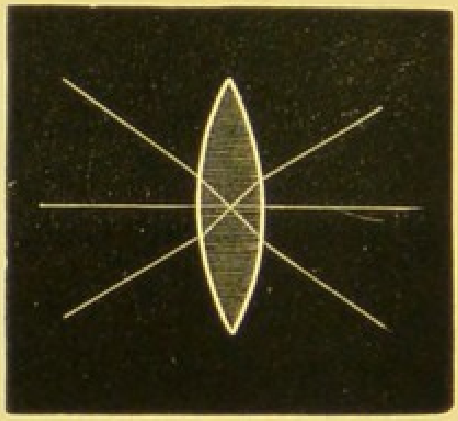
A ray passing from a less refracting medium (as air) through a lens, is deviated towards the thickest part, therefore the three first lenses, which are thickest at the centre, are called *converging;* and the others, which are thickest at the borders, *diverging.*

A line passing through the centre of the lens (called the *optical centre*) at right angles to the surfaces of the lens is termed the *principal axis,* and any ray passing through that axis is not refracted.

All other rays undergo more or less refraction.

Rays passing through the optical centre of a lens, but not through the principal axis, suffer slight deviation, but emerge in the same direction as they entered; the deviation in thin lenses is so slight that they are usually assumed to pass through in a straight line; these are called *secondary axes* (Fig. 13).

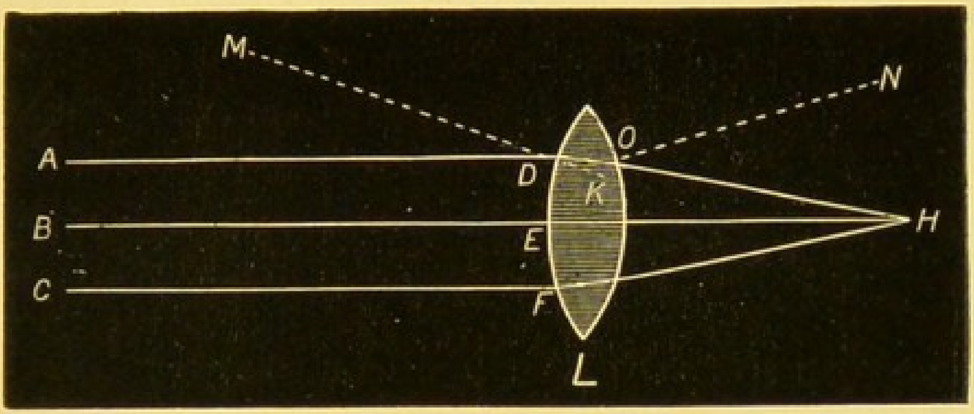
Fig. 13.



Lens with secondary axes undergoing slight deviation.

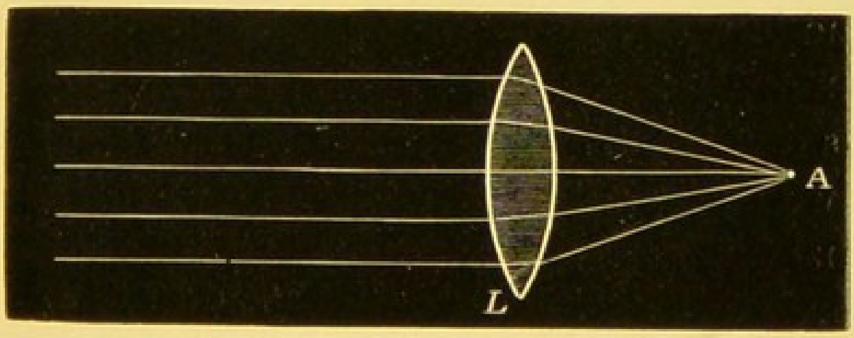
Parallel rays falling on a biconvex lens are rendered convergent; thus in Fig. 14 the rays A, B, C, strike the surface of the lens (L) at the points D, E, F; the centre ray (B) falls on the lens at E perpendicular to its surface, and therefore passes through in a straight line; it also emerges from the lens at right angles to its opposite surface, and so continues its course without deviation; but the ray (A) strikes the surface of the lens obliquely at D, and as the ray is passing from one medium (air) to another (glass) which is of greater density, it is bent towards the perpendicular of the surface of the lens, shown by the dotted line M K; the ray after deviation passes through the lens, striking its opposite surface obliquely at O, and as it leaves the lens, enters the rarer medium (air), being deflected from the perpendicular N O; it is now directed to H, where it meets the central ray B H; ray C, after undergoing similar refractions meets the other rays at H, and so also all parallel rays falling on the biconvex lens (L).

FIG. 14.



Parallel rays, therefore, passing through a convex lens (L) are brought to a focus at a certain fixed point (A) beyond the lens; this point is called the *principal focus*, and the distance of this focus from the lens is called the focal length of the lens.

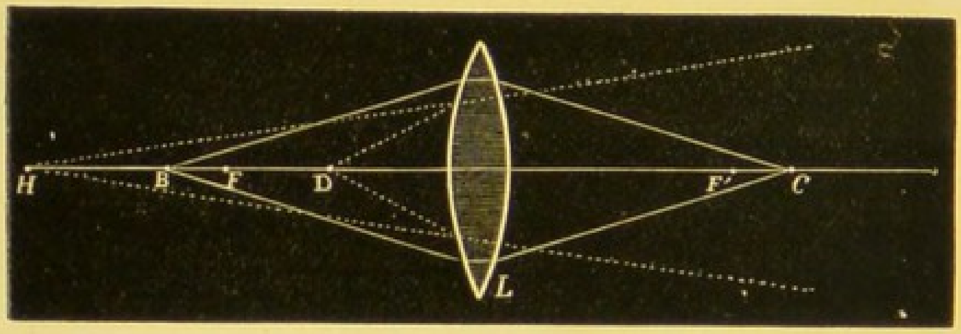
FIG. 15.



Rays from a luminous point placed at the principal focus (A) emerge as parallel after passing through the lens.

Divergent rays from a point (B) outside the principal focus (F, Fig. 16) meet at a distance beyond (F′) the principal focus on the other side of the lens (L), and if the distance of the luminous point (B) is equal to twice the focal length of the lens, the rays will focus at a point (C) the same distance on the opposite side of the lens, rays coming from C would also focus at B; they are therefore called conjugate foci, for we can indifferently replace the image (C) by the object (B) and the object (B) by the image (C).

FIG. 16.



If the luminous point (D) be between the lens and the principal focus (F), then the rays will issue from the lens divergent, though less so than before entering; and if we prolong them backwards they will meet at a point (H) further from the lens than the point D; H will therefore be the virtual focus of D, and the conjugate focus of D may be spoken of as *negative.*

Biconvex lenses have therefore two principal foci, F and F′, one on either side, at an equal distance from the centre.

In ordinary lenses, and those in which the radii of the two surfaces are nearly equal, the principal focus closely coincides with the centre of curvature.

We have assumed the luminous point to be situated on the principal axis, supposing, however, it be to one side of it as at E (Fig. 17), then the line (E F) passing through the optical centre (C) of the lens (L) is a secondary axis, and the focus of the point E will be found somewhere on this line, say at F, so that what has been said respecting the focus of a luminous point on the principal axis (A B), is equally true for points on a secondary axis, provided always that the inclination of this secondary axis is not too great, when the focus would become imperfect from much spherical aberration.

FIG. 17.

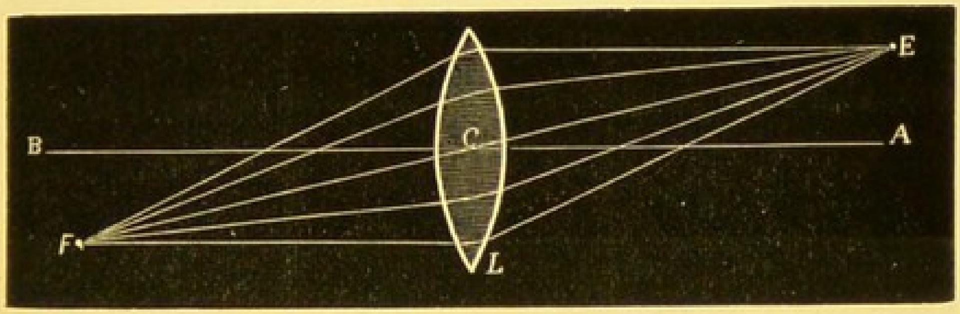
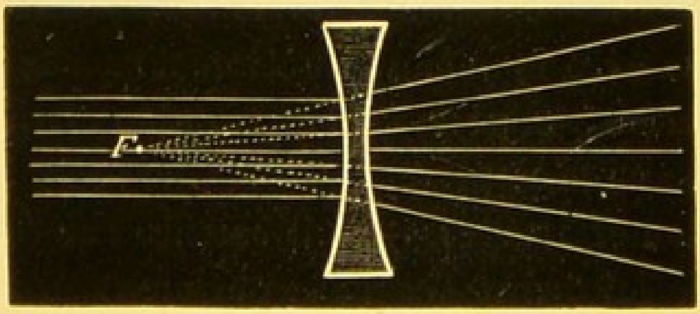


FIG. 18.

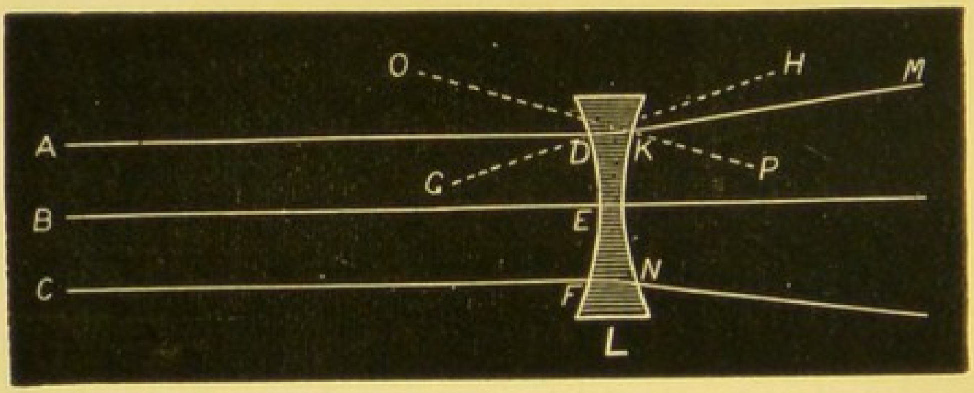


In biconcave lenses the foci are always virtual, whatever the distance of the object.

Rays of light parallel to the axis, diverge after refraction, and if their direction be continued backward, they will meet at a point termed the principal focus (Fig. 18, F).

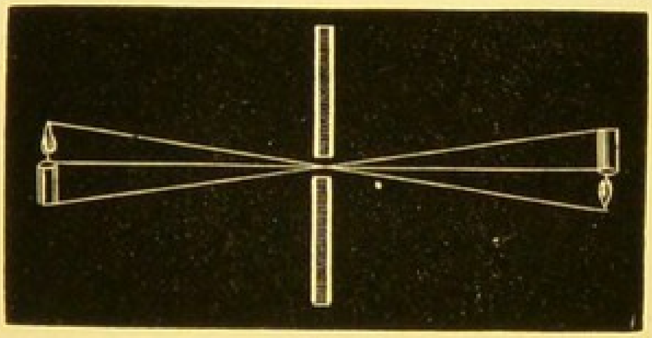
Fig. 19 shows the refraction of parallel rays by a biconcave lens (L); the centre ray B, strikes the lens at E perpendicular to its surface, passing through without refraction, and as it emerges from the opposite side of the lens perpendicular to its surface, it continues in a straight line; the ray A, strikes the lens obliquely at D and is refracted towards the perpendicular, shown by the dotted line G H; the ray after deviation passes through the lens to K, where, on entering the medium of less density obliquely, it is refracted from the perpendicular O P, in the direction K M; the same takes place with ray C, at F, and N, so also with all intermediate parallel rays.

FIG. 19.



Formation of images.—To illustrate the formation of images the following simple experiment may be carried out; place on one side of a screen having a small perforation, a candle, and on the other side a sheet of white cardboard at some distance from the object, to receive the image formed; rays diverge from the candle in all directions, most of those falling on the screen are intercepted by it, but some few rays pass through the perforation and form an image of the candle on the cardboard, the image being inverted because the rays cross each other at the orifice; it can further be shown that when the candle and cardboard are equally distant from the perforated screen, the candle flame and its image will be of the same size. If the cardboard be moved further from the perforation the image is enlarged, if it be moved nearer it is diminished; if we make a dozen more perforations in the screen, a dozen more images will be formed on the cardboard, if a hundred then a hundred; but if the apertures come so close together that the images overlap, then instead of so many distinct images we get a general illumination of the cardboard.

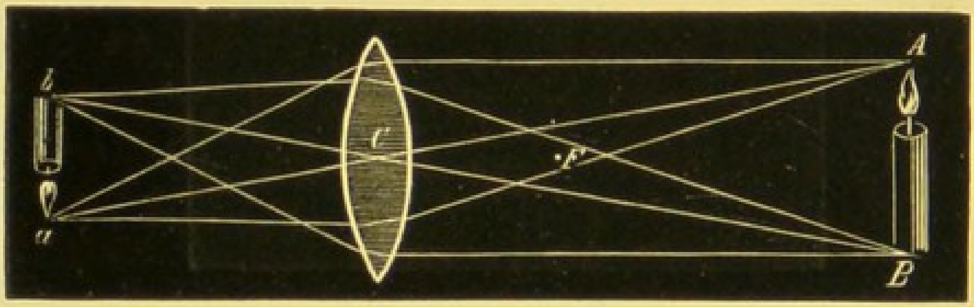
FIG. 20.



The image of an object is the collection of the foci of its several points; the images formed by lenses are, as in the case of the foci, real or virtual. Images formed therefore by convex lenses may be real or virtual.

In Fig. 21, let A B be a candle situated at an infinite distance; from the extremities of A B, draw two lines passing through the optical centre (C) of a biconvex lens, the image of A will be formed somewhere on this line (termed a secondary axis), say at *a*, rays from B at *b*, so *b a* is a small inverted image of the candle A B, formed at the principal focus of the convex lens. Had the candle been placed at twice the focal distance of the lens, then its image would be formed at the same point on the opposite side of the lens, of the same size as the object, and inverted.

Fig. 21.

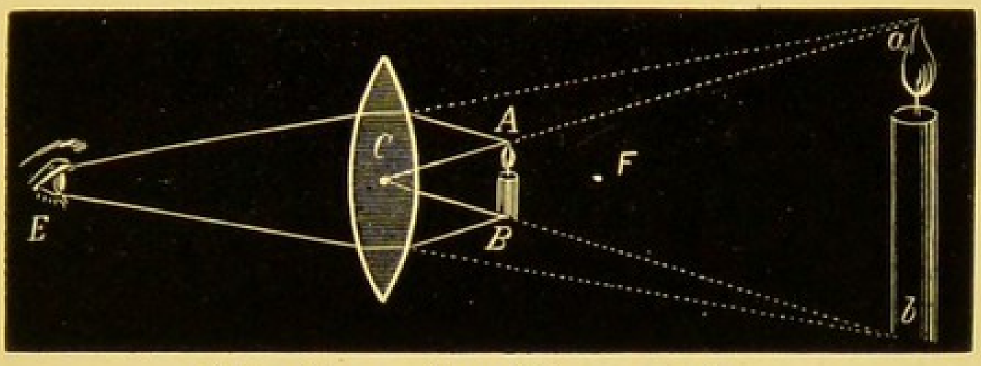


Real inverted image formed by convex lens.

If the candle be at the principal focus (F) then the image is at an infinite distance, the rays after refraction being parallel.

If, however, the candle (A B) be nearer the lens than the focus, then the rays which diverge from the candle will, after passing through the convex lens, be still divergent, so that no image is formed; an eye placed at E would receive the rays from A B as if they came from *a b*; *a b* is therefore a virtual image of A B, erect and larger than the object, and formed on the same side of the lens as the object.

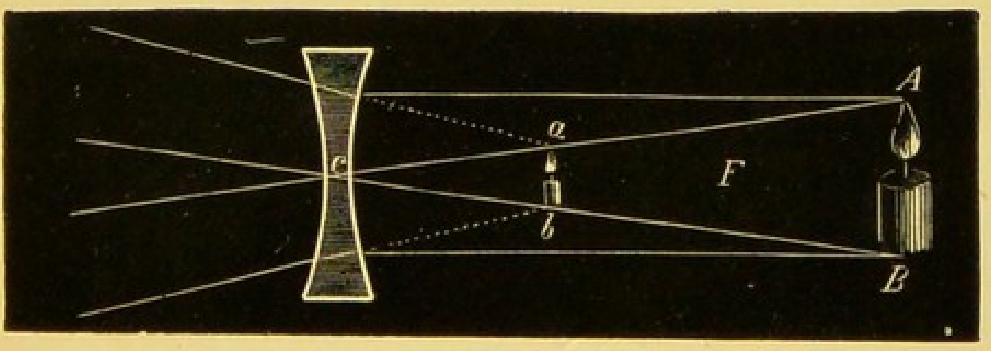
FIG. 22.



Virtual image formed by convex lens.

Images formed by biconcave lenses are always virtual, erect, and smaller than the object; let A B be a candle, and F the principal focus of a biconcave lens; draw from A B two lines through C, the optical centre of the lens, and lines also from A and B parallel to the axis; after passing through the lens they diverge and

FIG. 23.



Virtual image formed by concave lens.

have the appearance of coming from *a b*, which is, therefore, the virtual image of A B.

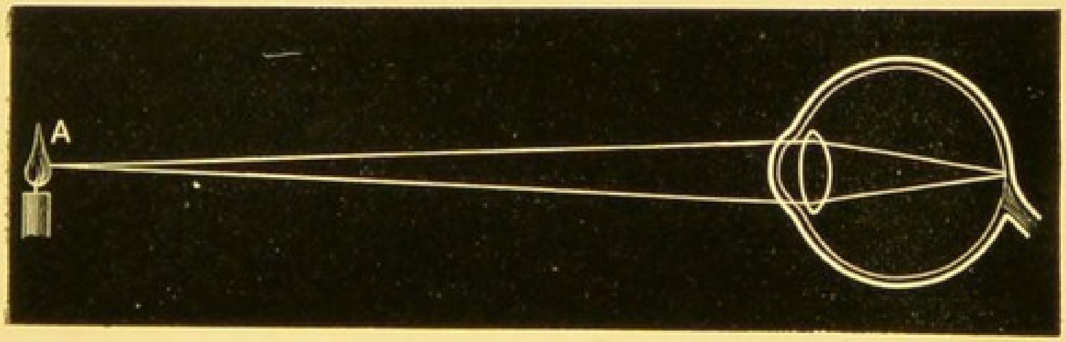
A real image can be projected on to a screen, but a virtual one can only be seen by looking through the lens.

CHAPTER II

THE OPHTHALMOSCOPE

When an eye is looked at the pupil appears black although the media are perfectly transparent, this is because the rays entering the eye return to the point from which they emanate, and therefore, unless the observing eye can be placed in the path of returning rays, none of them will pass through the observer's pupil, and so no illumination will be seen.

Fig. 24.



In Fig. 24 rays will be seen entering the eye from candle A, returning by the same path.

In the albino, as in the white rabbit, a red reflex may be seen; this is due to the transparency of the iris, so that the returning rays cover a larger area than is the case when passing through an ordinary pupil, then some of the outer rays may pass through the observer's pupil, if placed nearly in the line of light from which the observed eye receives its rays: that this is the correct explanation can easily be proved, by covering up the part corresponding to the iris by an opaque diaphragm, when the pupil will at once appear black, as in the normal eye. In hypermetropia and myopia with a dilated pupil, one frequently gets a slight fundus illumination. This is illustrated in the following figures.

In hypermetropia, Fig. 25, the returning rays instead of being parallel as in emmetropia, diverge somewhat, so that the observing eye placed at B would receive some of the returning rays.

Fig. 25.

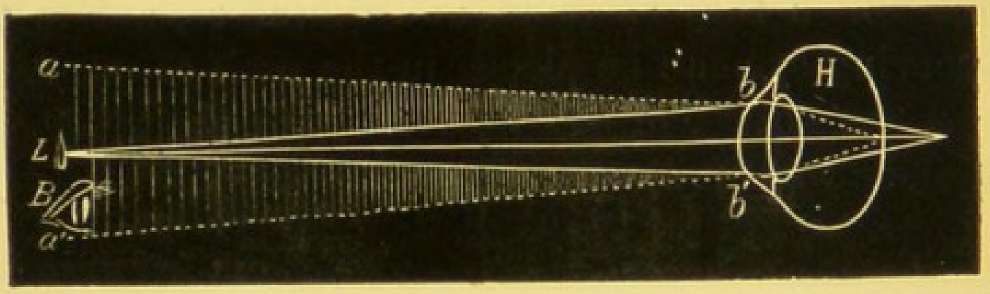
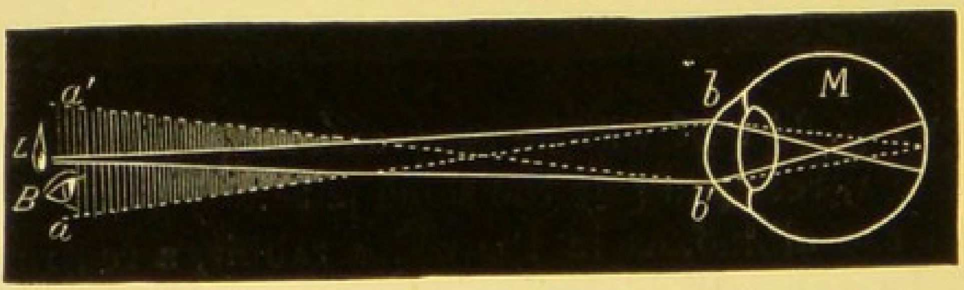


Fig. 26.

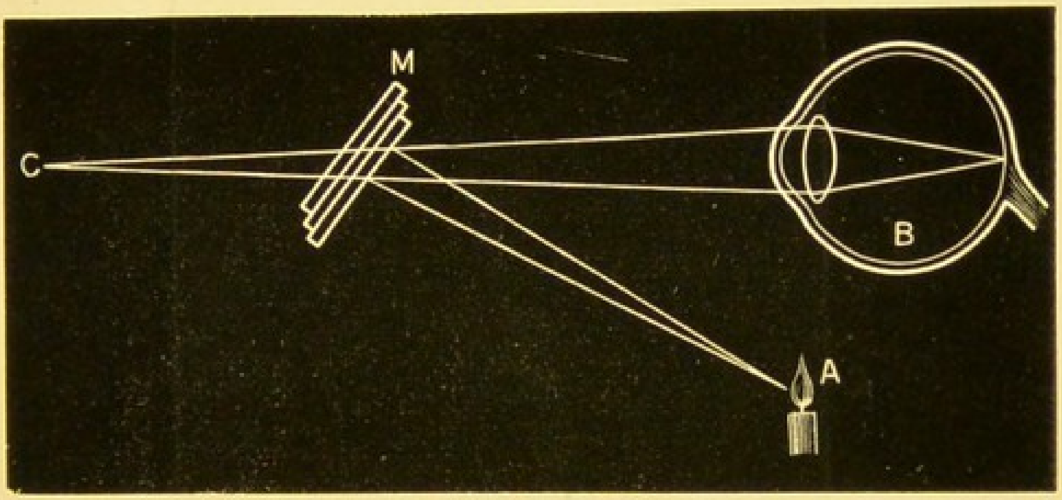


In myopia, Fig. 26, the returning rays converge, cross, and diverge, so that the eye placed at B would also receive some illumination.

The ophthalmoscope is a contrivance which enables the observing eye to be placed in the path of the returning rays, and consists of a reflector with a hole in the centre.

Helmholtz's first ophthalmoscope, which he introduced in 1851, was composed of three thicknesses of plain glass.

FIG. 27.



Rays reflected from a light A, were projected into the eye B, by the mirror M, the light returning from the observed eye by the same path, will fall on the glass M, a part is reflected to A, and a part passes through the glass towards C; an observing eye placed behind the mirror, will, therefore, receive some of the returning rays.

Ophthalmoscopes have undergone numerous modifications, and the instrument with which we now work, consists of a silvered concave glass mirror, with a central perforation.

In Fig. 28, divergent rays from a candle C, falling on the mirror M, are rendered convergent, and when

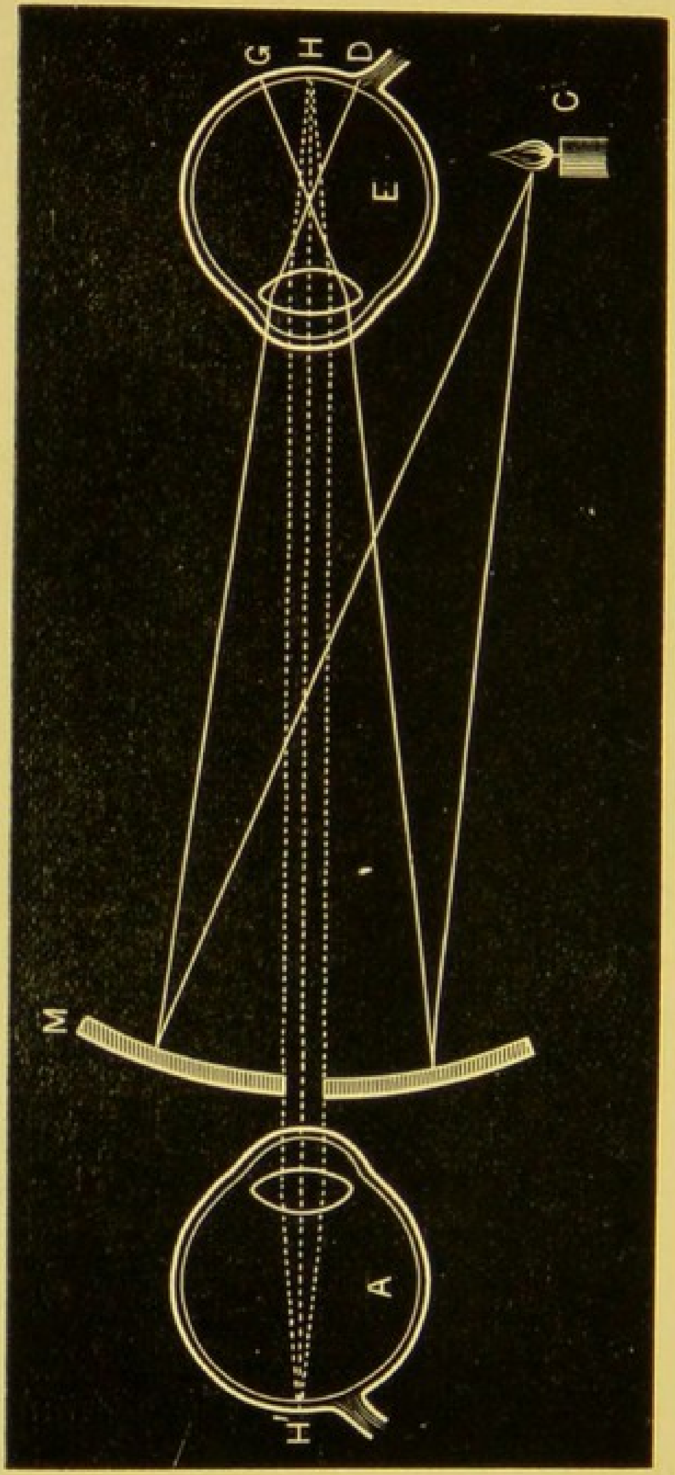


Fig. 28.

reflected into the eye E, cross in the vitreous and light up the fundus between the points G and D; if point H of this illuminated area be taken, the rays will, in the emmetropic eye, issue parallel, and passing through the sight-hole of the mirror, will enter the observing eye A, forming on the retina at H′ an image of H.

The amount of fundus illumination obtained will necessarily depend upon the source and intensity of the light, the concavity of the mirror used, the distance from the eye at which the examination is made, and the size of the pupil in the observed eye. Modern ophthalmoscopes are fitted with a series of lenses, which can be revolved in front of the sight-hole; these are known as refracting ophthalmoscopes. Many good ones have been devised varying but slightly in some or other minor particulars.

The essential points of a thoroughly complete ophthalmoscope are, that it should be supplied with three mirrors, a small concave, a large concave, and a plain one, together with a fairly complete set of lenses, which can be brought in front of the sight-hole of the instrument as occasion requires. (1) The small concave mirror is for the direct examination; it should have a focus of about 8 cm., so that light reflected from it will enter the eye as convergent rays. The sight-hole should not be larger than 2½ mm., because only that part of the mirror which immediately surrounds the aperture is available in the direct examination, and should the sight-hole be larger than the pupil, then no fundus illumination will be obtained. This small mirror may be conveniently tilted about 25°; this allows the ophthalmoscope to be held perfectly straight while the light is reflected into the observed eye, and thus one looks through the lens which may be behind the sight-hole at right angles to its surface. With the old-fashioned mirror the ophthalmoscope itself had to be tilted towards the light, and with it, of course, the lenses, so that they were looked through obliquely, and thus the strength of the lens was increased and some astigmatism produced, hence the estimation of the refraction by the direct method was liable to be inaccurate. The disadvantage of some tilted mirrors, is the distance that intervenes between the two sides of the sight-hole, for the nearer the observing eye can approach the observed, the more accurate will be the estimation of the refraction. (2) The large concave mirror is for the indirect method and for retinoscopy; it should have a focal length of 25 cm., so that rays from a light, situated 25 cm. from the mirror, will be reflected parallel; when the light is further off than 25 cm. then the rays will be slightly convergent; this mirror may possess an aperture of 3 or 3½ mm. (3) The plain mirror is occasionally useful for the examination of the vitreous, and in some cases of high myopia; in this case, light coming from a lamp at a finite distance will be reflected into the eye as divergent rays.

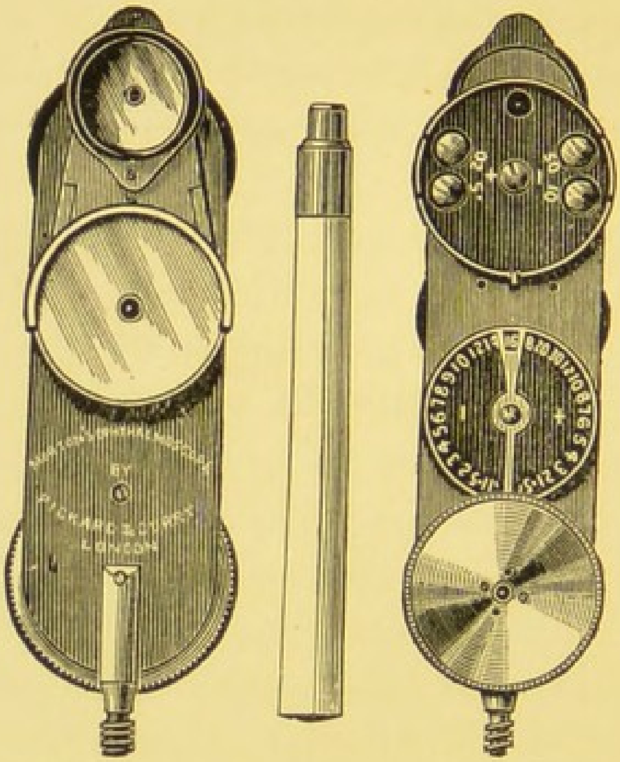
The instrument should be supplied with a set of lenses, which can in turn be brought behind the sight-hole by means of a finger wheel; this wheel should be so made and placed, that it may be rotated easily while the ophthalmoscope is in position without losing sight of the fundus. The lenses may be somewhat as follows: a convex series +·5 D., +1 D., increasing by one dioptre up to +10 D.; and a concave series −·5 D., −1 D., increasing by one dioptre up to −12 D., and then by two dioptres up to −20 D. Sometimes a higher glass may be required; these may be supplied on a separate disc; the lenses in this disc may, by combination with the other lenses, form a very large series.

These lenses should not be less than 6 mm. in diameter, otherwise they are difficult to centre properly, and cannot be easily cleaned, a point of some importance; they may occasionally be used for the subjective test of estimating the visual acuteness, should the box of trial lenses not be at hand.

It will be sufficient here to describe and illustrate one of the ophthalmoscopes in general use, though numerous other good instruments will be found in this country and abroad.

Morton's ophthalmoscope, shown in Fig. 29, is a modification of an instrument introduced by Mr. Couper; it contains a series of twenty-nine lenses in metal rings, and one metal ring without a glass; these run round a continuous channel, and are so arranged that each can be brought successively in front of the sight-hole by means of a driving wheel. When no lens is required, then the empty ring occupies the sight-hole; these lenses touch each other sideways, but are not fixed in any way; on the spindle that carries the driving wheel is another wheel with teeth, which propel the lenses round the instrument; a spring and notch attached to the driving wheel centres each lens as it arrives at the sight-hole. The strength of the glass before the sight-hole is recorded by an index wheel which, being geared to the driving wheel, keeps pace with it, and therefore with the lens series. The minus glasses are contained in white rings and are indicated by white numbers; the convex glasses are in red rings and have red numbers.

FIG. 29.



This series of lenses is usually sufficient for most ordinary purposes, but occasionally other lenses are required and are provided on a special disc. Sometimes a strong convex glass is required for the examination of the cornea or lens; at other times a strong concave lens is necessary for a case of high myopia. This separate disc, therefore, has a + 20 D. and a − 50 D.

so placed that they can be instantly put in front of, or removed away from, the sight-hole without rotating the whole series of lenses. On this same disc are also a + ·5 D. and a – 10 D.; the former of these enables one to estimate to within half a dioptre in special cases, and the latter, by use in conjunction with other concave lenses contained in the series, gives us from – 1 D. to – 20 D., with intervals of one dioptre, and – 20 D. to – 30 D., with intervals of two dioptres; this disc is well shown in the illustration. The instrument is supplied with three mirrors; a large concave one of 25 cm. focus, a small tilted one of 7·5 cm. focus, fixed by a pivot, so that either can be turned in front of the sight-hole as occasion requires; the large concave mirror can be replaced, when necessary, by a plain one.

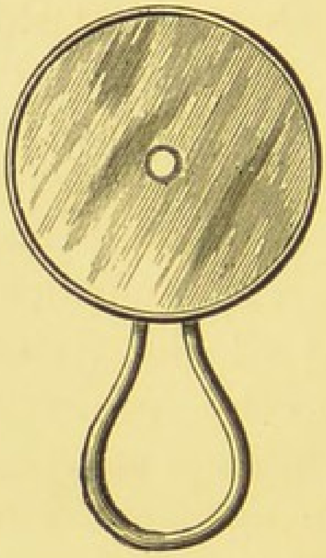
The movement in this ophthalmoscope is a great improvement over the method formerly employed, of placing the lenses in a revolving wheel. The credit of this ingenious invention is due to Mr. Couper, who was much assisted by Mr. Paxton, of the firm of Curry and Paxton.

M. Parent, of Paris, has recently brought out a very beautiful instrument, combining the advantages of all the recent ophthalmoscopes, and fitted with a series of cylindrical lenses in addition to the ordinary spherical series. M. Parent strongly advocates the use of this system of cylindrical lenses for the estimation of the refraction by means of the direct method, and for the correction of astigmatism.

Lang's ophthalmoscope is also used a good deal in this country, and is a very convenient instrument.

A useful mirror to carry in the waistcoat pocket is that known by the name of Galizowski, and figured in the following plate; it is convenient for the indirect examination and for retinoscopy; its focal length is 25 c.m. If the handle be made to double over the face, it will require no case to protect it.

Fig. 30.



A couple of large biconvex lenses having a focus of about 13 D. will complete the ophthalmoscopist armamentum; one is required for the focal illumination and the indirect examination, while the other is useful as a magnifying glass when examining the cornea.

A convenient magnifying lens is made by Messrs. Curry and Paxton; it is an achromatic combination of flint and crown glass, and has a focus of about 1·5 cm.

Demonstrating ophthalmoscopes also exist, but need not be described.

CHAPTER III

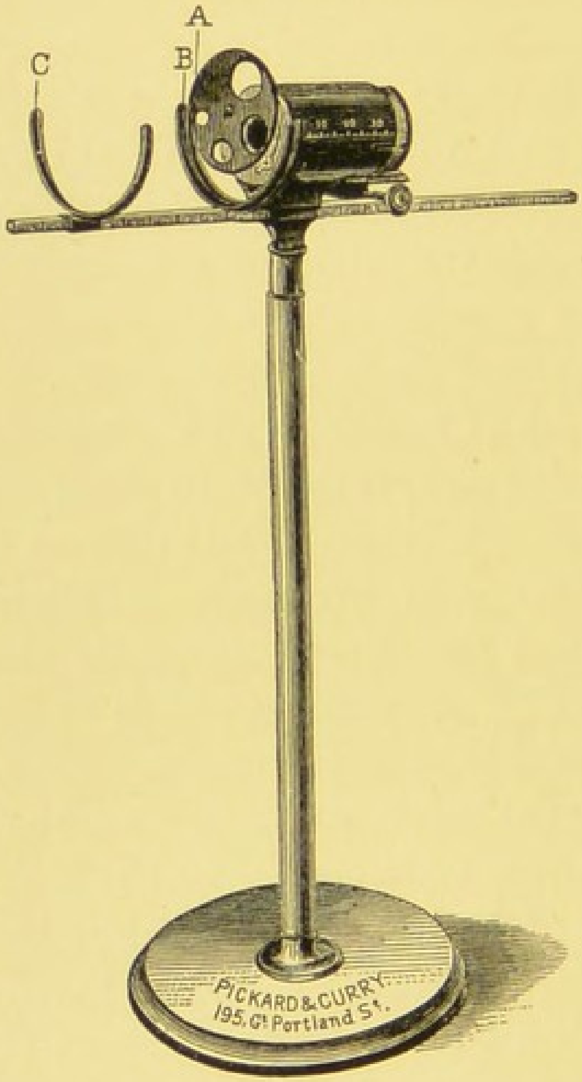
METHODS OF EXAMINATION

The best light to employ is the ordinary gas Argand burner on a bracket, capable of up and down as well as lateral movement. When this is not to be obtained an ordinary oil lamp may be used or even a candle. The patient should be seated on a chair, while the observer may conveniently use a music stool, the height of which can be altered as occasion requires; some observers prefer to stand when making an examination. A dark room is also an advantage.

In many cases it is necessary to dilate the pupil with a mydriatic; one that acts quickly and fully, and the effect of which soon passes off is to be preferred. In many people it is most inconvenient to use atropine as its effects last for many days; the mydriatic which is, perhaps, most convenient is a solution containing 4 grs. of hydrobromate of homatropine with 10 grs. of hydrochlorate of cocaine; a drop of this produces a full dilatation in a very short time and the effect passes off in two or three hours; of course, in many cases no mydriatic is required, but when a thorough examination is necessary, it is a great advantage to examine the eye through a well-dilated pupil; this is especially the case when some changes have been detected in the fundus, and further information may be required by a more searching examination.

But the student should learn not to rely too much upon these minor aids, but accustom himself to examine the fundus in various positions and under different surroundings, with or without a mydriatic.

Fig. 31.



It is recommended that every opportunity be taken to make repeated ophthalmoscopic examinations, and where a large number of patients is not to be met with, the artificial eye of Mr. Adams Frost (Fig. 31) will be of the greatest service in enabling the student to acquire the necessary associated movements, as well as to understand and appreciate many points of importance, with regard to the size and formation of the images in the various conditions of refraction.

The first thing for a beginner, is to familiarise himself with the variations of the normal fundus. Very great differences are met with; as numerous almost as the various shades of hair found in the human race.

Besides even in those cases where the visual acuteness is normal, and no symptoms indicative of disease are present, gross changes may be found, or physiological peculiarities may exist which ought not to be missed.

Generally, young ophthalmologists disdain to look at a normal fundus, caring only for pathological conditions; it would be much better for every one to look at a certain number of normal fundi before passing on to the various diseases. Usually the reverse is the method of procedure; abnormal cases are looked at first, varied only very occasionally by a normal case.

In undertaking an ophthalmoscopic examination, it should be conducted quietly and without hurry; a number of students standing round anxious to look at the same case is not conducive to a thorough examination. A regular routine is absolutely necessary; accuracy and confidence are thereby attained. First, the cornea, iris, and lens must be examined by *focal* *illumination;* then the large concave mirror is used *at a distance* of about two thirds of a metre, and may give an indication of the refraction of the eye, and allow the condition of the vitreous to be ascertained; this should be followed by the *indirect method of examination,* which enables that part of the fundus which is within reach of the ophthalmoscope to be readily scanned; the examination is completed by the *direct method,* which gives an image magnified some eighteen diameters, and allows minute changes, not visible by the indirect method, to be detected, while at the same time it allows of an estimate of the refraction being made.

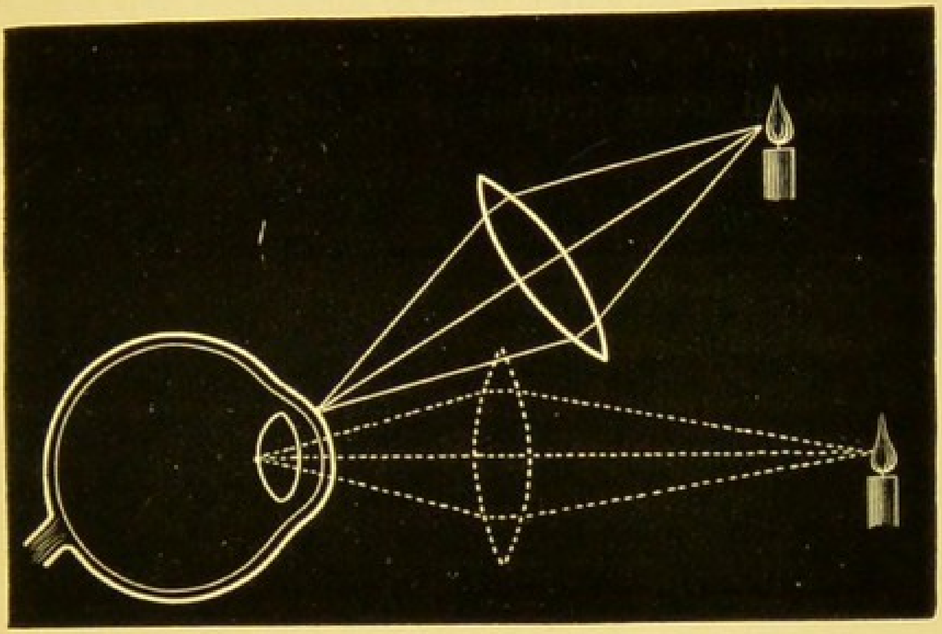
When any change has been detected in the cornea, iris, or lens, this may conveniently be examined with the oblique mirror, having a +20 D. behind the sight-hole of the ophthalmoscope, and approaching close to the patient as with the direct method; when the iris and lens are examined in this way a somewhat weaker glass is necessary, +16 D.

The Focal Illumination.

The patient should be seated opposite a good gas light, a large biconvex lens of about 13 D. is held between the thumb and forefinger of one hand, so as to concentrate the light obliquely on the cornea, iris, and lens successively; by this means opacities and irregularities of the cornea; opacities of the lens; and even affections of the anterior part of the vitreous may be detected, and will appear in their real colour and position.

By varying the position of the light and the eye under examination, every part can be thoroughly inspected. When the deeper parts of the lens and the anterior part of the vitreous are examined, the light must be thrown into the eye in an almost perpendicular manner.

FIG. 32.



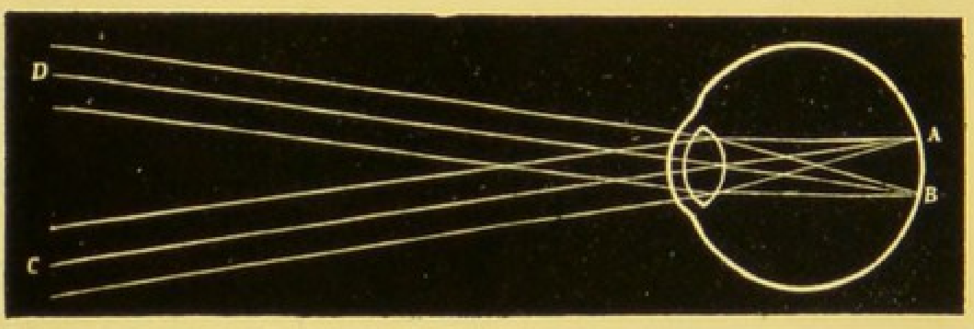
This examination may with advantage be supplemented by using a second lens before the eye as a magnifying glass, or a small magnifying glass made for that purpose and referred to on p. 30.

The large Concave Mirror at a Distance.

The gas light should now be placed on one side of the patient, on a level with the head and slightly behind, so that no direct light falls on his face; the observer sitting opposite, places before his eye the *large concave mirror*, and at a *distance* of about two thirds of a metre reflects the light into the eye he wishes to examine; usually a red fundus reflex is obtained, but no details will be visible; should any of the vessels or a part of the disc be seen, then we shall know that the eye under examination is ametropic.

Because in emmetropia (Fig. 33) the rays which come from the two extremities of the disc (A B), emerge as two sets of parallel rays in the same direction as the rays A C, B D, which, having passed through the nodal point, undergo no refraction. These two sets of rays soon diverge, leaving a space between them, so that an observer, unless he be quite close to the observed eye, is unable to bring these rays to a focus on his retina; and therefore at a distance from the eye the observer sees only a diffused and blurred image.

FIG. 33.



In hypermetropia (Fig. 34) the rays from the two points (A B) emerge from the eye in two sets of diverging rays, in the same direction as the rays A C, B D, which undergo no refraction. These diverging rays have the appearance of coming from two points (*a*, *b*) behind the eye, where an erect imaginary image is formed (*a b*).

Here the observer at a distance sees a clear, erect image, which is formed behind the eye.

FIG. 34.

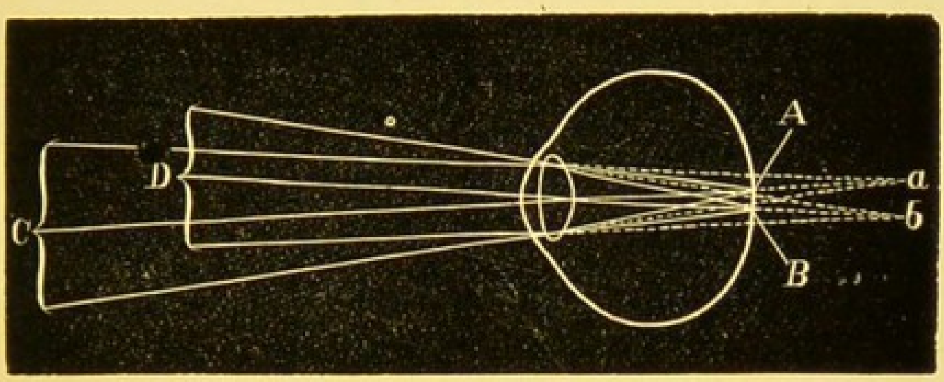
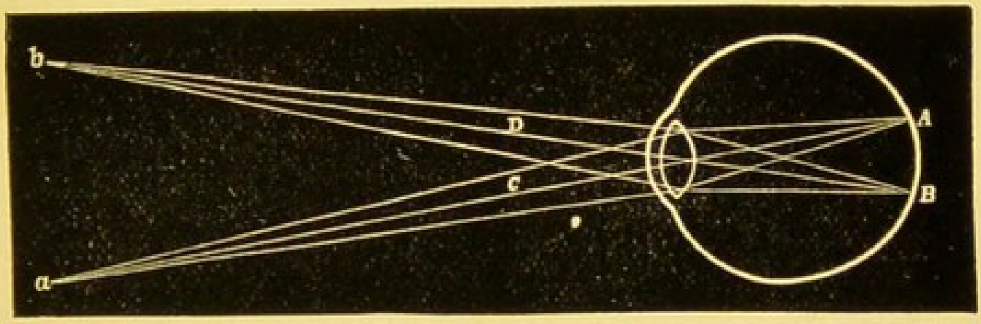


FIG. 35.



In myopia (Fig. 35) the rays from the two points (A B) emerge as two converging sets of rays, which meet at *a b* on their secondary axes, thus forming an inverted image in front of the eye. This image can be distinctly seen by the observer, if he be at a sufficient distance from the point, and accommodating for the particular spot at which the aërial image is formed, and the higher the myopia the nearer to the eye will this image be formed.

If the observer now move his head from side to side, and the vessels of the disc are seen to move in the same direction, the case would be one of hypermetropia, the image formed being an erect one.

Had the vessels moved in the opposite direction to the observer's head the case would be one of myopia, the image being an inverted one formed in the air in front of the eye.

If the vessels of one meridian only are visible, then we have a case of astigmatism, hypermetropic if moving in the same, and myopic if moving in the opposite direction to the observer's head, that meridian being ametropic which is at right angles to the vessels seen.

In mixed astigmatism the vessels of one meridian move against the observer's movements, and those of the other meridian with them; this is difficult to see.

Should no fundus reflex be obtained when the light is thus properly reflected into the eye, the case may be one of hæmorrhage into the vitreous or other serious lesion: but the reflex may be good, and yet it may appear irregular by the presence of black spots here or there; in this case probably some opacity exists in the cornea, lens, or vitreous, which interferes with the returning rays of light, and so appears black, whatever the real colour of the opacity may be; and if nothing was seen by careful inspection with focal illumination, the opacity is in all probability situated in the vitreous; this is certainly the case if the opacity is *floating*. The movements of these floating opacities will be more conspicuous if the patient be directed to first look upwards, then downwards, and finally straight in front of him; the rate of movement will be a guide as to the consistency of the vitreous; the direction of their movements will depend upon their position in the vitreous, whether they are in front of or behind the centre of rotation of the eyeball; a point situated in the normal emmetropic eye 9·2 mm. in front of the retina.

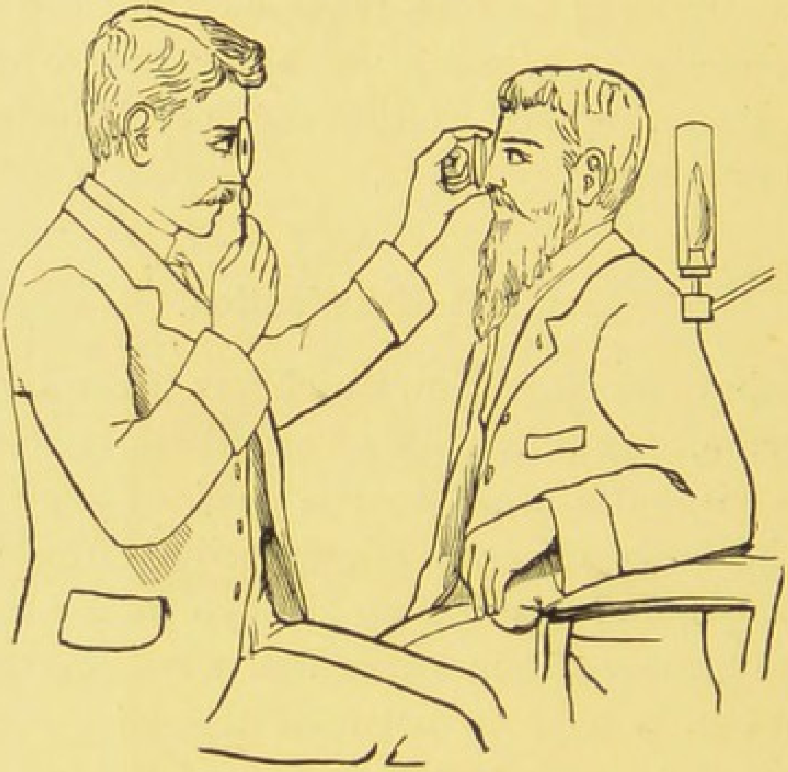
In some cases the vitreous opacities may be so thin, that some of the returning light may pass through them; they will then appear more or less white or pink, occasionally light may be reflected from the surface of the opacity, and then it will appear white and more or less glistening, as in the case of cholesterine or tyrosin crystals.

Indirect Examination.

The above examination, which has taken some time to describe, occupies only a very short time, and we pass on without a break to the *indirect examination*. With the large concave mirror still before the observer's eye, and lighting up the eye under examination, the biconvex lens which was used for the focal illumination is held up between the mirror and the patient's eye; an inverted image of the fundus will thus be obtained, magnified about five diameters; the amount of magnification depends upon the strength of the objective used; the stronger the lens the less is the image magnified, and therefore the greater the field that comes into view. The size of the field that can be seen at once will depend upon the strength and size of the object-glass: thus, with a dilated pupil and a lens of +13 D., having a diameter of about 5 cm., the size of the field will be about 8 mm., or four times as large a field as will be seen by the direct method.

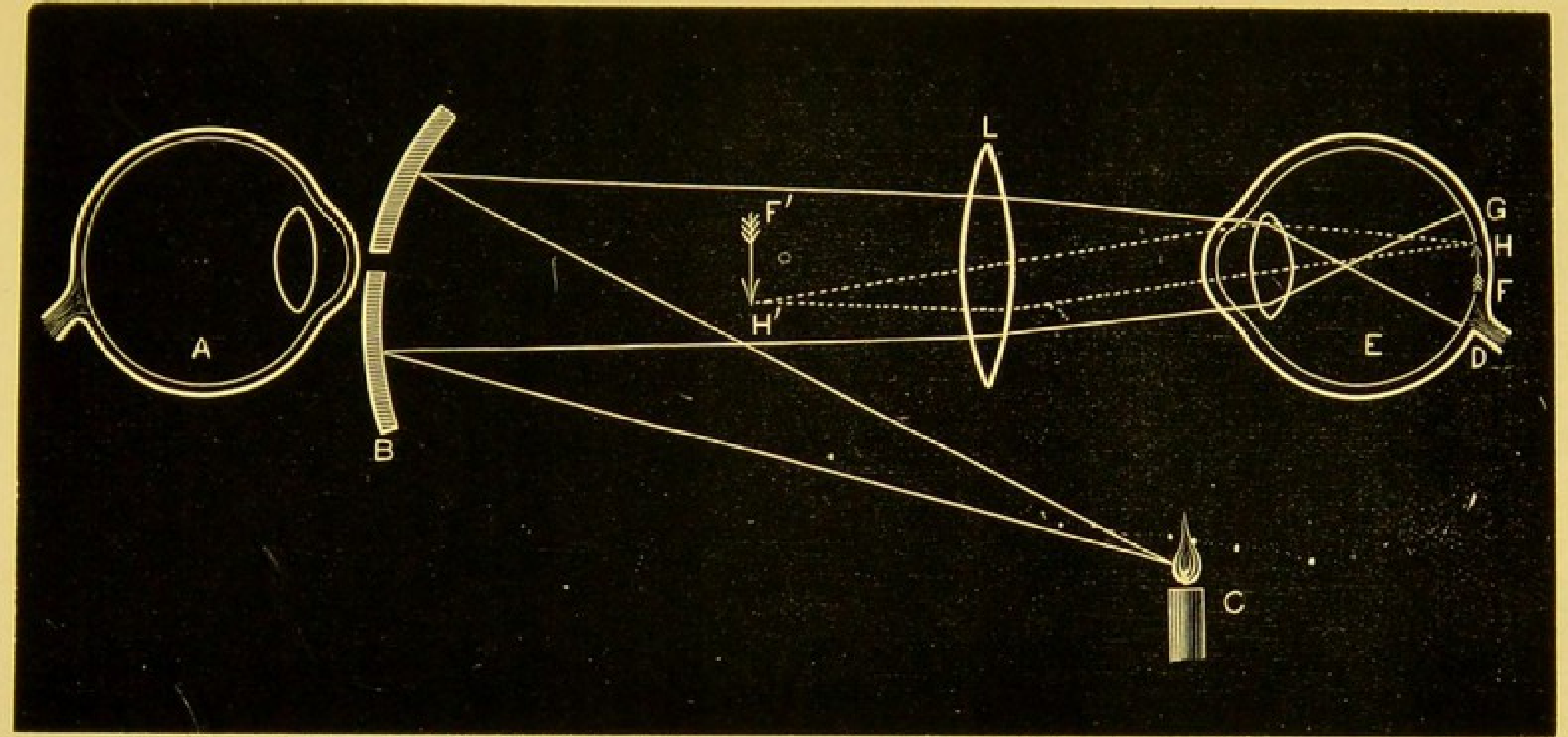
The image formed by the objective will in the case of emmetropia be at the focus of the convex glass, between it and the observing eye, so that the learner has to remember to accommodate for the image at this distance.

Fig. 36.



It is convenient to use the mirror before the right eye when examining the patient's right, and the left when examining the patient's left; then the objective will be held between the finger and thumb of the opposite hand. This may be steadied if necessary by resting the little finger against the forehead. By adopting this procedure the hand holding the objective is not over the patient's face. Some observers, however, always use the same eye for the indirect examination; thus if the right be the one preferred, the

FIG. 37.



This figure is intended to show the indirect method. Rays of light reflected from C are thrown through lens L into the emmetropic eye E, lighting up that portion between G and D. Rays returning from H will pass out of the eye parallel, and falling on the objective L will be brought to a focus at H′; so also will rays from F be brought to a focus at F′, so that the lens L will give an enlarged inverted image of H F at F′ H′, which will be situated in the air at the focus of the convex lens L, and will be visible to the observing eye, A. The rays are only drawn from the one point, H, so as not to confuse the diagram. The distance between the aërial image thus formed and the observing eye is too short. This is done to make the figure a convenient size.

observer will always hold the ophthalmoscope in his right hand, using the objective with the left: this is simply a matter of individual convenience. The eye of the observer not in use may with advantage be kept open.

Although not necessary it is an advantage to use a +4 D. behind the ophthalmoscope; one thus obtains a somewhat larger image, which can be seen without accommodating at the focus of the biconvex lens used. Thus when examining the fundus of an emmetrope, the aërial inverted image will be formed at the focus of the objective, which, in the case of a +13 D., will be 8 cm., the observer (with a +4 D. behind his mirror) situated at 25 cm. from this image, will see it clearly and well defined at this distance without any accommodation; the advantage of this plan is that the observer sits nearer the patient than when the examination is made without the +4 D.

The first part to which attention should be directed is *the disc*. If one is examining the right eye, the patient should be directed to look toward one's right ear, or, what is perhaps better, at the upheld little finger of the right hand which is holding the mirror; the light reflected from the concave mirror gives the fundus reflex, which is somewhat whiter when coming from the optic disc; the large convex glass is held between the thumb and finger of the left hand, about 3 or 4 cm. directly in front of the observed eye; this will form an inverted image of the disc, which should be clearly seen by the observer. The beginner will find some difficulty at first in performing these associated movements of lighting up the fundus with the mirror and keeping the light steadily on the eye, while the objective is held in the other hand and moved about backwards and forwards, and from side to side.

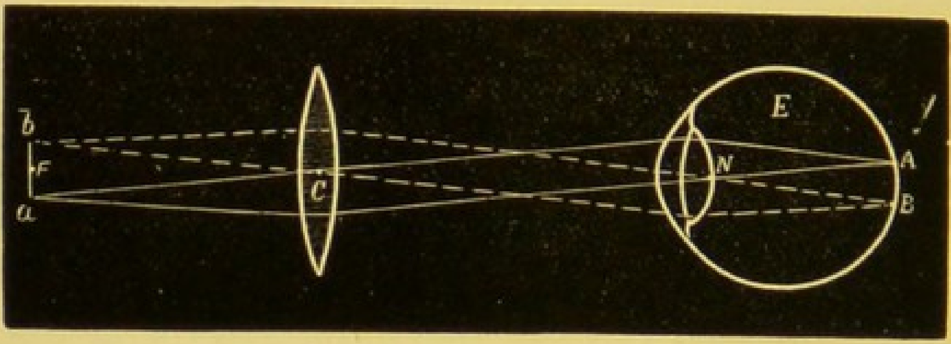
The next part to examine is the *periphery ;* this must be gone over systematically by directing the patient to look up, then down, then to the right, and finally to the left. By this means the posterior hemisphere of the eyeball may be thoroughly inspected, especially when the pupil has been dilated with a mydriatic.

Finally the *macula* region demands attention. This is rather difficult, as the pupil contracts vigorously when the light is directed on this the most sensitive part of the fundus ; besides, one is liable to get a good deal of reflex. The patient should be directed to look at the mirror or slightly to one side of it ; then with a little manœuvring with the light and lens, and a certain amount of practice a fairly good view of this part may be obtained.

The reflections formed by the cornea and by the objective are always somewhat troublesome to the beginner; by tilting the lens slightly these images will be thrown out of the line of vision.

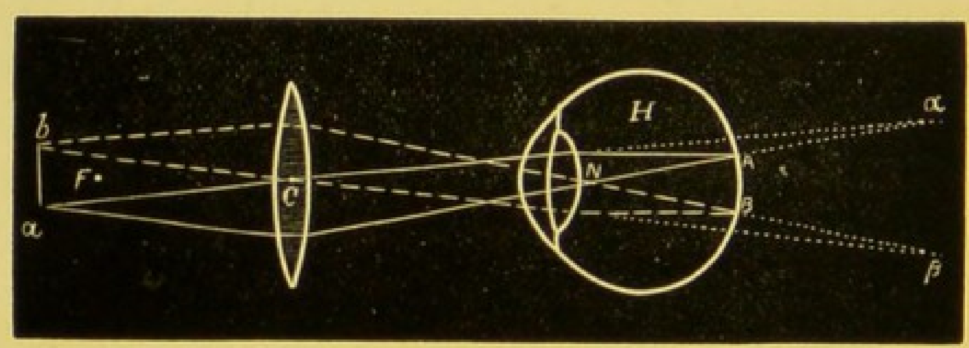
The condition of the refraction of the eye under examination will cause some variation in the size of the images obtained ; thus in emmetropia rays coming from A, Fig. 38, emerge from the eye parallel, and are focussed by the biconvex lens at *a*, and rays coming from B are focussed at *b*, so also with rays coming from every part of A B, forming an inverted image of A B at *b a*, situated in the air at the principal focus of the biconvex lens.

FIG. 38.



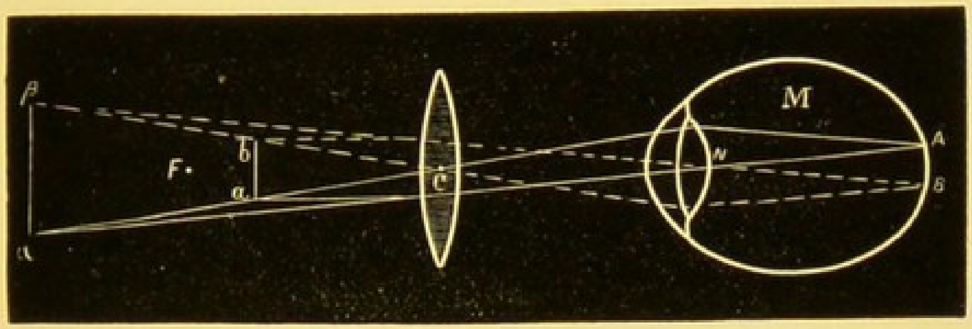
In hypermetropia (Fig. 39), the rays from A emerge divergent, so also of course those from B; if these rays are continued backwards, they will meet behind the eye, and there form an enlarged, inverted image (*α β*) of A B; it is of this imaginary projected image, that we obtain by the help of the biconvex lens a final inverted image (*b a*), situated in front of the lens beyond its principal focus.

FIG. 39.



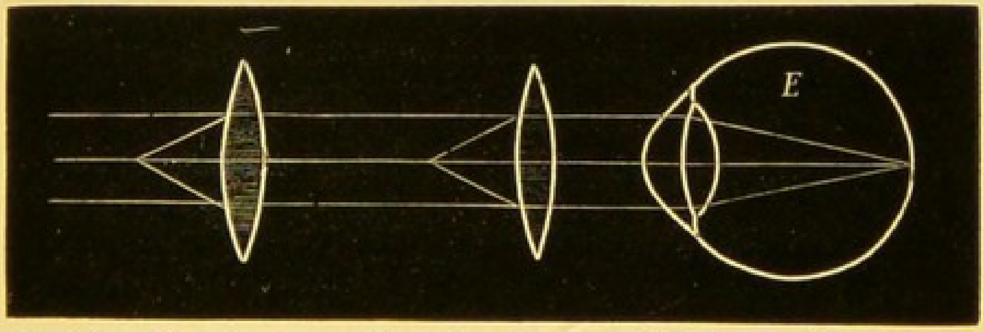
In myopia (Fig. 40) the rays from A and B emerge from the eye convergent, forming an inverted aërial image in front of the eye at *β α*, its punctum remotum. It is of this image we obtain, with a biconvex lens placed between it and the eye, a final image (*b a*), situated within the focus of the biconvex lens.

FIG. 40.



The inverted image of the disc, produced by a convex lens at a certain fixed distance from the cornea, is larger in hypermetropia, and smaller in myopia, than in emmetropia. The lens should be held close to the patient's eye, and as it is gradually withdrawn, the aërial image of the disc must be steadily kept in view; if any increase or decrease takes place in the size of this image, we shall know that the eye is ametropic.

FIG. 41.

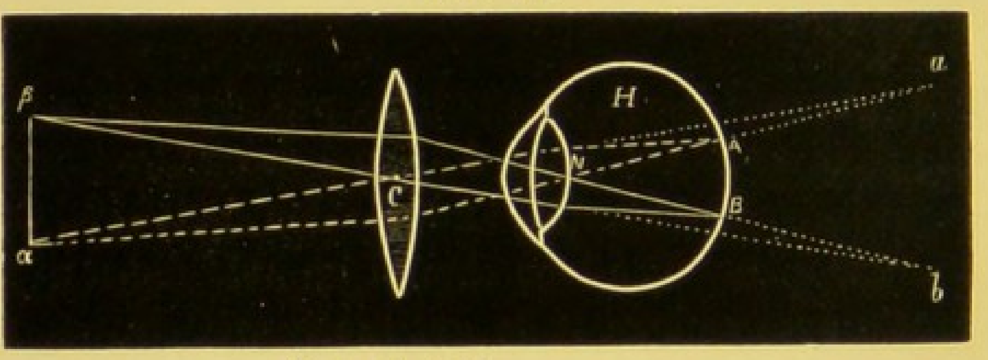


E. Emmetropic eye. Rays issuing parallel, image formed at the principal focus of lens, no matter at what distance the lens is from the eye.

If no change take place in the size of the image on thus withdrawing the objective, the case is one of emmetropia, because rays issue from such an eye parallel, and the image formed by the object-glass will always be situated at its principal focus, no matter at what distance the glass is from the observed eye (Fig. 41). As the relative distance of the image and the object from the lens is the same, the size of the image will also be the same.

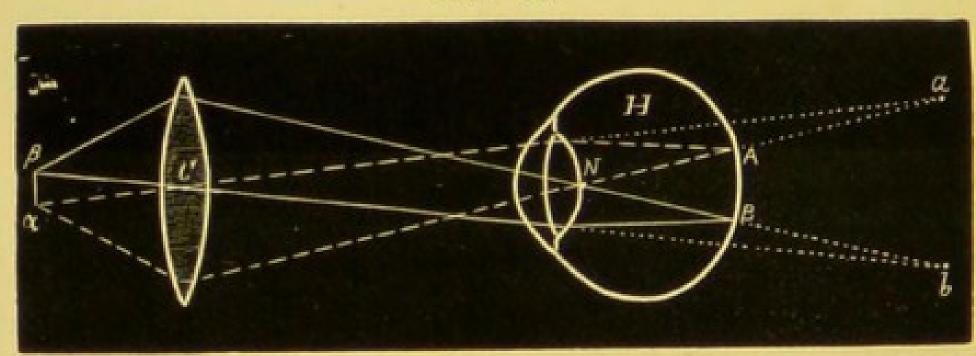
If diminution take place in the size of the image

Fig. 42.



Lens at 4 cm.

Fig. 43.



Lens at 12 cm.

H. Hypermetropic eye. C. The centre of the lens. A B. Image on retina. *a b*. Projected image. *β a*. The final image formed by the objective.

the case is one of hypermetropia, and the greater the diminution the higher is the hypermetropia.

This change in size may be explained by remembering that in hypermetropia the image of the disc is projected backwards (Fig. 34), and it is of this projected image we obtain a final image with the help of the objective. The two diagrams 42 and 43 show images formed by the object-glass, when held at 4 cm. and at 12 cm. from the cornea, the latter image being the smaller.

The following explains this:

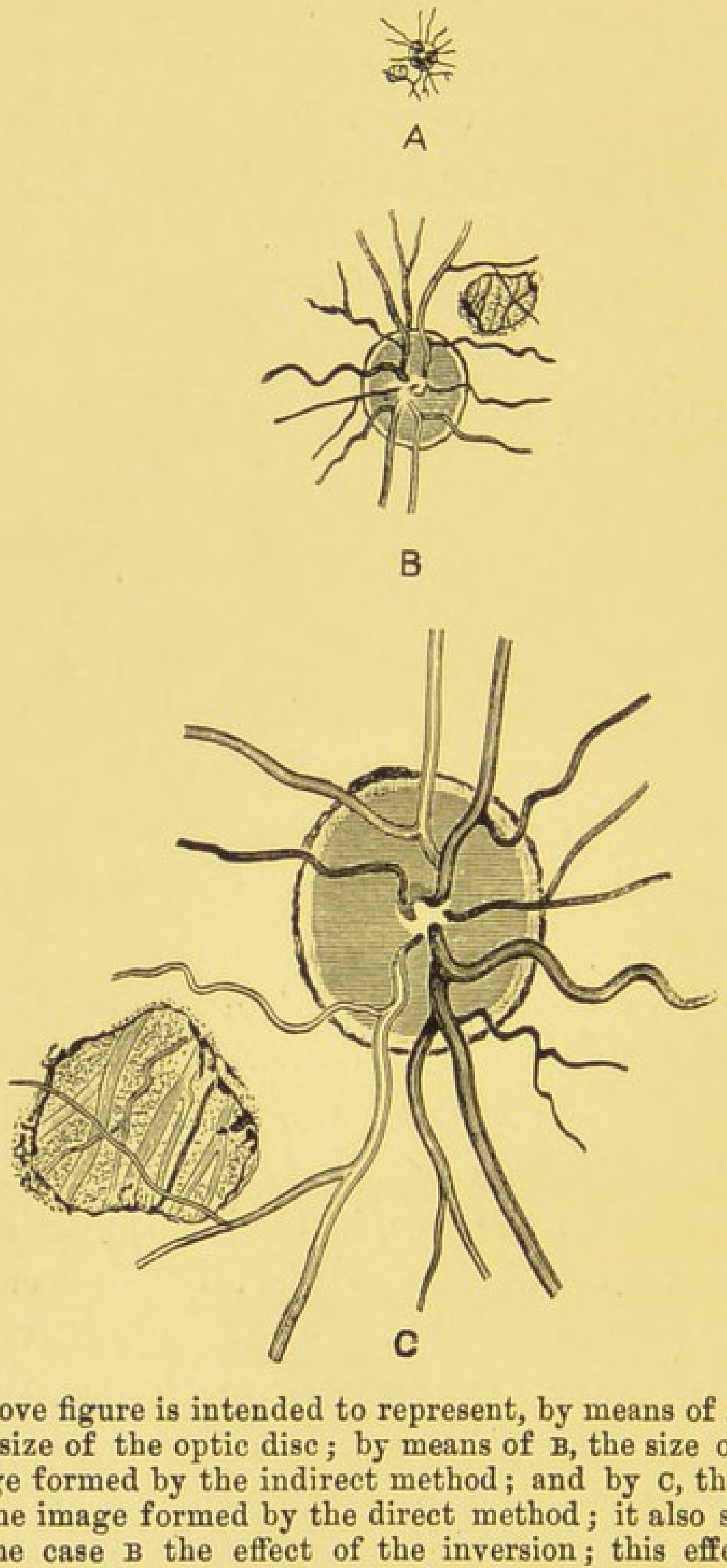
The ratio of $\alpha \beta$ to $a b$ varies directly as the length c α, and inversely as the length c a; on withdrawing the lens c from the observed eye, c α diminishes and c a increases; therefore the ratio of $\alpha \beta$ to $a b$ diminishes, *i. e.* the size of the image diminishes.

If the image become larger on withdrawing the object-glass, the case is one of myopia; the greater the increase of the image, the higher the myopia.

This increase in the size of the image can also be explained with the help of mathematics, remembering that, in myopia, an inverted image is formed in front of the eye (Fig. 35), and it is of this we obtain an image, with a convex glass placed between the eye and the inverted image, which we must regard as the object, the object and its image being both on the same side of the lens.

In astigmatism the disc, instead of appearing round, is frequently oval. If one meridian decrease, while the other remain stationary as the objective is withdrawn, it is a case of simple hypermetropic astigmatism. If the whole disc decrease in size, one meridian diminishing more than the other, it is compound hypermetropic astigmatism, the meridian being most hypermetropic which diminishes most.

FIG. 44.



The above figure is intended to represent, by means of A, the real size of the optic disc; by means of B, the size of the image formed by the indirect method; and by C, the size of the image formed by the direct method; it also shows in the case B the effect of the inversion; this effect is rendered more apparent by the patch of choroiditis shown in the figure.

Increase in one meridian, the other remaining stationary, indicates simple myopic astigmatism.

Increase in disc, but one meridian more so than the other, indicates compound myopic astigmatism; that meridian being most myopic which increases most.

If one meridian increases while the other decreases, the case is one of mixed astigmatism.

It must be remembered that by the indirect method everything is inverted; thus the apparent position of the macula is to the inner side, when of course its real position is outside, the apparent upper edge of the disc is the lower, and so on. Fig. 44 is intended to represent this inversion.

The ophthalmoscopic image of the same disc does not always appear of the same size to different observers; this is because the size of the object is not arrived at by the size of the retinal image alone, but partly also by the distance to which the image is mentally projected by the observer.

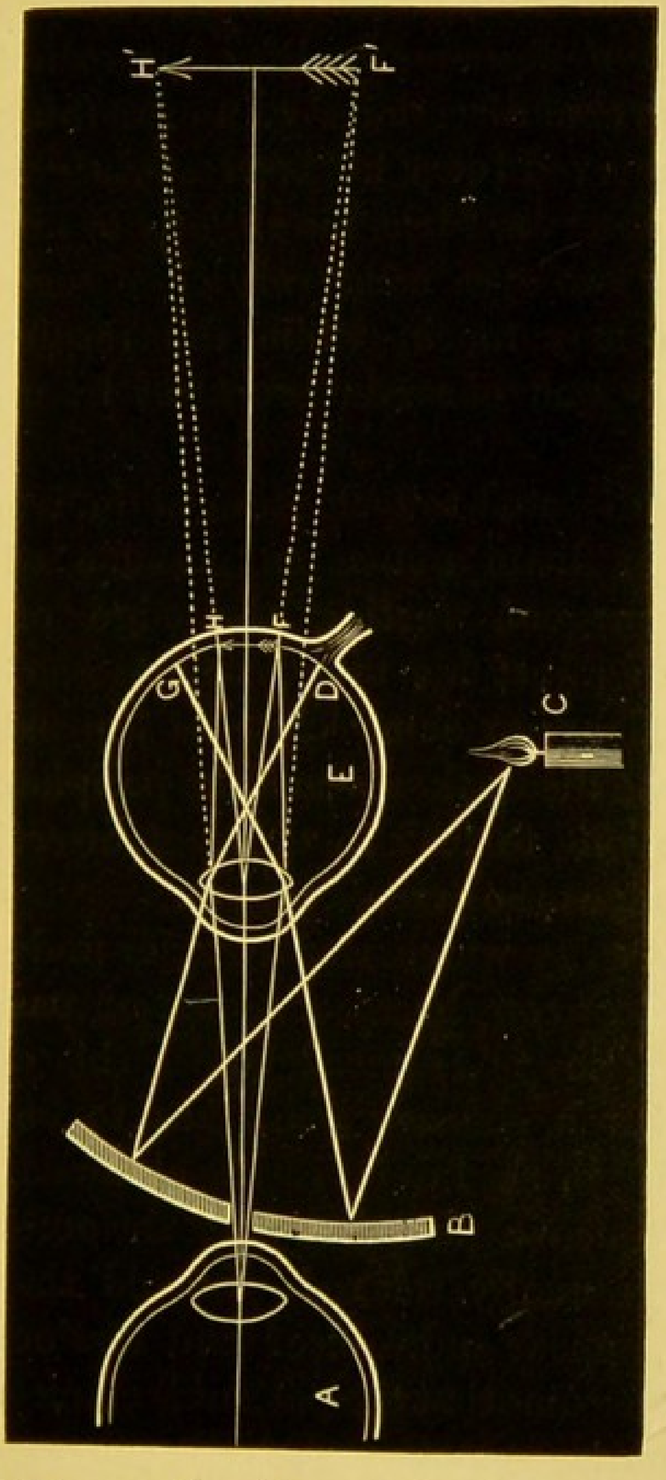
The Direct Method.

The direct method of examination is next employed. This method has the advantage of enabling us to see the parts in their true position, and gives us an image magnified some 16 to 18 diameters, though, of course, a much smaller part of the fundus is seen at once. The amount of fundus which will be visible depends chiefly upon the size of the pupil, but partly also upon the size of the light used; with a pupil of 4 mm. and a large gas flame, one gets a field little bigger than 2 mm.; although only this small part can be seen at once, yet by varying the position of the head and ophthalmoscope one is able to look over a considerable part of the posterior hemisphere of the eye.

FIG. 45.

For this examination the tilted short focussed mirror is used; it may be quite small, as only those rays reflected from the part immediately around the sight-hole enter the pupil,—this is especially the case when the pupil is small; the sight-hole should not be larger than about 2½ mm., for if the sight-hole be larger than the pupil, then no rays may enter the eye and we shall fail to get any illumination. The observer first corrects any ametropia that he may have, by means of his refracting ophthalmoscope, then sits or stands as he may prefer on the same side as the eye he is about to examine, so that the observer uses his right eye for the patient's right and his left for the patient's left.

Fig. 46.



In Fig. 46, A is the observing eye, E the observed, C the candle from which divergent rays fall on the mirror B, and being reflected into the eye light up the area between G and D, rays from the points H and F pass through the sight-hole of the mirror and enter the observing eye A, forming on A's retina an image of H F. By continuing these rays backwards an enlarged upright image of H F will be formed behind the eye at H′ F′.

The light is placed on that side a little behind and on a level with the patient's ear; the examinee's head may with advantage be inclined slightly towards the observer, while the observer inclines his own head slightly in the reverse direction, *i. e.* in examining the right eye, the observed turns his head slightly to his right, while the observer turns his slightly to his own right, so that the two eyes come very close together, the brows even may touch, while the respiratory orifices of patient and observer are away from each other.

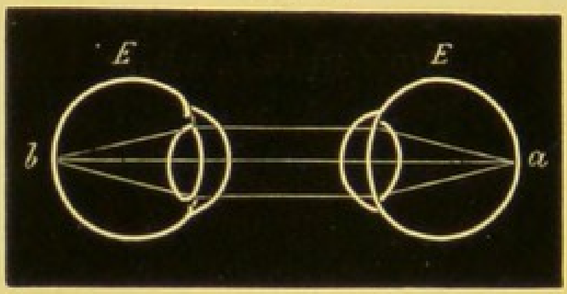
The patient is directed to look straight in front of him and take as little notice as possible of the examiner, the surgeon resting the edge of the ophthalmoscope against his brow, reflects the light into the eye, and approaching close to the patient, first looks for the disc; then scans the periphery by directing the patient to look in different directions; and finally examines the macula region.

The great difficulty which the beginner finds with this method is to keep the accommodation passive; usually some practice is required before this can be managed, so that a concave glass has to be used before a clear view of the fundus can be obtained. By using a weaker concave glass each time, the accommodation will be gradually relaxed. Should the disc, when first seen, appear quite clear and distinct, one must not at once assume that the patient is emmetropic, but only on finding that the weakest convex glass behind the ophthalmoscope impairs the clearness of the image. Another difficulty the beginner has, is to disregard the corneal reflex, which is most troublesome when the macula region is inspected.

Both the *indirect* and *direct* examination should always be employed, each method has its own special advantages; thus the *indirect* gives us a large field and allows us quickly to scan over the whole of the posterior part of the fundus, while the patient's refraction need not be corrected, and the observer may disregard his own ametropia provided he can see the aërial image at the point where it will be formed. The *direct* gives a smaller field but greatly magnified, so that minute changes, which are not visible by the indirect, can be detected; it also gives us more accurate information of any lesion with regard to its level, &c., and being an upright image everything is seen in its proper position, whereas with the indirect the image is inverted; and finally with the direct, the refraction of the observer and observed must be corrected.

To the experienced ophthalmoscopist this becomes an advantage, as an estimate of the patient's refraction can thus be made. To estimate the refraction of the patient by the direct method, it is necessary that the patient's accommodation should be relaxed, this will generally be the case when the examination is made in a dark room, or atropine may be used; then if the observer's own accommodation be suspended, and the image of the disc appear quite clear and distinct, the case is one of emmetropia; because rays coming from an emmetropic eye (Fig. 47, E) issue parallel, and the observing eye receiving these rays will, if emmetropic with its accommodation suspended, be adapted for parallel rays, so that a clear image of *a* in the observed eye will be formed at *b* on the retina of the observing eye.

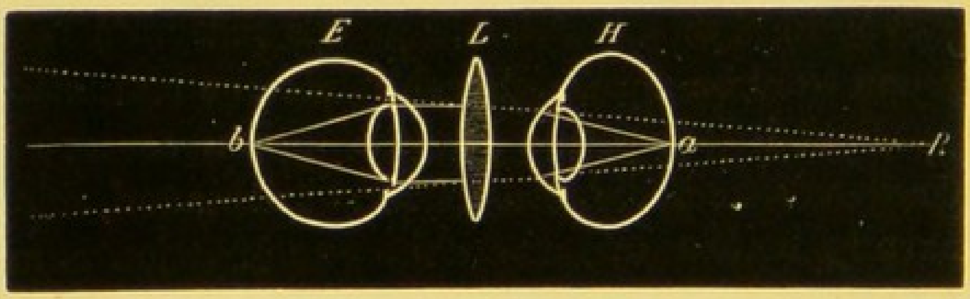
FIG. 47.



Supposing the image does not appear clear and distinct without an effort of the accommodation, then we turn on convex glasses behind the sight-hole of the ophthalmoscope.

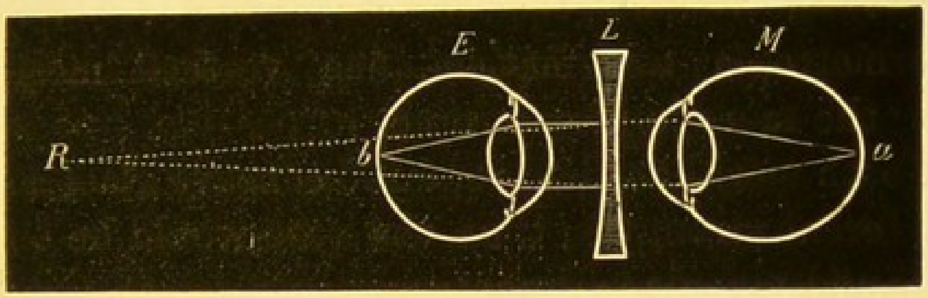
The *strongest* positive glass with which we are able to get a perfectly clear image, is a measure of the hypermetropia, because rays coming from *a* (Fig. 48) in the hypermetropic eye (H) issue in a divergent direction as though coming from R, the punctum remotum behind the eye. The convex lens (L) renders them parallel, and they then focus at *b*, on the retina of the observing emmetropic eye (E).

FIG. 48.



If, however, the image of the disc appear indistinct, and the convex glass, instead of rendering the image clearer, have the opposite effect, we must turn the wheel of the ophthalmoscope in the other direction, and so bring forward the concave glasses. The *weakest* with which we can see the details of the fundus clearly is a measure of the myopia, because any stronger glass merely brings into play the accommodation of the observer. Rays from *a* (Fig. 49) leave the myopic eye (M) so convergent, that they would meet at (R) the punctum remotum. The concave lens (L) renders them parallel before falling on the relaxed eye (E) of the observer.

FIG. 49.



If the ophthalmoscope is not held very close to the eye, we must deduct from the focal distance of the lens, the distance between the cornea and the instrument in hypermetropia, adding them together in myopia.

If astigmatism exist, the plan is to find the glass which enables the vertical vessels and lateral sides of the disc to be seen distinctly, and then the glass with which the vessels at right angles are best seen.

Suppose the vertical vessels and lateral sides of the disc appear distinct without any glass, then the horizontal meridian, *i. e.* the meridian at right angles to the vessels clearly seen, is emmetropic; and suppose, also, that the horizontal vessels, with the upper and lower borders of the discs, require a convex or concave glass to render them clear and distinct, then the vertical meridian is hypermetropic or myopic, and the case is one of simple hypermetropic or myopic astigmatism.

If both the vertical and horizontal vessels require convex glasses, but a stronger one for the horizontal than for the vertical, then the case is one of compound hypermetropic astigmatism, the vertical meridian being the more hypermetropic.

If both meridians had required concave glasses, but of different strengths, then the case would be one of compound myopic astigmatism.

If the vertical vessels and the lateral sides of the disc require a convex glass to render them distinct, while the horizontal vessels require a concave glass, the case is one of mixed astigmatism, the horizontal meridian being hypermetropic, the vertical meridian myopic.

The essential point to remember is, that the glass with which the vessels in one direction are seen, is a measure of the refraction of the meridian at right angles to them.

The estimation of the refraction by the direct ophthalmoscopic method is exceedingly valuable, but requires great practice. In cases of hypermetropia and low myopia, one is able to estimate the amount of error within half a dioptre, and in cases of astigmatism where the chief meridians are horizontal and vertical, one can come very near the exact correction, and without subjecting the patient to the inconvenience of having his accommodation paralysed with atropine.

The comparison of the direct and indirect methods of examination is also very useful in astigmatism. If, for instance, the disc is elongated horizontally in the erect, and oval vertically in the inverted image, we know that the curvature of the cornea is greater in the horizontal than in the vertical meridian.

The ametropic observer must always remember, when using the direct method, for the estimation of errors of refraction, that he must correct his own defect, either by wearing spectacles or by having a suitable glass in a clip behind his ophthalmoscope; he is then in the position of an emmetrope: but, if he prefer it, he may subtract the amount of his own hypermetropia or myopia from the glass with which he sees clearly the patient's discs. Thus, if the observer have 2 D. of hypermetropia and require $+3$ D. to see the fundus clearly, $(+3\text{ D.}) - (+2\text{ D.}) = +1$ D., the patient would have 1 D. of hypermetropia; had he required -2 D. then $(-2\text{ D.}) + (-2\text{ D.}) = (-4\text{ D.})$ the observed would have 4 D. of myopia.

The same with the myopic observer; if his myopia amount to 3 D., then he will require -3 D. to see clearly the emmetropic fundus; if he sees well without a glass, then the eye under examination has 3 D. of hypermetropia; if he require a $+2$ D., then the hypermetropia will be 5 D., and so on.

Retinoscopy.

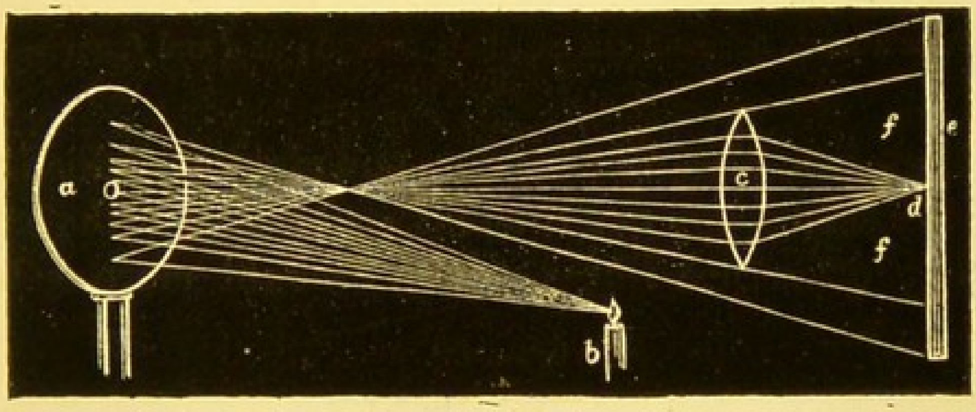
Retinoscopy or the shadow test may conclude our ophthalmoscopic examination; this is especially necessary when the vision has been found defective, and nothing has been detected by the indirect and direct methods.

Retinoscopy is carried out by means of the large concave mirror used in the indirect method, or by the Galizowski figured on p. 30. The light is placed over the patient's head, and the observer sitting at one and a quarter metres away, reflects the light into the eye he wishes to examine; the converging rays of light reflected from the mirror focus 25 cm. in front of it, cross and diverge. Some of these rays passing through the pupil of the observed eye, form a cone of light which in the case of emmetropia would form an exact focus on the retina.

When the observer looks through the sight-hole of the mirror, he will obtain the ordinary red fundus reflex; on slightly rotating the mirror the illuminated area of the pupil may disappear (or, what may be more easily seen, the edge of the shadow bounding this illuminated area may appear) on the same side as the rotation or in the opposite direction, according to the refraction of the eye under observation; thus if the mirror be rotated to the right and the edge of the shadow move across the pupil also to the right, *i. e.* in the same direction as the rotation of the mirror, the case is one of myopia, whereas if the shadow had moved in the opposite direction to the mirror, the case would be one of hypermetropia.

If we place before a screen a convex lens, at such a distance from it that converging rays from a concave mirror, having crossed and become divergent, are brought to an exact focus, a small, erect, well-defined image will be formed on the screen of the lamp, from which the concave mirror received its rays; erect, because it has suffered two inversions.

FIG. 50.



a. The concave mirror. *b.* The candle. *c.* The lens. *e.* The screen. *d.* Small image of candle formed on screen. *f.* Dense shadow around.

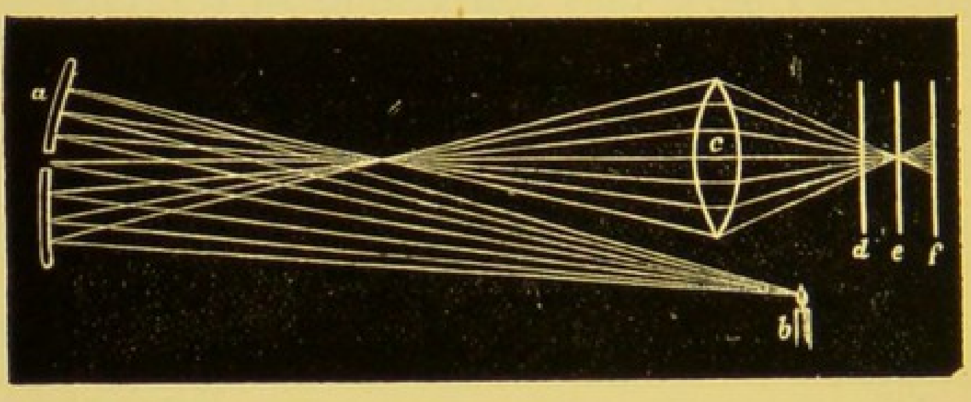
This image of the lamp is surrounded by a sharply defined and dark shadow.

If we move the lens nearer to, or farther from, the screen, a circle of diffusion and not an accurate image is formed, as shown in Fig. 51.

The mirror being rotated on its vertical axis, the image of the candle, with the surrounding shadow, will always be found to move in the opposite direction to the mirror, whatever be the distance of the lens from the screen.

This is exactly what takes place in the eye, of which our screen and lens are a representation.

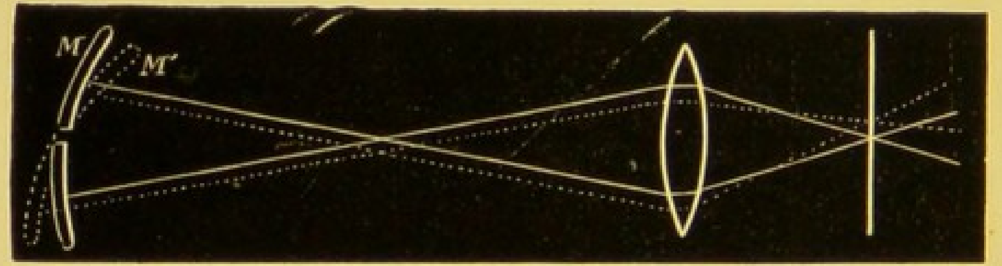
FIG. 51.



At *e* a small image of the candle is formed; at *d* and *f*, circles of diffusion.

Therefore the illumination and shadows which we see in retinoscopy are the enlarged image of the lamp with the surrounding shadow, brought more or less to a focus on the retina according to the refraction of the eye. They always move against the mirror, but as these movements are seen through the transparent media of the eye, and thereby undergo refraction, the "apparent" may differ from the "real" movements. The image we see of the lamp, and its surrounding

FIG. 52.



M. The mirror. M′. The mirror after rotation. The extremities of the dotted line have moved in the opposite direction to the rotation of the mirror.

shadows, are formed in the same manner as all other images.

In emmetropia the image is formed at infinity, and therefore, at a distance from the eye, the observer sees only a diffused and blurred image (Fig. 33).

In hypermetropia the final image of the candle and its surrounding shadow, produced by the concave mirror, is an erect one formed behind the eye, and as it is viewed through the dioptric system of the eye, it therefore moves against the mirror (Fig. 34).

In myopia the final image is an inverted one, projected forwards. This, therefore, moves with the mirror, it having undergone one more inversion (Fig. 35).

To this rule, that in myopia the image moves with the mirror, there are two exceptions:

1st. If the observer be nearer the patient than his far point, but not within the focal distance of the mirror, the image will move against the mirror. This is frequently the case in low degrees of myopia where the patient's far point is beyond 120 cm.

2nd. If the observer be within the focal distance of the mirror, although beyond the far point of the patient, the image will in this case also move against the mirror. This latter source of error can always be avoided by using a concave mirror of 25 cm. focus, and keeping 120 cm. from the patient.

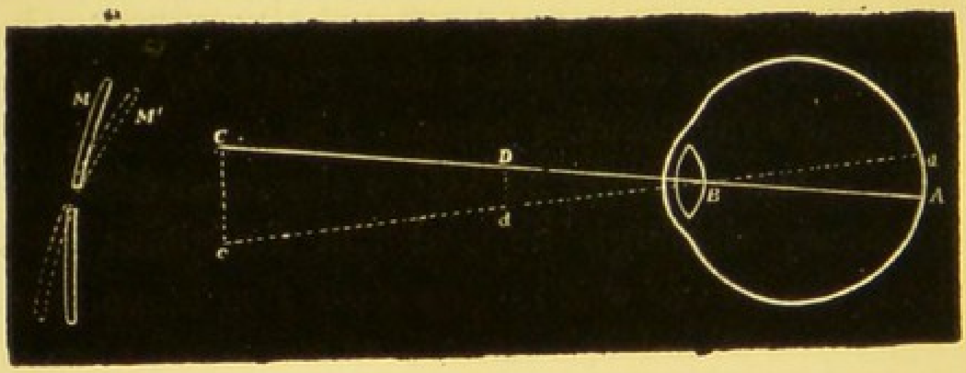
Therefore, if the image move with the mirror, the case is certainly one of myopia. If it move against the mirror, it is most likely one of hypermetropia; but it may be emmetropia, or a low degree of myopia.

The movements tell us the form of ametropia we have to deal with. The extent of the movements on rotation of the mirror, the clearness of the image and the brightness of its edge, enable us to judge approximately the amount of ametropia to be corrected; some practice, however, is required before we can form an opinion with anything like accuracy.

The extent and rate of movement is always in inverse proportion to the ametropia; the greater the error of refraction, the less the movement, and the slower does it take place. This may be explained in the following way:

Suppose A to be the image of a luminous point formed on the retina, and that a line be drawn from A through the nodal point B to C. Now, if the case be one of myopia (Fig. 53), an inverted projected image of A is formed somewhere on this line, say at C. The higher the myopia, the nearer to the nodal point will this image be; and hence we may suppose it formed as near as D. If the mirror be now rotated, so that it takes up the position of the dotted line M′, C will have

FIG. 53.

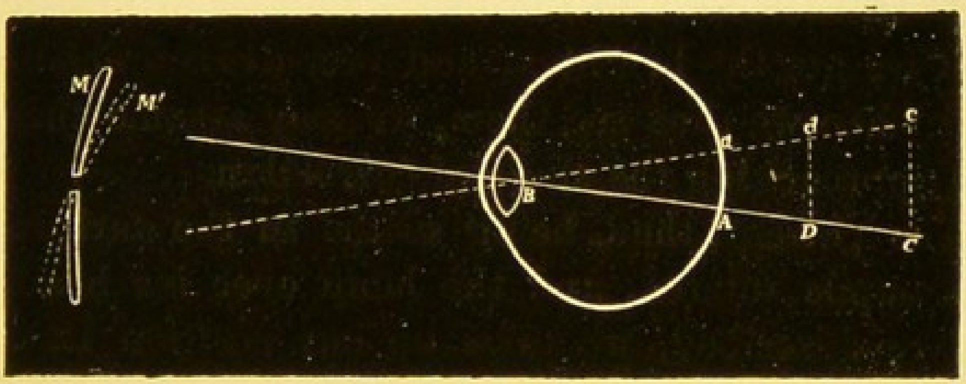


moved to *c*, and D to *d*; whence it is clear that C has made a greater movement than D.

Had the case been one of hypermetropia (Fig. 54), the image would have been projected backwards and as in myopia; the higher the degree of hypermetropia, the nearer to the nodal point is the image formed.

In this case, the line from the nodal point B to A is prolonged backwards, and the image of the luminous point in a low degree of hypermetropia is formed, say at C, and in a higher degree, say at D. On moving the mirror into the position of the dotted line M′, C moves to *c* and D to *d*; whence it is clear that C has made a greater movement than D.

FIG. 54.



Therefore, as the ametropia increases, the extent of the movement of the image decreases. The clearness of the image and the brightness of its edge decrease as the ametropia increases.

It was shown in Fig. 51, that on placing before a screen a convex lens at such a distance that converging rays from a concave mirror cross and become divergent, they are brought to an exact focus, forming a small, erect, well-defined image on the screen of the lamp from which the concave mirror received its rays. On moving the lens nearer to or farther from the screen, the larger becomes the area of light, and the feebler the illumination, owing to the circles of diffusion formed on the screen.

Therefore, in the case of the eye, the greater the ametropia, the larger is the circle of diffusion and the weaker the illumination, so that the image we see is less bright and its edge less distinct.

It is, therefore, in the lower degrees of ametropia that we get the brightest and best-defined shadows; and when we thus see them, we may assume that we are approaching the stage of correction.

The patient, then, being seated in the dark room, the pupils dilated, and the lamp over his head, as before described, we take up our position 120 cm. in front, with a concave mirror of 25 cm. focus. The patient is then directed to look at the centre of the mirror, so that the light from the lamp may be reflected along the visual axis. On looking through the perforation of the mirror, we get the ordinary fundus reflex, bright if the patient be emmetropic, less so if he be ametropic; and the greater the ametropia, the less bright will the fundus reflex be. We now rotate the mirror on its vertical axis to the right. If a vertical shadow come across the pupil from the patient's right, *i. e.* in the same direction as the movement of the mirror, or what is the same thing, if the shadow move in the same direction as the circle of light on the patient's face, the case is one of myopia. Should the edge of the image appear well-defined and move quickly, in addition to a bright fundus reflex, we infer that the myopia is of low degree and proceed to correct it.

Each eye must of course be tried separately.

The patient having put on a pair of trial spectacle-frames, we place a weak concave glass, say −1 D., before the eye we are about to correct. If the image still move with the mirror, we place in the frame −1·5 D., then −2 D., and so on, until we find the point at which no distinct shadow can be seen. Supposing this to be −2 D., and that on trying −2·5 D. the image move against the mirror, −2 D. is assumed to be the correcting-glass. This, however, will be found not to be the full correction of the myopia, because, being situated at 120 cm. from the patient, when his far point approaches that distance, we are unable to distinguish the movements of the shadow; and when the far point of the observed, though not situated at infinity, is still at a greater distance than the observer, we get a shadow moving in the opposite direction. Hence it is customary in cases of myopia to add on −·5 D. to the correcting-glass, and this would give us −2·5 D. as the proper glass for our case.

In correcting myopia, it is a convenient and reliable plan to stop at the weakest concave glass which makes the image move against the mirror, and put that down as the correcting-glass.

When the myopia is of high degree, and a strong concave glass has to be used for its correction, the light reflected from the mirror is so spread out by the concave glass, that fewer rays pass into the eye, and therefore the illumination is not so good as in other states of refraction.

Had we obtained a reverse shadow, we should then try convex glasses, when, if +·5 D. neutralised, we should assume the case to have been one of low myopia. Had it required +1 D. then it would be one of emmetropia; above this, hypermetropia. We proceed exactly as before, putting up stronger and stronger glasses, until we are unable to make out the movements of the image. This is assumed to be the correcting-glass, and just as in the above case the myopia was under-corrected, so in this, the hypermetropia is slightly over-corrected; and hence it is usual to deduct from this glass +1 D., or we may stop at the strongest convex glass with which we still get a reverse shadow.

To sum up, therefore, if the shadow move with the mirror, it is a case of "myopia;" if against, it may be weak myopia if +·5 D. cause the image to move with the mirror; emmetropia if +1 D. neutralised it; hypermetropia if a stronger glass is required.

The points to be observed are—(1) the direction of the movement of the image, as indicating the kind of ametropia, (2) the rate and amount of movement, (3) the brightness of the edge of the image, and (4) the amount of fundus reflex; all indicate the degree of ametropia.

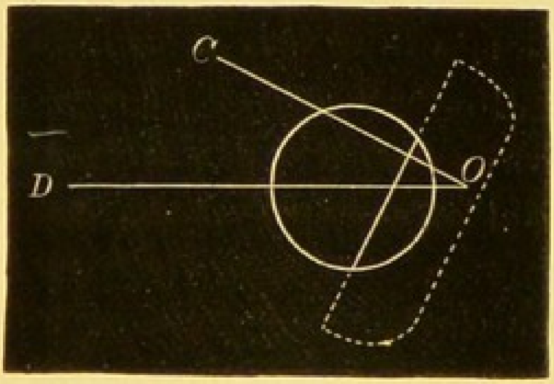
We have taken notice only of the horizontal axis, but any other meridian will, of course, do equally well, if the case be one of hypermetropia or myopia simply. If, however, the case be one of astigmatism, then the axes are different.

In astigmatism, the diffusion patch on the retina is more or less of an oval, instead of being either a small well-defined image of the candle, or a circle, according to whether the eye be emmetropic, myopic, or hypermetropic. This oval may have its edges horizontal and vertical; frequently, however, they are more or less oblique.

The oblique movements of the shadow are independent of the direction in which the mirror is rotated.

This obliquity is produced thus: (Fig. 55) if behind a circular opening, which is to represent the pupil, we place obliquely an oval piece of card, which is to represent the image on the retina; on moving the card across in the direction O D, it has the appearance of moving in the direction C O, at right angles to the edge of the card. Hence the direction of the shadow's

Fig. 55.



movement is deceiving, and its oblique edge is due to the fact that only that edge which coincides in direction with one of the principal meridians is seen well defined by the observer. Therefore the apparent movements are always at right angles to the edge of the shadow.

The same takes place in astigmatism, the two chief meridians of which are parallel and perpendicular to the shadows in retinoscopy, therefore, when the edge of the image is oblique, we know at once that the case is one of astigmatism. If, however, it should be horizontal or vertical, we judge if one shadow be more distinct or quicker in its movements than the other, though we are not always able to say at once that astigmatism exists. We therefore proceed to correct one meridian. If the shadow move against in all meridians, we first take the vertical, and put up in front of the patient, in a spectacle-frame, convex spherical glasses, until we find the *strongest* with which the shadow still moves against the mirror. We put this down as the correcting-glass for this meridian, and let us suppose that glass to be +2 D. We next take notice of the horizontal meridian, and if +2 D. is also the highest glass with which we still get a reverse shadow, then, of course, we know the case is one of simple hypermetropia. But supposing the highest convex glass had been +4 D., we indicate it conveniently thus:

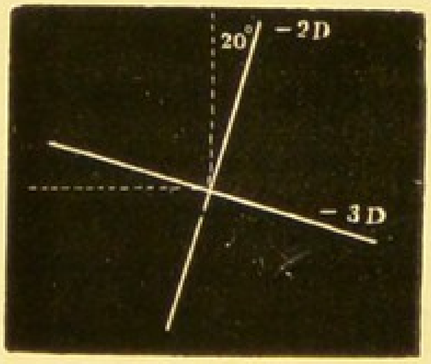
|+2 D.
—|—+4 D.
|

The case is one of compound hypermetropic astigmatism, and should require for its correction +2 D. spherical combined with +2 D. cylinder axis vertical.

We will take another case—that in which the vertical meridian requires −2 D. to give a reverse shadow, and the horizontal +2 D., this being the highest glass with which we still obtain a reverse shadow. Here we have a case of mixed astigmatism which can be corrected by a +2 D. sphere combined with −4 D. cylinder axis horizontal.

Supposing the axis of the shadow to be oblique, we know at once that astigmatism exists, and we proceed to correct each meridian separately, moving the mirror at right angles to the edge of the shadow, not horizontally and vertically. We judge of the amount of obliquity by the eye, and can frequently tell within a few degrees. If the vertical meridian be 20° out, and require for its correction −2 D., and the axis at right angles to this (which will be therefore at 110°) require −3 D., we express it as Fig. 56, and

FIG. 56.



correct it with sphere −2 D. combined with cylinder −1 D. axis 20°, the case being one of compound myopic astigmatism.

Often one is able to put up the cylinder in the spectacle-frame with the exact degree of obliquity.

Having found the glasses which correct the two meridians, we put up the combination in a spectacle trial frame, and if we now get only a slightly reversed shadow in every direction, the glasses are assumed to be the right ones, and we proceed to confirm it by trying the patient at the distant type, making any slight alterations that may be necessary.

In most cases it is necessary to dilate the pupils for retinoscopy, the refraction at the macula can then be obtained; without a mydriatic one would only be able to estimate the refraction at the disc.

CHAPTER IV

THE APPEARANCES OF THE NORMAL FUNDUS

It is essential that the learner should become familiar with the different varieties of the normal fundus before passing on to the various pathological conditions. The beginner may think this a very easy matter, but he will soon discover that this is far from being the case; for instance, in cases of slight indistinctness of the margin of the disc, it may sometimes be exceedingly difficult for even the most experienced and skillful ophthalmoscopist to know exactly when this slight blurring has passed the border line of health and become pathological.

As the complexion and the colour of the hair varies greatly in the human race, it is not to be wondered at, that the colour and appearance of the back of the eye, which depend in great measure on the amount of pigment contained in the tissues, should also show great variations. In Plates I and II, I have endeavoured to illustrate some of the types of the normal fundus; and when we consider that no distinct line separates these different types, but that one passes imperceptibly into another, it will be understood how numerous the varieties of the normal fundus must be.

The differences met with, depend in great measure upon the amount of pigment contained in the hexagonal cells of the epithelial layer of the retina, and upon the stellate pigment present in the tissue of the choroid.

The pigmentation varies greatly in different people, as a rule the lighter the complexion the less pigment is found in the retina and choroid; the albino may be taken as the specimen at one end of the scale, in which the least pigment is found, while the negro represents the other end of the scale, in which there is the greatest amount of pigment. Plate I, fig. 2, represents the right fundus of an albino, as seen with the indirect; Plate II, fig. 1, the left eye of a very dark English child, seen by the direct method.

The ordinary red fundus reflex is due to the colour of the blood contained in the choroid, modified more or less according to the amount of pigment present; the colour and amount of light used will also, of course, have considerable influence on it; and some variations will be found in different parts of the same fundus; thus the macula region is somewhat darker than the rest of the fundus, shading off gradually into the colour of the other parts. The periphery is usually lighter and may possibly show some of the details of the deeper parts of the choroid; the colour immediately round the disc may also be somewhat lighter than the general tint of the fundus.

The retina.—The retina, anterior to its epithelial layer, is transparent, sometimes in dark people a sort of shimmer or bloom may be detected, especially

Plate I.

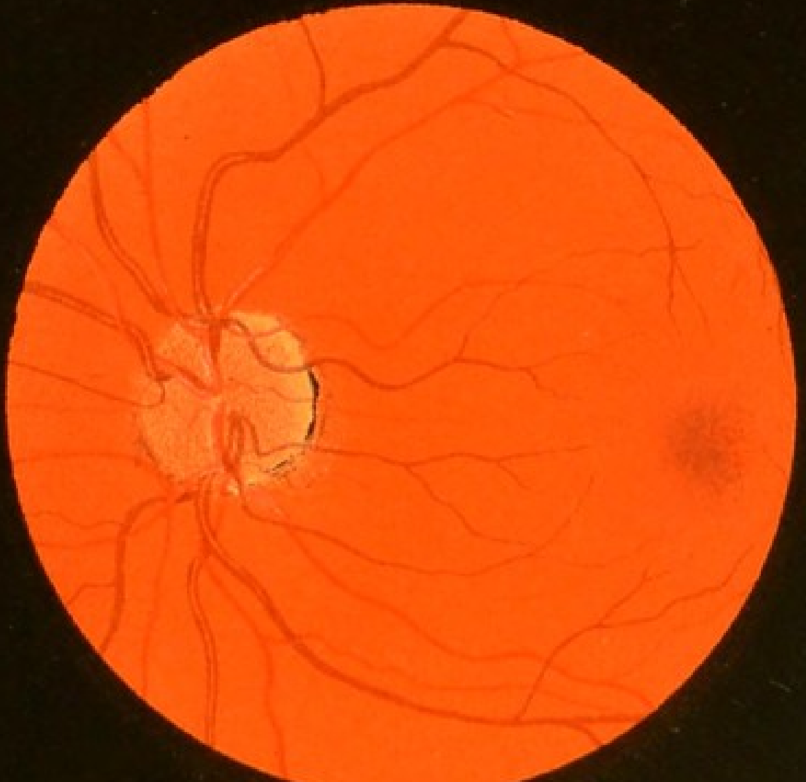


Fig. 1.

Fig. 2.

A. W. Head, del. Danielsson & Co, chromo-lith.

PLATE I.

Fig. 1.—Fundus of a child, aged 10 years; of medium complexion, light brown hair, grey irides, fair skin. Erect image. Left eye.

Fig. 2.—Fundus of an albino, aged 24; white hair, eyebrows, and eyelashes; irides light grey and translucent. Inverted image. Right eye.

PLATE II.

FIG. 1.—Fundus of a very dark child, aged 10; skin dark, hair black, eyebrows and eyelashes black; irides dark brown. Erect image. Left eye.

FIG. 2.—Fundus of a child, aged 10 years; hair dark brown, eyebrows brown, eyelashes black; irides dark brown. Inverted image. Right eye.

Plate II.

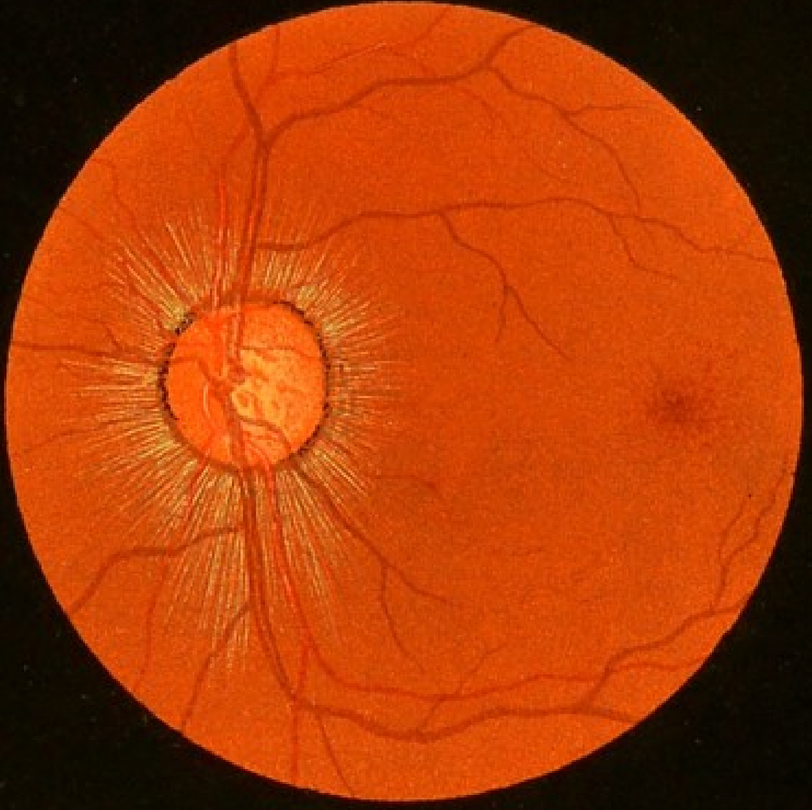


Fig. 1.

Fig. 2.

A W. Head, del.   Danielsson & Co, chromo-lith.

around the macula; occasionally a striated appearance is visible at the upper and lower margins of the disc, spreading a considerable way over the retina. This is due to the nerve-fibres being slightly visible over the part where they are thickest, and is best seen in young hypermetropic children. The case from which Fig. 1, Plate II, was drawn afforded a good example of this striation. But, speaking generally, the retina, except for its large vessels, may be spoken of as transparent, so that in most medium or dark complexioned people one looks with the ophthalmoscope through the retina on to the retinal epithelium, which, if fairly pigmented, allows the red of the choroid to shine through, but effectually hides any of the vessels or details, so that one gets a uniform red reflex, often having a slightly granular appearance due to the pigment contained in the epithelial layer; this is, perhaps, the commonest type of the normal fundus and is shown in Fig. 1, Plate I. When this epithelial layer contains but little pigment or pigment of a light colour, as in fair people, then we can see through this layer more or less of the details of the choroid; the capillaries of the chorio-capillaris are too small to be seen, but the large choroidal vessels may be fairly distinct, having between them small islands of tissue, which may be lighter than the vessels themselves in very fair individuals, where very little pigment is present in the connective tissue of the choroid (a very striking example of this condition is seen in the albino Fig. 1, Plate II); or the interspaces may be darker than the vessels, when a good deal of pigment is present, Fig. 2, Plate II; these interspaces are small, triangular, or irregular about the disc; more elongated in the periphery. The details of the choroid are often best seen in the periphery, sometimes only there. Thus there are three distinct types of the normal fundus.

1. The fundus having a slightly granular appearance, with no choroidal details visible. Met with chiefly in people of dark complexions, Fig. 1, Plate I, and Fig. 1, Plate II.

2. The fundus, in which the large choroidal vessels are seen with lighter coloured interspaces; light complexioned people, Fig. 2, Plate I.

3. The fundus, in which the large choroidal vessels appear, with dark coloured interspaces; this is sometimes known under the name of "choroid tigré," and is found in people with medium complexions. Fig. 2, Plate II, is intended to represent this condition.

Though these are the three chief types of the normal fundus, it will be understood that one variety gradually verges into the next, so that every possible variation will be met with.

In old persons the epithelial layer may become deprived of its pigment, and so allow the deeper layers of the choroid to come into view.

It must be remembered that the arteries and veins of the choroid cannot be distinguished from each other with the ophthalmoscope.

The macula lutea, which is the part of most distinct vision, is free from any visible vessels; it is situated about 2 mm. on the temporal side of the disc, being directly in the line of vision; in shape it is an ill-defined oval, darker than the rest of the fundus and shading off gradually into the general red colour. This oval has its long diameter horizontal, and is a little larger than the disc, while the vertical diameter is rather less; its centre is marked by a depressed whitish pink spot, the fovea centralis; although the macula is devoid of visible vessels, it is exceedingly vascular, the capillary meshes being much closer together than in any other part. The macula is sometimes surrounded by a sort of ring or halo, which is due to reflection from the edge of the slight depression; this halo is often seen in dark children with the indirect method. It requires some practice before this region can be satisfactorily seen with the ophthalmoscope. The macula is never yellow, and it is rather unfortunate it should have received the name of the yellow spot; this colour is only found as a post-mortem change. Sometimes a good deal of reflex takes place from other parts of the retina, and is spoken of as a "shot silk" appearance.

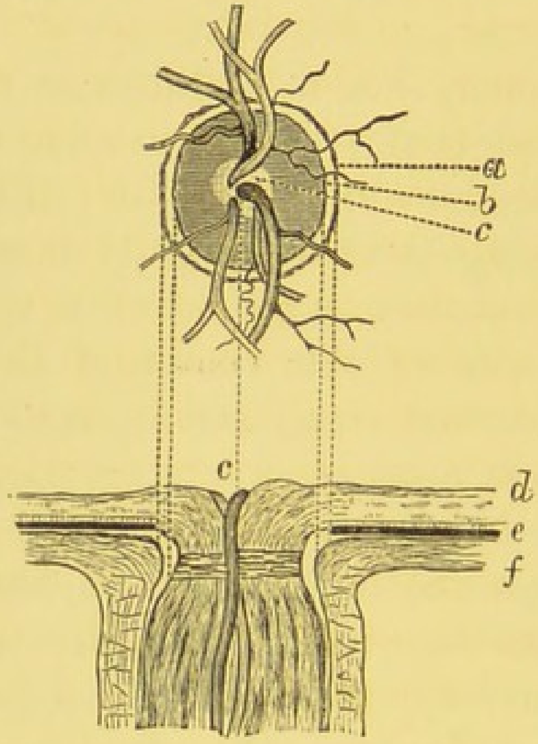
The optic disc is the intraocular end of the optic nerve, and consists of nerve-fibres which spread out to form the retina, together with a certain amount of connective tissue, and the central artery and vein of the retina. It is situated a little to the nasal side of the visual axis, and is usually circular or slightly oval, with its long axis nearly vertical; its real size is about 1·75 mm., sometimes one side is slightly flattened; the anatomically oval disc must not be confounded with the oval, due to astigmatism; the diagnosis between the two can easily be made, when using the indirect method, the anatomically oval disc will not alter its shape as the objective is gradually withdrawn, while the astigmatic oval will undergo considerable change in its shape as the convex glass is moved away from the eye.

The colour of the disc varies much from the rest of the fundus, being much lighter; the colour varies also at different periods of life, being rather paler in old people. The colour of the disc is due to the combined effect of the nerve-fibres, the blood-vessels, and the connective tissue, the result being a pinkish rose tint; considerable variations of colour are found in different parts of the disc; thus the pinkish colour is often most pronounced on the nasal side, while the whitest part of the disc is often its centre and towards the temporal side; in many cases the nerve-fibres separate immediately after perforating the lamina cribrosa, leaving a conical depression between them, at the bottom of which is seen the white stippling of this lamina; this pit is known as the "physiological cup." This cup may vary much in size and shape, but always has the one characteristic, that it never involves the whole disc, as is the case with the glaucoma cup. The physiological is usually a deep shelving cup, while that due to glaucoma is overhanging. When the physiological cup is large and deep, its nasal side may be steep or even excavated, but the temporal side is invariably a gradual slope, which may extend in this direction to the margin of the disc. Frequently a stippling is seen at the bottom of a deep cup, this is due to the details and perforations of the lamina cribrosa being visible. Fig. 59 represents a deep physiological cup, and should be compared with the figures representing the other two varieties of cupping, Figs. 60 and 61.

The disc usually has a well-defined margin with some traces of pigment; this is known as the *choroidal ring* and is well shown in Fig. 57 (*a*); the edge of the choroidal opening is often slightly larger than the corresponding opening in the sclerotic, and when this is so, a small rim of this coat may be visible just within the choroidal ring; this is called the *sclerotic ring* (*b*). The sclerotic ring is often partially hidden by the slight expansion of the optic nerve, after passing through the lamina cribrosa, though usually a trace of it can be seen on the outer side; so that one usually notices from within outwards, (1) a white central depression, the *physiological cup*, (2) surrounded by a zone of a pinkish colour, most marked usually on the nasal side. This zone is composed chiefly of nerve-fibres and their capillaries, (3) outside this is a well-defined white margin, the *sclerotic ring*, and, finally, (4) the slightly pigmented margin of the *choroidal ring*. Great variation will be met with in different subjects; the discs on the two sides should always be compared. The colour of the different parts of the disc can be best appreciated by the direct examination, and by using only a moderate illumination. The edges of the disc should be clearly defined; sometimes the upper and lower margins are less distinct than the sides; this may be due to the nerve-fibres being thickest over these parts.

Fig. 57, a diagrammatical representation of the optic

FIG. 57.



disc; the choroidal and sclerotic rings are seldom seen in the complete form as here represented, but it is necessary the student should be acquainted with them and know how they are formed; (*a*) choroidal ring, (*b*) sclerotic ring, (*c*) physiological cup. (*d*) The retina, (*e*) the choroid, (*f*) the sclerotic, (*c*) the central vessels.

The central artery and vein of the retina are seen issuing from near the centre of the disc; their distribution varies much in different persons. The retinal vessels are exceedingly small, although, with the direct method, they give one the idea of being of fair size;

the main divisions of the retinal artery may be about ·4 mm. in diameter, while the smallest visible vessels will be about ·06 mm., the capillaries being considerably smaller than this are necessarily invisible.

The arteries may be distinguished from the veins, (*a*) by their colour, (*b*) by their size, and (*c*) by their general appearance. The vessels are really transparent tubes, so that it would be more correct to speak of the blood columns contained in them.

The arteries are bright red in colour, about one third smaller than the corresponding vein; they cross over the veins, and have a marked white central streak. There is some difference of opinion as to the cause of this white streak, some observers consider it is due to reflection from the column of blood, while others think it is due to the refraction of the rays of light passing through the vessels and reflected back. Probably the latter is the true explanation.

The veins are darker in colour, larger, and pass under the arteries, they have little or no central white streak; frequently pulsation may be seen in the veins, or can be easily produced by very slight pressure on the eyeball.

The main central artery often divides just before emerging from the disc into two branches, a superior and inferior, these again divide into temporal and nasal branches, other branches are given off dichotomously; sometimes the main artery divides on the disc itself. As one would expect, the distribution varies much in different persons, though there is frequently great similarity in the circulation of the two eyes. Occasionally a separate artery is found on the outer side of the disc curving outwards on to the retina, and fulfilling the functions of a retinal artery ; this is ~~un~~usually a branch of one of the posterior ciliary arteries, and is known as a *cilio-retinal* vessel.

CHAPTER V

CORNEA—ANTERIOR CHAMBER—IRIS—LENS

I HAVE no intention to enter into a discussion on the various diseases which affect the different structures of the eye, but it may be well to refer briefly to the methods recommended for the examination of each part in a systematic manner, while at the same time the ophthalmoscopic appearances indicative of disease of the various parts of the eyeball may be shortly described.

The cornea.—Affections of the cornea usually produce some loss of transparency which may be combined with other symptoms: foreign bodies frequently become embedded in the tissue of the cornea; nebulæ, ulcers, and irregularities of its surface are conditions very frequently met with; they can all be thoroughly examined by focal illumination, when everything will appear in its true position and colour; this examination may be supplemented when necessary by the high magnifying glass already referred to on p. 30; keratitis punctata may also be detected in this way; it consists of small particles of lymph deposited on the posterior surface of the cornea, where they cause proliferation of the epithelium, these dots will usually be found arranged in a pyramidal shape, having its apex to the centre of the cornea and its base downwards. Vessels may be detected on the surface, or in the tissue of the cornea itself, in the latter condition the separate vessels are generally not to be distinguished; this examination having been extended to the anterior chamber, iris, and lens, the large concave mirror is next taken up, and light reflected into the eye from a distance of half a metre; corneal opacities will now appear as black spots in the red of the fundus, due to the interruptions of the rays of light from the back of the eyeball. In conical cornea a central illumination will be seen with the mirror, surrounded with a dark circular shadow, corresponding to the base of the cone. On moving a little further back, so as to use retinoscopy, the shadow will be found to have a circular movement. Finally the corneal examination may be completed by using the direct ophthalmoscope, having behind the sight-hole +20 D. and approaching close to the patient. By this means the various opacities may be seen in detail, sometimes a number of fine arborescent lines may be detected. These are the transparent remains of vessels which are left as permanent evidence of previous keratitis.

Aqueous chamber and iris.—With the oblique illumination the contents of the aqueous chamber may be seen to be muddy; this is due to inflammatory material poured out in iritis or cyclitis; here the apparent colour of the iris may be altered, or the contents of the aqueous chamber being quite transparent, the surface of the iris may be seen to be dull, discoloured, and indistinct, the result of inflammatory exudation into its tissue; sometimes the exudation forms a distinct gumma; points of adhesion between the iris and lens may be detected; sometimes one or two fibres may be seen crossing the anterior chamber from one point of the iris to another, these fibres arise not from the extreme pupillary edge, but from the junction of the radiating and circular fibres; these fibres are the remains of the pupillary membrane which exists during intra-uterine life. Perforations of the iris from a penetrating wound may be readily detected with the oblique illumination, and with the mirror the red reflex will be seen through the opening; the iris may have become more or less detached from its ciliary border (iridialysis), as the result of a violent blow. Atrophy of the iris and growths may also be conveniently examined by these means; finally, the iris may be examined with the ophthalmoscope, having a + 16 D. behind the sight-hole. Foreign bodies may occasionally be detected in the anterior chamber, and now and then a cilium is carried into this chamber by a perforation body.

The lens.—To examine the lens thoroughly, the pupil must first be dilated with a mydriatic, the examination should be commenced with the focal illumination; and here a word of warning is necessary—not to be too hasty to assume that the lens is becoming opaque. This mistake is especially liable to be made by the inexperienced, especially when light from a window is concentrated on the eye with the biconvex lens. The reason of this apparent opacity is, that as age advances, the lens becomes harder, so that the refractive index of the aqueous and lens becomes very different, and, therefore, a good deal of reflection takes place from the latter, and gives somewhat the appearance of opacity.

With the oblique illumination the opacities appear in their true colour, spots of pigment may be detected on the anterior capsule, and are evidence of previous iritis; the iris has been adherent to the lens at this point, and when the synechia is torn away by a mydriatic the pigment is left attached to the lens; pigment in this position may increase by proliferation. Anterior polar and pyramidal cataract may easily be detected; the latter variety is usually due to the cornea having been in contact with the lens owing to perforation, a nebula may often be seen in the cornea at the point where perforation took place; cortical, central, and posterior polar opacities may easily be seen. When examining the latter the light must be directed into the eye almost at right angles to the cornea.

The ophthalmoscope mirror is next used and affords us valuable information as to the amount of opacity present; the opacities in this method of examination show up as black spots, patches, or striæ, against the ordinary red of the fundus, the returning rays of light being interrupted by the opaque portions of the lens.

Lamellar cataract, which consists of a layer of opaque lens substance having a clear nucleus and periphery, may be recognised both by the focal illumination and by the concave mirror; the opacity is denser at the margin of the opacity, and is surrounded by a transparent cortex.

CHAPTER VI

THE VITREOUS

The two chief indications of disease of the vitreous are, *loss of transparency* and *diminished consistency.* The focal illumination is sometimes useful in detecting disease in the anterior part of the vitreous, but to use this method to the best advantage it is necessary to place the light in front of the patient, so that the rays may be concentrated on the part we wish to examine, almost at right angles to the cornea (Fig. 32). In this way blood may be detected near the posterior surface of the lens; a growth or a detached retina projecting a long way forward may occasionally be seen. This method has the distinct advantage of allowing things to be seen in their proper colour and position; but as a rule much more information will be gained by the ophthalmoscope mirror, though the examination of the cornea and lens by the focal illumination should always extend to the vitreous before taking up the mirror.

Vitreous opacities are best seen with the large concave mirror at a distance from the eye, the light being reflected into the eye under observation. The patient should be directed to look quickly upwards, then downwards, and finally straight in front of him. This movement will stir up any opacities which may have gravitated to the lowest part of the vitreous chamber. When the opacities are very fine and difficult to see, a plain mirror and a subdued light may be an advantage.

Usually these opacities are floating, moving with every movement of the eye, and continuing to do so after the eye has come to rest, but sometimes the opacities may be fixed. They vary much in shape, size, and position, sometimes being exceedingly small like dust, and may require some trouble to detect; at other times they are large and membranous, or in shreds, or resembling the wings of insects. Their rate of movement will give us some idea of the consistency of the vitreous—when they move very quickly the vitreous must be abnormally fluid; should the opacity float very slowly across the field, then its consistency may not be diminished.

These opacities may be: (1) Inflammatory exudation from one of the surrounding tissues, as the choroid or ciliary body. (2) Hæmorrhage from the retina, choroid, or ciliary body. (3) Coagulation of the albuminous elements of the vitreous itself.

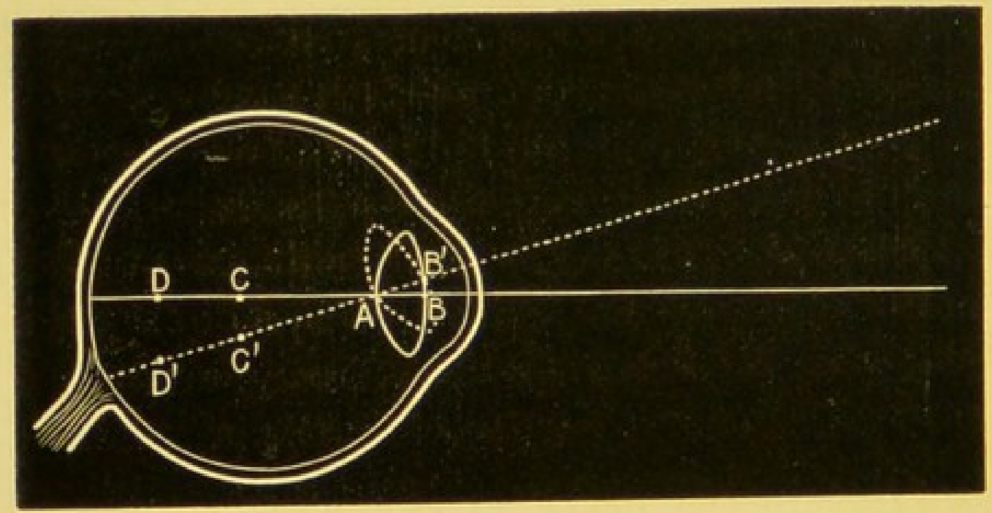
When the opacities are very fine, they may simply cause a slight blurring of the details of the fundus, which may easily be mistaken for papillitis. These very fine opacities can best be seen by using the direct method of examination with a +8 D. behind the sight-hole, but to thoroughly examine every part of the vitreous the observer must vary his distance from the patient as well as the strength of the lens behind the ophthalmoscope; the stronger the lens used the more forward will the vitreous opacity be. Fine opacities are generally due to the migration of cells accompanying the exudation of inflammatory material of a serous character from some part of the adjacent uveal tract. When hæmorrhage takes place into the vitreous, or the exudation is rich in fibrin, the opacities are liable to be large and membranous, and may, if very numerous, prevent any details of the fundus from being seen.

Opacities usually appear as black spots, whatever their real colour may be, owing to the interruption to the returning light, unless they happen to be fairly transparent, when they will appear grey. Should they reflect light from their surface, as do crystals of cholesterine and tyrosin, then they may sparkle like particles of gold leaf. A beautiful illustration of this condition may be occasionally seen, and goes by the name of *sparkling synchysis;* it is usually accompanied with great fluidity of the vitreous.

In making a diagnosis of opacities in the vitreous, corneal and lenticular affections should first be excluded by the oblique illumination; the position of any opacity may be judged of, partly by their direction and amount of movement, and partly also by the convex glass through which it can best be seen.

To estimate the depth of any fixed opacity, we must take the corneal reflex as a fixed object. Then if the patient be directed to look upwards, it will be obvious that any opacity situated in front of the point round which the eye turns (a point closely corresponding with the posterior surface of the lens, about 8 mm. behind the cornea) will also move upwards, while if the opacity be behind this point, it will move downwards, and the farther the opacity is from the point of rotation, the greater will its movement be, and therefore the deeper will it be. A glance at the following drawing will make this clear; A is the point of rotation of the eye, B is an opacity on the anterior surface of the lens, which on movement of the eye upwards will move with it to B′; C and D are vitreous opacities, which, being situated behind A, will move in the opposite direction to the eye, so that on turning the eye upwards C will move to C′, and D to D′; as D is deeper than C, D will have made a greater change in its position than C.

FIG. 58.



The real movement, therefore, which opacities in the media make, is with the eye when the opacities are in front of the centre of rotation, and in the reverse direction when behind this centre. Foreign bodies may sometimes be seen in the vitreous more or less covered with lymph according to the time which has elapsed since the accident. Now and then a few air bubbles are carried in with the foreign body, which the observer might easily mistake for the foreign body itself, unless aware of this possibility; air bubbles are round, reflect light from their centres, and have dark margins, whereas the reflex from a foreign body is chiefly from its edges.

In the case of a perforating wound, a streak of opacity may be seen extending through the vitreous along the line taken by the penetrating substance. I have seen cases where after a puncture of this kind the vitreous has remained clear for several days, then gradually an opaque line has formed, become more marked each day, and leading eventually to shrinking of the vitreous. Here, probably, some bacilli have been introduced by the perforating body, and finding the vitreous a suitable medium, have here undergone cultivation.

Occasionally some remains of the hyaloid artery may be seen floating about in the vitreous, one end being attached to the disc, while the other is connected with the posterior surface of the lens.

CHAPTER VII

THE CHOROID

The important part taken by the choroid in the ophthalmoscopic picture of the fundus has already been somewhat fully described. Alterations produced by disease of this structure may display themselves as—

1. Changes in colour and pigmentation.
2. Changes produced by inflammatory exudations.
3. Scars or atrophic patches which remain as permanent evidence of previous mischief.
4. Hæmorrhage from one of the choroid vessels.

Hyperæmia of the choroid is in most cases not to be recognised; when inflammation has commenced it shows a tendency to occur in patches or spots distributed over the fundus, or a large sector-shaped area may be involved, while the remainder of the fundus is free from disturbance. In many cases where the deeper part of the choroid is primarily affected and where no disturbance of the retinal hexagonal epithelium has taken place, nothing may be detected with the ophthalmoscope; but sooner or later this layer becomes involved, the epithelium undergoes atrophy, and the pigment being set free will be heaped up in places and may there proliferate, while from other parts the pigment may be absent. Where the inflammatory symptoms are marked, vitreous opacities usually take place and more or less veil the appearances of the choroid; in some acute cases no details of the fundus can be seen, owing to the density and number of the vitreous opacities, and it may only be after these have partially cleared up that the patches of choroiditis come into view. When the retinal epithelium is involved in the inflammatory process the condition may be spoken of as *choroido-retinitis*. Here the pigment is set free from the epithelial cells, and some of it may travel forward into the retina, accumulating there into spots, &c., exactly like retinitis pigmentosa, which will be referred to in Chapter IX. When a case of choroiditis is seen early the patches of exudation may have a pinkish, yellowish colour, slightly raised, and with soft-looking edges; they may appear in every possible shape, but most frequently they tend to the circular. As the inflammatory symptoms diminish, the exudation undergoes absorption together with destruction of the affected portions of the choroid, so that ultimately a white patch or scar remains, surrounded or dotted over more or less with pigment. These white patches are the bare sclerotic, and may be described as patches of choroidal atrophy: in the disseminated variety of choroiditis, the scars left are often circular in shape with a collar of pigment, having a sharply defined and punched out appearance. Any part of the choroid may be the seat of inflammation; sometimes the periphery is chiefly affected, while in others the region of the macula is alone involved. Here the vision is usually very bad, while in some cases of peripheral mischief the vision may be much better than would be expected.

Choroidal hæmorrhages are not so frequent as retinal; they are usually large, somewhat irregular, and of a diffused character, and the retinal vessels will be seen passing over them; they are never flame-shaped, as is the case with hæmorrhages taking place in the nerve-fibre layer of the retina. The most frequent cause is a blow on the eyeball.

The myopic crescent, which is so commonly formed in medium and high degrees of myopia, is due to the choroid being dragged away from the margin of the disc to a greater or less extent according to the degree of myopia; it is almost invariably found on the outer side of the disc, sometimes it completely surrounds the disc, but even then its greatest breadth is usually at the outer side. In high myopia, where a large posterior staphyloma is present, a good deal of thinning of the choroid may take place, the retinal epithelium may be more or less atrophied, and in addition to all this some horizontal markings may be seen midway between the disc and yellow spot; these are probably slight tears in the superficial part of the choroid and pigment layer of the retina. The myopic crescent will be again referred to in Chapter IX.

Rupture of the choroid occasionally takes place as the result of a severe blow on the eye; the rupture is usually curved, with the concavity towards the disc.

When the case is seen early, the details of the rupture are usually hidden by the hæmorrhage that has taken place; later, a white curved scar will be seen having pigmented edges; the impairment of vision of course depends upon the situation of the rupture, when near the macula this impairment may be very great.

Tubercle of the choroid may be found either in the miliary form or as a large tubercular mass; they are not very frequently met with, though probably often existing in cases of tuberculosis. They appear as small white or yellowish white spots, somewhat raised, sometimes several spots become confluent, making a mass as large or larger than the disc.

Coloboma of the choroid is a congenital condition occasionally met with, and unless the student is aware of its existence, he will be sure to confound it with some serious pathological condition.

Coloboma of the choroid is due to an arrest of development, it always occurs downwards and may be associated with a similar defect of the iris, lens, or ciliary body. The coloboma may vary much in size, is usually very white with variations in its colour at different parts, owing to irregularities of the sclerotic, sometimes there is considerable bulging outwards of the part. The retinal vessels may be seen coursing across the white area; when the coloboma extends up to the edge of the disc, this is usually misshapen, being more or less of a horizontal oval.

Colloid disease of the choroid.—Occasionally small transparent bodies may be found growing from some part of the choroid, especially in eyes that have been affected with choroiditis; these bodies may occur as minute separate spots or arranged in a group; each spot grows from the lamina vitrea, at first pushing forward the retinal epithelium, which gradually undergoes atrophy, and finally allows the most prominent part of the growth to pass through; in this case some pigment may be found surrounding the base of the small transparent growth.

Sarcoma of the choroid may be met with either pigmented or unpigmented, and may belong to either of the varieties—round-celled, spindle-celled, or mixed. When seen in an early stage of the disease it may be difficult to distinguish it from a simple detachment of the retina (p. 115).

In the **albino** there is a congenital absence of pigment both in the retinal epithelium and in the tissue of the choroid. This condition is shown in Plate I, fig. 2.

CHAPTER VIII

THE OPTIC NERVE

THE only part of the optic nerve that is visible to the ophthalmoscope is the disc; changes taking place in the nerve may or may not cause alterations in the disc; it is necessary to remember that the optic nerve passes through the rigid sclerotic opening which is somewhat funnel-shaped, the narrowest part being in front, the nerve fits it closely, so that when any swelling takes place in this part, the sclerotic opening acts as a ligature, and may cause serious changes in the nerve-fibres as well as considerable obstruction to the retinal circulation. These changes may be made apparent by swelling, &c., of the optic disc.

The central artery and vein are for the nutrition of the retina, and have nothing to do with the nutrition of the disc itself. Since no anastomoses take place between these vessels and those of the surrounding structures, the retinal circulation is terminal.

Abnormal conditions of the disc may cause—

1. Alterations in colour.
2. Alterations in surface level.
3. Changes in the margins of the disc.

1. **Alteration in colour.**—Great variations are met

with in the colour of the discs in different subjects, so that it is extremely difficult in many cases to decide when any increase of the normal colour has taken place; sometimes, no doubt, the illumination necessary for the examination may cause temporary flushing of the disc, hence too much reliance must not be placed on the colour of the disc alone; a comparison of the colour of the discs on the two sides may help one to arrive at a correct conclusion. No doubt *hyperæmia* does frequently exist and will cause an increase in the normal pink colour; this increase of colour is due to a greater number of capillaries being visible; when the hyperæmia is marked in character, it is usually accompanied by some fulness of the retinal vessels, with possibly some slight softening of the margin of the disc; this change will be best detected by the direct examination.

Both eyes are usually affected. This condition of hyperæmia may remain for a long time and then gradually subside, or it may pass on to inflammation, and will be referred to later under the head of Papillitis; or it may pass on to the opposite condition, atrophy of the optic disc.

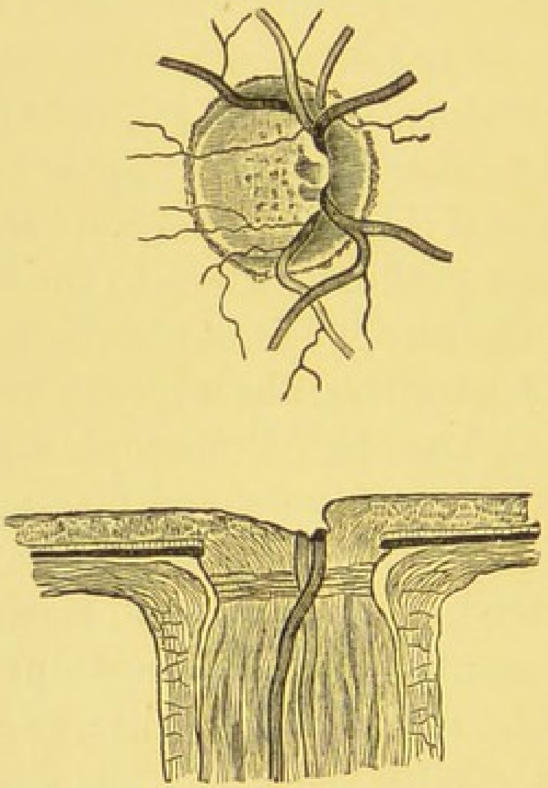
Anæmia may cause the discs to look paler than usual, at the same time the retinal vessels will be badly filled; in extreme cases the red of the choroid may be much diminished. As age advances the disc becomes paler, so that a pale disc which when seen in an old person may be normal, might in a young individual indicate a condition bordering on atrophy.

In *atrophy* the disc is usually very white, but the ophthalmoscopic appearances will vary considerably with the stage of the disease and its cause. The whiteness of the disc is due to degeneration of the nerve-fibres, together with the capillaries which supply them. If a case of primary atrophy is seen when fairly advanced, with *the indirect* the disc will appear intensely white, with well-marked disc margin ; this margin is rendered very distinct by the shrinking of the nerve-fibres, which thus exposes the sclerotic ring. With *the direct* the white may be less marked ; in fact, it may be of a bluish-white colour or grey ; usually the stippling produced by the perforations of the lamina cribrosa is very distinct. As the optic nerve shrinks no decrease takes place in the size of the disc, but a depression of its surface is gradually produced, forming what is known as the atrophic cup. This cup is always of a shelving character, and the vessels can be seen to slope gradually down to the bottom of the disc. When the atrophy is of a secondary character, as in cases of papillitis, the atrophy is spoken of as post-papillitic. The ophthalmoscopic signs indicating this condition are, badly defined disc margin, vessels somewhat tortuous and diminished in size, with a white line extending along some of them ; little or no cupping is present, while some remains of organised material may be seen about the disc, or covering some of the vessels. With the direct the disc has often a strikingly opaque appearance.

Atrophy following retinitis pigmentosa produces a waxy-looking disc, while the vessels are often very small. But very great differences will be found in different cases; some may have very white discs and yet retain fair vision, while others have very bad vision and yet the discs may not be very white. Sometimes the margins of the disc are a safe guide as to the cause of the atrophy, while in others this is not the case.

2. **Alterations in surface level.**—Although the disc is spoken of as the papilla, it is really but very slightly raised above the general level of this part. The disc may be depressed so as to form a cup, of which there are three kinds: (1) the physiological cup; (2) the atrophic cup; (3) the glaucoma cup. The disc may be raised as in papillitis.

Fig. 59.

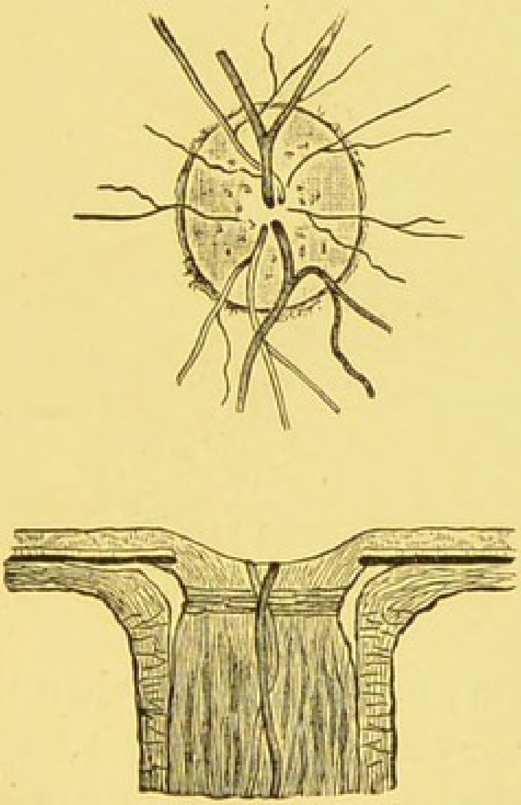


Physiological cup.

The *physiological cup* is a congenital condition, and was mentioned on p. 76. It is formed by the separation of the nerve-fibres which spread out to form the retina; its chief and important characteristic is that it does not involve the whole disc. The cup is usually the whitest part of the disc, because it contains few nerve-fibres, and is therefore less vascular; it occupies more or less the centre, and when deep allows the details of the lamina cribrosa to be seen.

The *atrophic cup* involves nearly the whole disc, but is shallow, and formed by a very gradual slope from the disc margins. The vessels can be traced down the cup without any interruption.

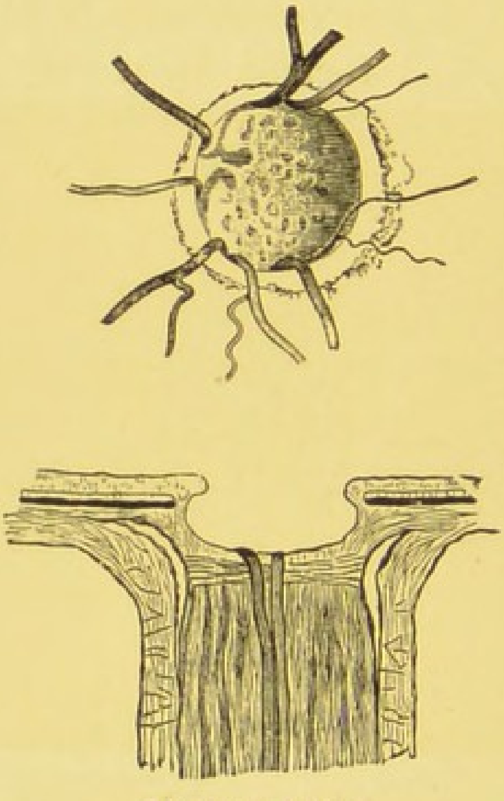
FIG. 60.



Atrophic cup.

The *glaucoma cup* is produced by an increase of the intra-ocular pressure, driving the nerve backwards; it may even displace the lamina cribrosa. The essential characteristics of this cup are, that it involves the whole disc, and is more or less excavated. When these characteristics are well marked it is impossible to mistake them; but in others, when the cup is only forming, it is very easy to mistake it for one of the two preceding varieties. Besides, in some cases the two conditions may coexist; thus a case of glaucoma occurring in an eye with a well-marked physiological cup may be some time before it develops the characteristics belonging to the glaucoma cup.

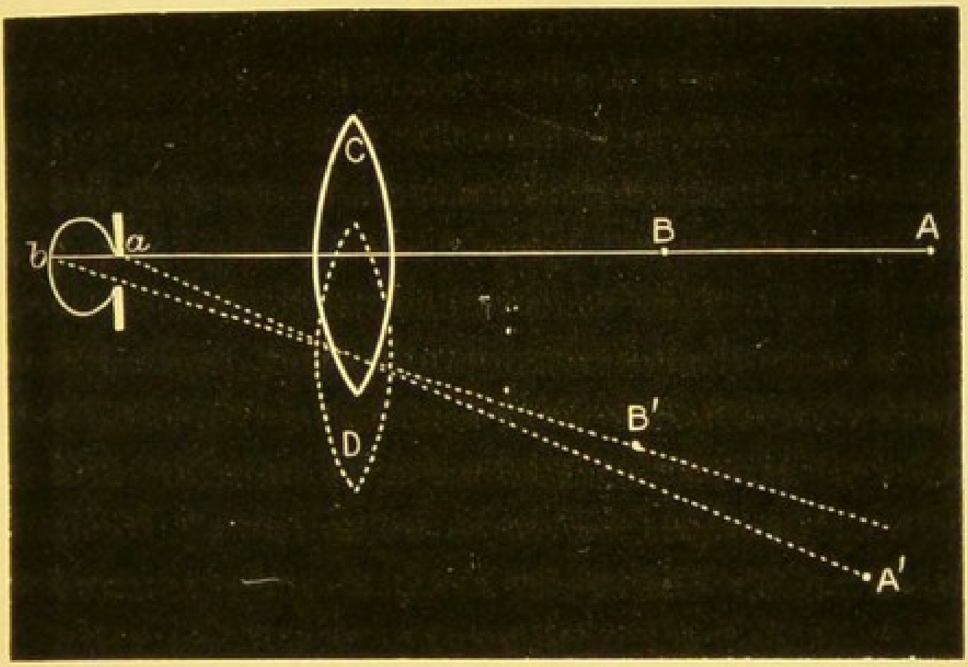
FIG. 61.



Glaucoma cup.

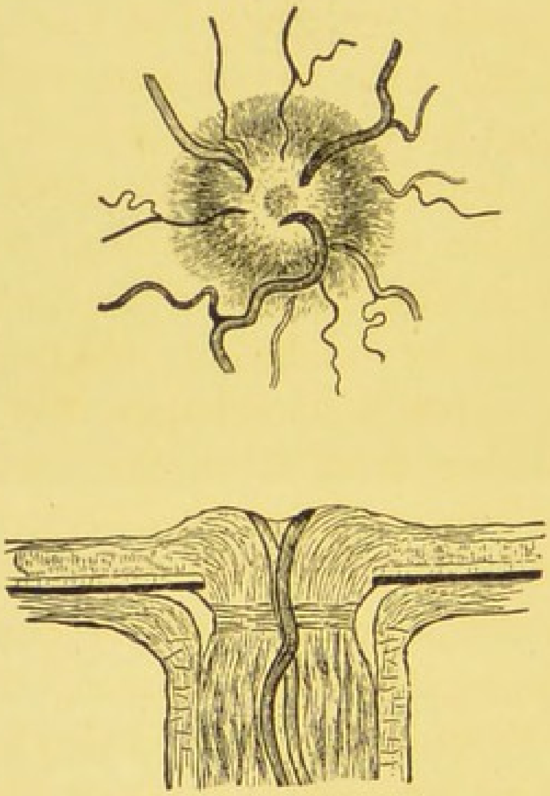
With the ophthalmoscope the vessels of the retina will appear to stop at the edge of the disc, as they twist under the overhanging edge; they will be seen again at the bottom of the disc, only more or less out of focus. With the indirect examination one will see, on moving the objective slightly from side to side, a well-marked *parallax, i. e.* the margin of the disc will appear to slide over the bottom of the cup. This is due to the image of the margin of the disc making a greater movement than the image of the bottom of the cup. Thus, in Fig. 62, let *a* represent the edge of a glaucoma cup, and *b* the lower part of the same; the image of *a* will be formed at A, and *b* at B. On moving the lens C to D, B will move to B′ and A to A′; therefore the image A, which represents the margin of the edge of the cup, will have made a greater movement than B, which is the image of the bottom of the cup. With *the direct* the edge of the

FIG. 62.



disc can first be focussed, and a different glass will be required to focus the vessels at the lower part. We may thus estimate the depth of the cup if we remember that 3 D. = 1 mm.; for example, if the edge of the disc is seen clearly with a +2 D., while the lowest part of the cup requires −4 D., we should know that the cup was 2 mm. deep. Another characteristic of the glaucoma cup is, that the vessels are pushed towards the nasal side; frequently also pulsation may be detected in the arteries. This pulsation will be found referred to on p. 119.

FIG. 63.



Papillitis.

Papillitis.—In papillitis the disc may be swollen and raised somewhat like the end of a champagne cork; this inflammation may exist alone or in conjunction with retinitis.

No distinct line of demarcation exists between hyperæmia and inflammation of the disc; one passes imperceptibly into the other. When the edge of the disc has become slightly indistinct, and is accompanied with distinct swelling, papillitis may be said to have commenced. Papillitis may exist in varying degrees; it is usually manifested by increased redness, with swelling of the optic nerve, which fills up the physiological cup, and gradually raises up the centre of the disc, sometimes to an enormous extent; the swollen disc overlaps its edges, so that the margins are very ill-defined or quite lost, while the colour of the disc may be much the same as the surrounding choroid: the disc margins have a striated or woolly appearance, due partly to opacity of the nerve-fibres and partly also to exudation of inflammatory material. The arteries may be diminished in size, and at places hidden from view by exudation; the veins are dilated and tortuous; a few hæmorrhages may be seen near the disc, radiating from it in the direction of the nerve-fibres. The condition may be well seen by the indirect method, but the indistinctness of the disc margins and the difference in level of the swollen disc can best be appreciated by the direct. The amount of swelling may be estimated if we remember that every +3 D. means an increase in level of 1 mm. As the swelling diminishes, shrinkage takes place, and the condition is liable to pass on to atrophy.

3. **Changes in the margin of the disc** have already

been referred to under the diseases papillitis and post-papillitic atrophy. In the first condition the margin of the disc is often completely lost, as is shown in Fig. 63; in slight cases, or in an early stage of the inflammation, the edge of the disc can still be made out, but it has a woolly striated appearance, more marked at some parts than at others. In post-papillitic atrophy the margin of the disc is usually somewhat irregular, with disturbance and heaping up of the displaced pigment.

The most common cause of change in the margin of the disc is, however, that produced by myopia, a crescent being formed on the outer side of the disc. Myopia is nearly always due to an increase in the antero-posterior diameter of the eyeball. This increase in length is usually produced by a stretching of the tissues at the back of the eye; the sclerotic stretches at the point of least resistance, *i. e.* on the outer side of the optic nerve, between it and the macula, while the choroid, instead of stretching with it, becomes dragged away from the disc margin, exposing a crescentic-shaped portion of the sclerotic. In slight cases a mere increase of the sclerotic ring will become visible on the outer side of the disc; while in high degrees of myopia the crescent may attain an enormous size, completely surrounding the disc and extending a long way towards the macula, the broadest part of the myopic crescent being invariably outwards. This myopic crescent is occasionally seen in cases of emmetropia or even hypermetropia; here probably the eye was originally hypermetropic, and is on the high road to myopia, but the crescent becomes formed before it has arrived at this condition. Sometimes it is not quite easy to distinguish the line of demarcation between the disc and the crescent; frequently some traces of pigment are to be seen on the outer edge of the crescent.

Congenital crescent was first accurately described by Fuchs under the name coloboma of the nerve-sheath. It is not a very uncommon defect, and is almost always met with downwards; in some cases there is difficulty in making out the demarcation between the disc and the crescent. The disc is often horizontally oval and sometimes misshapen; frequently the crescent is staphylomatous; the eyes in which it is present have usually more or less astigmatism, with a visual acuteness below the normal.

Opaque nerve-fibres is a congenital condition sometimes met with. As a rule, when the nerve-fibres penetrate the lamina cribrosa they become divested of their neurilemma; passing on as transparent fibres, occasionally some of them retain their sheaths for a time after passing into the eye, or having lost them at the optic nerve entrance, quickly regain them for a short distance. The patches of opaque nerve-fibres may be met with in various shapes and sizes; perhaps the commonest form met with is that in which a tuft is present above and below the disc, extending from near its margin upwards and downwards for some distance on to the retina; sometimes isolated patches are seen a short way from the disc. They are always white and opaque-looking, somewhat flame-shaped, with well-defined lateral margins and feathery ends, shading off gradually into the normal retina. The opacity occupies the anterior part of the retina, and may even hide the retinal vessels more or less completely. When the patches are large, and extend a long way over the retina, they bend out towards the macula. Opaque nerve-fibres may exist in one or both eyes, and when once seen are not likely to be mistaken for a pathological condition; their dense white appearance, elongated shape, and feathery ends are quite characteristic. It may be mentioned that in the rabbit opaque nerve-fibres are the normal condition; here they are arranged in four tufts, somewhat like a Maltese cross. Opaque nerve-fibres should be examined both with the indirect and the direct methods.

Connective tissue on the disc.—Some part of the disc or its vessels is occasionally more or less obscured by a small shred, band, or irregular mass of connective tissue; sometimes it is a mere shred, like the smallest piece of cotton wool, just faintly blurring the vessels beneath it, at others forming a very opaque white patch concealing a good portion of the disc and vessels. The condition is most probably a congenital one, being the slight remains of the fœtal hyaloid artery; when not congenital it may be the remains of inflammatory exudation poured out in papillitis.

CHAPER IX

The Retina

WHEN it is remembered that the retina in front of the pigment layer is transparent, it will be understood that the appearances produced by disease of this part may be much modified by the condition of the choroid, &c. Affections of the retina may give rise to—

1. A loss of transparency.
2. Patches of inflammatory exudation into its tissue.
3. Hæmorrhages of various kinds.
4. Changes in pigmentation.
5. Differences in level of different parts, due to detachment or new growth.
6. Changes in the retinal vessels.

(1) **Loss of transparency** is most commonly the result of retinitis, and may vary from the slightest degree which is found in the early stage of inflammation, and which can only be detected with difficulty by the direct examination and by using a very subdued light, to dense white patches which may conceal everything behind it.

(2) These dense white patches are not due to opacity only, but in part also to inflammatory exudation in various stages of degeneration, together with

thickening and degeneration of the nerve-fibres. These patches may lie in front of and partly hide the retinal vessels; when this is the case we know that the anterior part of the retina must be involved in the morbid process. Sometimes the patches are behind the vessels, which may then be slightly lifted up by them.

These white patches are most frequently seen about the disc and the macula, or between them; the most characteristic appearance is that found in *albuminuric retinitis,* in which the white patches may occur in a circular form, radiating from the macula like the spokes of a wheel, the whole forming a circle much larger than the disc, and having a white lustrous appearance. Numerous retinal hæmorrhages are generally present; both eyes are usually affected, and the kidney disease which most commonly gives rise to this form of retinitis is that known by the name of granular kidney, and then invariably in an advanced stage. This condition is usually accompanied with papillitis.

Diabetic retinitis presents very much the same ophthalmoscopic signs, though the patches appear less white, and have little tendency to form the stellate arrangement so characteristic of the albuminuric variety. The retinitis may be complicated with vitreous opacities.

(3) **Hæmorrhages** in the retina are most frequently symptomatic of some general disease; they are caused either by increased pressure within the vessels, or by degeneration of the coats of the vessels; they may be met with in retinitis, papillitis, embolism of

the central artery, thrombosis of one of the veins, pressure on any part of the optic nerve, between the disc and the point where the vessels pierce the nerve-sheath, fatty degeneration of the coats of the vessels, cardiac disease, glaucoma, or any of the numerous accidents to which the eye is liable. The shape and extent of the hæmorrhage depends in great measure upon the part of the retina in which they occur; the most common variety is that taking place in the nerve-fibre layer, when they are "flame-shaped," with well-marked lateral edges and feathery ends. These hæmorrhages have a linear shape, radiating from the disc; they are usually small and numerous, and occur near and follow the course of the vessels, especially the veins, though it is rare to find any visible rupture; sometimes they partially cover up one of the vessels. The next most frequent position for retinal hæmorrhages is the inner nuclear layer. Hæmorrhages taking place into the deeper parts of the retina may occur as small spots or irregular-shaped circles. When the bleeding takes place from a large vessel and is profuse, some may escape into the vitreous, or being effused backwards may separate the retina from its epithelial layer, and so produce a detachment of the retina.

Large hæmorrhages are occasionally seen in the macular region, and are called *sub-hyaloid* because they occur between the retina and the hyaloid membrane; these are usually circular in shape, several times as large as the disc, and are accompanied with great loss of vision for the time being. When the extravasated blood forms only a very thin layer over the retina the patient may see everything of a red colour. These hæmorrhages, which are at first circular, soon become decolourised above, partly no doubt from gravitation of the blood-corpuscles and partly also by absorption, so that when the case is seen later, it may have taken the form of a half-circle or crescent with its convexity downwards, the upper part of the circle being of a light colour and the lower part dark red, these being separated by a well-defined line of demarcation. Vision in these cases is usually completely restored.

Recent retinal hæmorrhages are of a bright red colour; they may retain this colour for a long time and then become of a dirty reddish-brown tint, ultimately becoming black, or the colouring matter may be absorbed, leaving white or yellow patches, which gradually undergo degeneration; ultimately they may leave no trace behind, or there may be irregular spots left to mark their previous position. These spots may be white or light-coloured, showing more or less of the structure of the choroid, with some pigment about their margins. Sometimes the spots are very small, and consist merely of pigment which may be either the remains of the colouring matter of the blood or pigment set free from the hexagonal epithelial cells. It is not always possible to make a diagnosis between inflammatory and hæmorrhagic scars in the retina and choroid. The only conditions which might be mistaken for a hæmorrhage of the retina are—(i) The cherry-coloured spot which occurs at the macula in cases of embolism of the central artery. (ii) The somewhat similar appearance produced in a detached retina in the macula region, the retina being detached all round but remaining adherent at the macula itself; this is a very rare condition. (iii) Minute new vessels which have formed in a retinal exudation. All these may more or less simulate a retinal hæmorrhage, and it is necessary the student should be on his guard.

(4) **Changes in pigmentation** may be due to any inflammatory or atrophic change taking place in the retinal epithelium; the pigment is set free, travels forwards into the anterior part of the retina, and there undergoes proliferation. It shows a great tendency to coalesce into spots with radiating processes; these spots resemble very much bone-corpuscles as seen under the microscope. As the radiating processes from one spot join with processes of those near, a fine network is produced, somewhat resembling black lace. In some cases the pigment will be found accumulating along the sheath of one of the retinal vessels; these pigment changes are usually most marked in the periphery, often occupying a circle midway between the margin of the disc and the periphery.

Retinitis pigmentosa is the disease in which these changes are most frequently seen; the retinal epithelium may be more or less atrophied, allowing the details of the choroid to be seen. The pigment set free travels forward into the anterior part of the retina. In an advanced condition the disc will be found white and waxy-looking, the retinal vessels much diminished in size, and the patient's vision very bad; both eyes are always affected. Some varieties of choroido-retinitis present much the same ophthalmoscopic appearances. It is important to distinguish retinal from choroidal pigmentation.

(5) **Difference in level of different parts of the retina.**—It is essential that the student should learn to recognise these differences, since detachments of the retina are very common. When such detachments are large and have become opaque they can hardly escape detection, but when the portion of retina detached is small and retains its transparency the diagnosis is by no means so easy. In making a systematic examination a detachment may now and then be seen by the focal illumination, when the displaced portion of the retina is very large and lies a long way forward. Usually, however, this is not the case, and having detected nothing with the focal illumination, one passes on to the concave mirror held at a distance from the eye, the patient being directed to look first up, then down, and finally straight in front of him; thus one is enabled to make a thorough examination of the vitreous. Should the reflex from one part of the fundus appear much lighter than the rest, we may suspect a detachment, especially if the reflex of the part alters while the eye is kept in one position, as it may do when the retina changes its position so that the light is reflected differently. Not only is there an alteration in the reflex of the part, especially when the detachment is opaque, but a portion of the details may come into view, while nothing can be seen of the

rest of the fundus; this is because the detached portion is very hypermetropic, so that an upright image of it will be seen. The detached portion may, if opaque, appear in white undulating folds, on which some of the vessels may be clearly seen; on movement of the eye it may be seen to float about. When, however, the retina retains its transparency, then the ordinary fundus reflex from the choroid will be seen, and the diagnosis will rest upon the position of the vessels on the detached transparent retina. When a retinal vessel on a transparent detachment thus comes into view it has a characteristic appearance; it shows up very clearly, appears smaller than normal, undulates when the eye is moved, and is more tortuous than usual. Besides all this it has a much darker appearance than normally; while if the retinal vessel be an artery, then the white line on it will be gone. The darker appearance is due to the light reflected from the choroid being somewhat obstructed by the vessel, so that it is seen partly by reflected and partly by transmitted light; this appearance is quite characteristic, and should at once put one on the right track. Then, on putting up the objective for the indirect method, the detached retina or the vessels on it will appear different to the rest of the fundus; and on moving the lens slightly from side to side while the image is kept in view, the detached portion will look to slide over the other part, and thus a "parallax" will be produced (p. 101).

The direct examination gives us much fuller information; when the detachment is thus looked at, the vessels have a foreshortened appearance, as well as being wavy; the detachment and the vessels on it will also be found to be very hypermetropic, that is supposing the details of the disc are seen clearly without a convex glass behind the ophthalmoscope, and that the weakest convex glass blurs these details: the detached portion of the retina, or if it be transparent, then the vessels on it, may be seen with a strong convex glass; the more forward the retina, the higher the glass through which it can be seen. If the strongest glass be thus found out, we may estimate the distance between the detachment and the sclera; for 3 D. equals 1 mm., so that if the case in question could be seen with a convex 12 D., while the disc was emmetropic, then we should know that this distance was 4 mm. Detachments are, however, most frequently met with in myopes, so that a concave glass would be necessary to see the details of the disc; and yet perhaps the detachment may be clearly seen with a convex glass, the difference between the weakest concave glass with which the disc can be clearly seen and the highest convex glass with which the particular vessel can be seen, will give us the measurement we require.

In many cases a part of the detachment is transparent while a part has become opaque; sometimes a rent can be detected, so that the fluid in front and behind the detachment being in direct communication, the retina can float about with every movement of the eye. The edges of the torn retina will be found turned in towards the vitreous.

When the detachment takes place in the macula region, the retina usually remains adherent to the macula itself, thus producing an ophthalmoscopic appearance somewhat like the cherry-red spot of embolism; this red spot might also be mistaken for a hæmorrhage by an inexperienced observer.

The character of fluid behind the detachment cannot often be diagnosed; a more important point to arrive at is—is the detachment due to fluid or is it due to a new growth? Other points not resting on the ophthalmoscope must be called to our aid to enable an accurate opinion to be formed. Thus the history of the case and the tension of the eyeball may help us to arrive at a correct conclusion; in simple detachment the tension is liable to be diminished, while in that due to a growth the tension is usually above the normal at some period of its growth. As a rule the surface of a growth is more prominent; sometimes a hæmorrhage may be seen on its surface, no movement will be detected on moving the eye, and if the case be watched for some weeks, it may be noticed if any increase is taking place. Detachments are most frequent in myopic eyes, but a new growth may occur in any eye, whatever its refraction. Detachments are frequently accompanied with vitreous opacities, which may more or less interfere with the ophthalmoscopic picture. Posterior polar cataract is another complication that may arise.

(6) **Changes in the retinal vessels.**—The retinal vessels may be increased or diminished in size; there may be pulsation in veins or arteries; their coats may be

thickened, or they may be unusually tortuous. Changes in the size of the retinal vessels is not always easily detected on account of the great individual differences that are met with; but a careful comparison of the vessels in the two eyes, together with the relative size of the arteries and veins, may assist one in arriving at a correct conclusion; the veins are as a rule about one third larger than the arteries.

The comparison of the relative size of the veins and arteries may be somewhat complicated if their distribution does not correspond; for instance, two veins may accompany one artery, or *vice versâ*. When both arteries and veins seem slightly enlarged, especially if the disc is redder than usual, the case may be one of *active hyperæmia;* when the veins only are full and tortuous *passive hyperæmia* may be the diagnosis, and is generally caused by obstruction to the returning blood by some form of pressure.

In *anæmia* the arteries are slightly diminished, and the discs and general fundus pale.

In albuminuric retinitis the coats of the arteries are always thickened and their calibre diminished. Occasionally small aneurisms are found on some of the arteries.

In atrophy of the papilla or retina, the vessels will be found diminished in size, and when this atrophy is the result of inflammation a white line may frequently be traced a good way along some of the larger arteries. This white line is due to sclerosis of the middle coat of the artery, or to an increase of the connective-tissue elements of the arterial sheath, which not being transparent can be easily seen by the direct method. In rare cases not only may the sides of the vessels be visible, but the front part also, so that no blood-stream can be detected, the vessels appearing as white-looking cords. The same condition may occasionally be seen in the choroidal vessels. When the vessels are very much diminished in size they may appear as small threads, stretching but a short distance over the fundus.

But the most obvious change produced in the size of the vessels is that due to *embolism* of the central artery; and since this artery has no anastomoses, the retinal circulation can never be thoroughly re-established. The cause of embolism is usually a plug of lymph detached from one of the cardiac valves, plugging the main central artery; there is sudden loss of sight, andif the case be seen early the ophthalmoscopic appearances are very characteristic. The embolus is not generally visible, but there is great pallor of the disc; the arteries are much diminished, the veins slightly dilated, but decreasing in size towards the disc; sometimes the blood-stream is broken up into segments, retinal hæmorrhages are usually present, and a white, hazy, opaque appearance surrounds the macula, the centre of which is occupied by a bright red spot (cherry-coloured spot). This opaque appearance is due to œdema of the nerve-fibre layer. The retina at the fovea centralis is very thin, and contains but little connective tissue, so that no œdema takes place here, therefore the red of the choroid shows through; this colour is much intensified by the white appearance around, so that really the cherry-coloured spot is merely the result of contrast. Should the embolus be too small to plug the central artery, then it may block up one of the main branches, and the ophthalmoscope picture will vary accordingly. Later, the disc becomes atrophic, the œdema subsides, and therefore the red spot disappears, while the arteries will always remain very small. A similar condition may be produced by a hæmorrhage into the nerve-sheath.

Thrombosis of the central vein produces somewhat analogous appearances, but the arteries are larger, the veins much fuller and not diminishing in size towards the disc, while retinal hæmorrhages are more numerous and larger.

The vessels may be unusually tortuous; these tortuosities when present are usually lateral. The condition may be met with in cases where a nævus of the skin of the lids or brow exists, or it may be one of the permanent remains of an attack of neuro-retinitis; it is also occasionally found as a congenital condition, and then usually in eyes that are highly hypermetropic. The tortuosity of vessels on a portion of detached retina have already been referred to, and may then be in an antero-posterior direction, *i. e.* at right angles to the surface of the retina, as well as lateral.

Pulsation of the arteries and veins.—Arterial pulsation is always a pathological condition, and is an important sign in glaucoma; it is also found in cases of aortic regurgitation, and is then much more extensive than in glaucoma, extending a considerable distance along the artery. Arterial pulsation occurs in glaucoma either spontaneously, or can easily be produced by slight pressure on the eye; and since the tension of a glaucomatous eye is liable to vary at different times, so will the pulsation be more apparent sometimes than at others: it is not usually to be seen in all the arteries at once, and is best seen on the disc. It consists of a sudden dilatation, which is synchronous with the cardiac systole, and is followed by a gradual emptying.

No pulsation exists in the normal eye, partly because the arteries here are so small that the pulse wave has become very feeble, and partly because the intra-ocular tension is less than the tension of the coats of the vessels, and therefore the blood passes on in an almost continuous stream. In glaucoma the condition of things may be reversed, the intra-ocular tension being greater than that in the vessels.

Venous pulsation is usually physiological, but it may occur with an increase of the intra-ocular tension. This pulsation can best be seen on the disc, sometimes at the point where the main vein is formed by the junction of the upper and lower retinal veins. It consists of a gradual emptying and refilling of the vessel, and is possibly due to the slight increase of the intra-ocular tension which occurs with each contraction of the left ventricle; this increase is transmitted through the vitreous to the veins, causing them to empty; they quickly refill as the tension is lowered.

Among ophthalmoscopic curiosities may be mentioned a very striking appearance; the whole macula region may be found dotted over with light-coloured spots of various sizes; the condition always exists in both eyes, and has been described under the name of *guttate choroiditis*, though it is probably not choroiditis at all, but a physiological condition due to the pigment in some of the hexagonal epithelial cells being of a lighter colour than it is in the rest of the fundus, and may be somewhat analogous to freckles on the face; but as no case has yet come within range of the microscope, the exact situation and cause of these spots is doubtful.

The vision in such cases is usually good; some have been watched for years without undergoing any change.

Now and then a small row of spots may be seen, somewhat like a row of small air-bubbles. These are probably small transparent growths from the lamina vitrea (p. 93).

A few very bright refracting spots are occasionally met with, usually near the vessels. Their pathology is unknown. Cases in which they are present usually suffer from asthenopia.

APPENDIX

I WILL now conclude this small volume by shortly recapitulating the plan of examination recommended; by carrying this out in the systematic manner suggested it will be very rare for any serious lesion to escape detection.

1. With the oblique illumination inspect the cornea, lens, iris, and the anterior part of the vitreous. Notice if any opacity or irregularity of the cornea is present, and if its curvature appear normal. The aqueous should be quite transparent, the iris moveable and free from adhesions, which may exist either between it and the cornea as a result of perforation; or between the iris and lens as a result of iritis. The lens should be perfectly transparent; sometimes it will be found dislocated, either congenitally or the result of an accident. Pigment may be noticed on the anterior capsule; this is torn from the posterior surface of the iris, and is evidence of previous inflammation of this tissue. Opacities may be detected in any part of the lens; when at the posterior pole the opacity is further back than might be expected. The anterior part of the vitreous may contain blood, which may thus be de-

tected, or a growth, or very prominent detached retina may come into view. This examination may be supplemented with a strong magnifying glass, or the cornea may be further examined with a +20 D. behind the ophthalmoscope, the observer approaching close to the patient.

2. Next take up the large concave mirror, and reflect the light into the eye from a distance. Opacities of the cornea and lens will now appear as black spots on a red ground. The cornea and lens being transparent, notice if any vitreous opacities are visible; these are usually floating, and can best be set in motion by directing the patient to look quickly up, then down, and finally straight in front of him ; should any vitreous opacities be detected, they may be further examined with a plain mirror and a +8 D. behind the ophthalmoscope. Nothing being detected in the vitreous, notice if the disc or any part of the fundus comes into view. Should a vessel be seen, note if it appear to move with the observer's head, when it will be hypermetropic; or against it, when it will be myopic. Should a detachment of the retina exist, then, of course, this part will be very hypermetropic, and will answer the tests for that condition. Should the detachment be transparent, then a vessel may be seen on the detached portion of retina ; it will appear darker than usual, more tortuous, have a foreshortened appearance, and move with the undulations of the detached retina.

3. Nothing being detected by the mirror alone, the large biconvex lens is held up in front of the eye we

are examining, while the light is still reflected by the large concave mirror; thus one obtains an inverted image of the fundus. Notice first the shape, size, and edges of the disc; if well defined or blurred, if cupped or otherwise. Distinguish the arteries from the veins, and note if they be full, tortuous, or if pulsation exist, if clearly defined or if covered up in parts, or if a line can be traced along the edge of any of the arteries; then examine the periphery by directing the patient first to look up, then down, and finally to either side. Attention must next be directed to the macula region.

4. Examine the eye by the direct method, first the disc, then the periphery, and finally the macula region; compare the result by this plan and the indirect method. Estimate the refraction at the disc. When any patches of pigment, exudation, or hæmorrhages are found, one must decide if they are retinal or choroidal.

5. Finally notice the refraction of the patient by retinoscopy. When the observer has time, a sketch may be made of the disc. Nothing improves one's powers of observation so much, or leads to such accuracy, as making a drawing of what is really seen; every detail must then necessarily receive considerable attention.

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