[illegible], and also by a little light reflected from the face of the observer.

When the image of the flame is larger than, and includes the field of view, the entire visible area of the fundus appears strongly illuminated.

When the (plane) mirror is slightly rotated, in any direction, the inverted image of the flame moves across the fundus of the observed eye in the same direction. When the observed eye is hypermetropic, or is focussed for a distance greater than that of the eye of the observer, the apparent motion of the image is in the same direction as its real motion; but when the observed eye is focussed for a distance notably less than that of the eye of the observer, the image appears to move in the opposite direction. Upon the observation of the direction of the apparent motion of the illuminated area at the fundus, is based a ready and very useful method for the diagnosis and measurement of ametropia (see *Shadow-Test*).

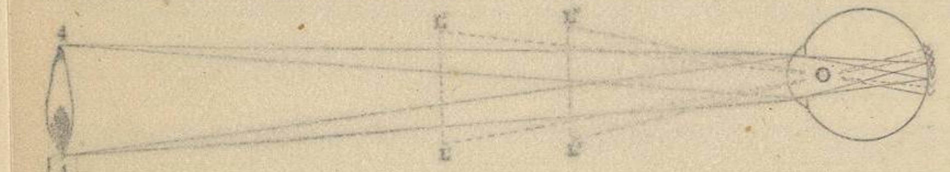


Fig. 3662.

In the living human eye the fundus appears ordinarily of a vivid red color, which is the expression of the color of the blood of the choroidal circulation showing through and more or less modified by the layer of hexagonal pigment cells.* This color is most intense in albinos, very bright in persons of blond complexion and light blue eyes, conspicuously darker in brunettes with deeply pigmented eyes, and least intense of all in the black races, in whom the illumination of the fundus is often so faint as to give off but little light, except from the white disc of the optic nerve and from the blood-filled vessels of the retina. Under normal conditions the red color is almost wholly due to the blood circulating in the capillary layer of the choroid, immediately underlying the layer of hexagonal pigment cells and hiding the more deeply seated choroidal arteries and veins. On this red background, which appears of a finely granulated texture, the retinal arteries and veins show conspicuously, branching from the central artery and vein on the nearly white optic disc (Pl. XLVII.).

Under favoring conditions of refraction in the observed and in the observing eye, the minuter details of the fundus are distinctly visible, both directly, in the erect image, and indirectly, in the inverted image. In the [illegible] rect method of examination the eye of the observer [illegible] brought very near to the observed eye, in order that [illegible] field of view, as determined by the area of the pupil, [illegible] be as large as possible (Figs. 3651, 3652, 3654, and [illegible] cf. Figs. 3653, 3655, 3657, and 3658). In the [illegible] method the observer is necessarily stationed at a [illegible] greater distance, [illegible] 20 cm. or more, [illegible] the position of [illegible] verted aërial [illegible] (Figs. 3667–367[illegible]).

In the direct [illegible] of examination the [illegible] ibility of the details [illegible] the fundus is affected in different ways according as the [illegible] tion of the observed eye is normal (emmetropic) or [illegible] normal (myopic or hypermetropic). These three [illegible] cipal cases must be considered in order, the observing eye being assumed to be emmetropic.

(a) The observed eye is emmetropic, and with relaxed accommodation (Fig. 3664). Let *a* and *b* represent the origins of two efferent pencils, at two points within the illuminated area at the fundus of the observed eye. [illegible] both eyes are assumed to be emmetropic, the rays composing these pencils become parallel after refraction [illegible] the cornea of the observed eye and, entering the eye of the observer, are focussed at *a'* and *b'* upon its retina, where they form an inverted image *b' a'*, equal [illegible] *a b*. The observer looking through the pupil of the observed eye sees the portion *a b* of its illuminated [illegible] in the erect position, and magnified as indicated by the dotted lines drawn toward *a''* and *b''*.

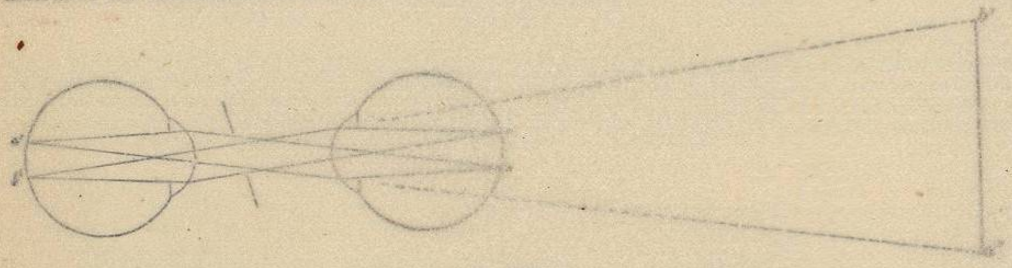


Fig. 3664.

(b) The observed eye is myopic (Fig. 3665). Let *a* and *b* again represent the origins of two efferent pencils. [illegible] the observed eye is myopic, the rays composing these pencils become convergent after refraction at its cornea and would, if continued, converge to foci at *α* and *β*. Entering the eye of the observer they take on increased convergence, to cross at focal points in the vitreous, from which they again diverge to be cut by the retina in circles of confusion, thus forming a blurred image. [illegible] the interposition of the concave lens *C*, of a negative focal length equal to the distance *a C*, the convergent pencils are rendered parallel before they enter the observing eye, so that they can be focussed accurately in the [illegible]

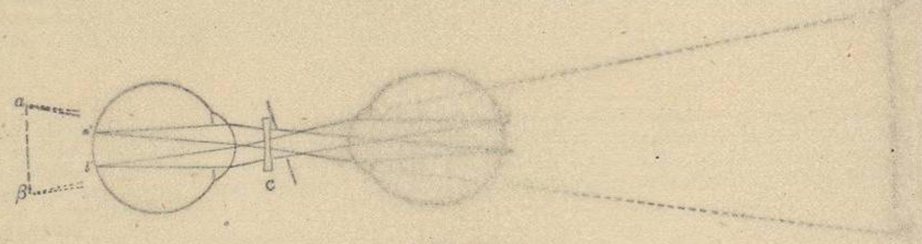
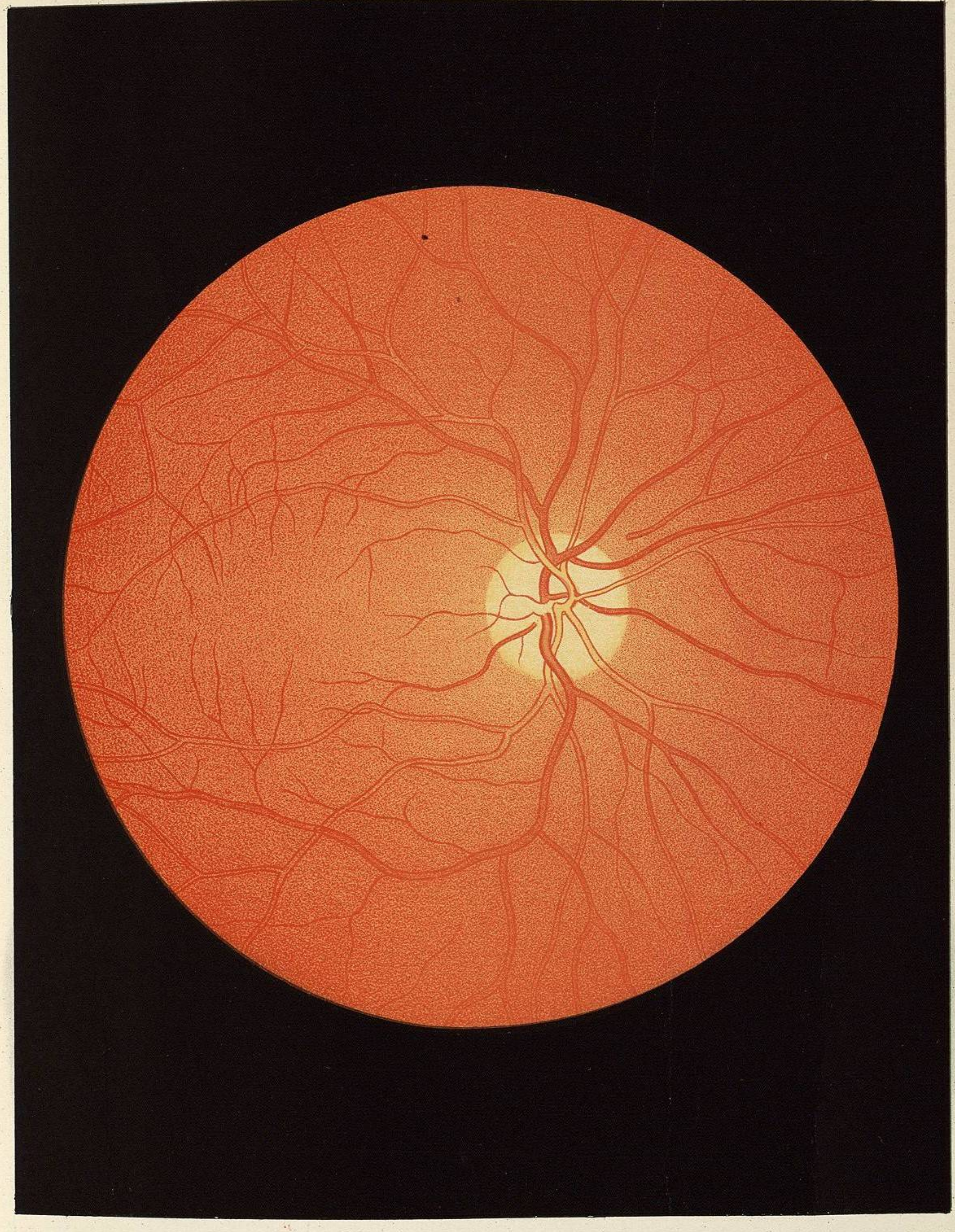


Fig. 3665.

* After death the red color of the human fundus is lost.



OPHTHALMOSCOPIC VIEW OF THE NORMAL FUNDUS OCULI.

(Copied after Jaeger.)

a' and b' at its retina to form a sharply defined image, somewhat larger than the object *a b*. The concave lens *C*, placed at the anterior focus of the observed eye—about 13 mm. in front of its cornea—exactly corrects its

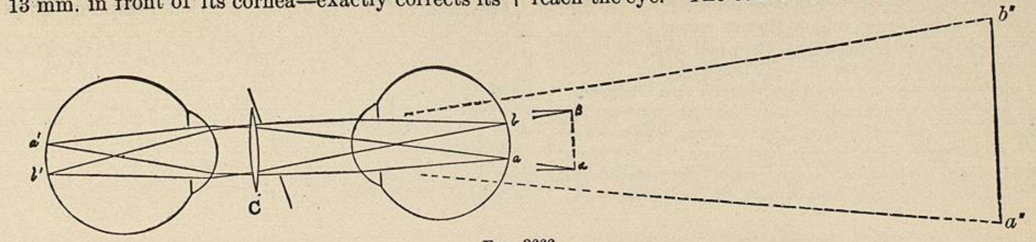


FIG. 3666.

myopia, and is, therefore, equal to the concave spectacle glass needed in distant vision. If the lens *C* is held a centimetre or more in front of the principal anterior focus of the observed eye, as is generally the case in ophthalmoscopic examinations, the negative focal length of the concave lens thus selected will be less than that of the required spectacle glass, by just its distance from the anterior focus of the eye. In low grades of myopia the error arising from a variation of 2 or 3 cm. in the distance of the concave lens is inappreciable, but in the higher grades (of 4 dioptries or more) the distance of the concave lens from the anterior focus must be added to its

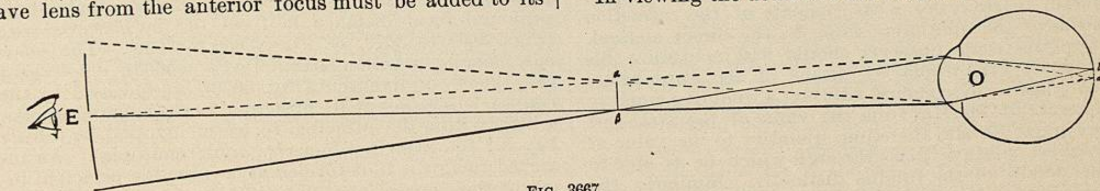


FIG. 3667.

(negative) focal length, in order to insure the highest degree of accuracy of which this method of examination is capable.*

The details of the fundus of the myopic eye, viewed through a concave lens placed behind the ophthalmoscopic mirror, are seen somewhat more magnified than in the case of the emmetropic eye.

(*c*) The observed eye is hypermetropic, and with relaxed accommodation (Fig. 3666). Let *a* and *b* again represent the origins of two efferent pencils. As the observed eye is hypermetropic, the rays composing these pencils emerge from the eye divergent, as if emanating from points *α* and *β* behind the eye, and, entering the eye of the observer, are rendered convergent, but not

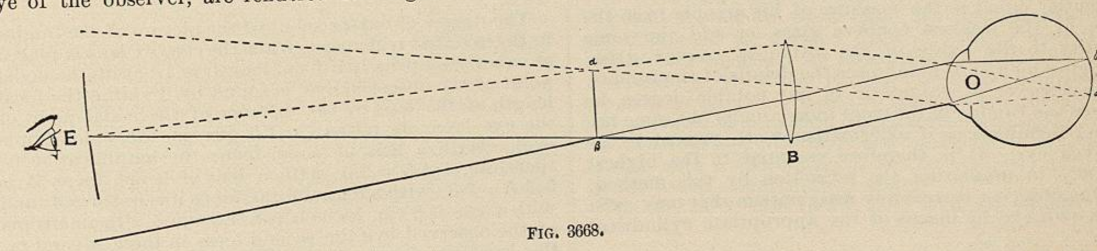


FIG. 3668.

sufficiently to focus them at its retina. An imperfectly defined image is therefore formed at b' a' of somewhat smaller size than the object *a b*. Here, however, the accommodation of the observer's eye may come into action, consciously or unconsciously, to focus the image upon its retina, and thus a distinct view of the fundus at *a b* may be obtained. Assuming that the eye of the observer

* The use of a concave lens behind the mirror, of a negative power sufficient to correct, or somewhat to overcorrect, the sum of the myopia of the observed and the observing eye, is a part of the original invention of Helmholtz (1851).

remains adjusted for parallel rays, we may interpose the convex lens *C*, of a focal length equal to the distance *a C*, and thus render the divergent rays parallel before they reach the eye. The convex lens *C*, placed at the anterior focus of the hypermetropic observed eye, exactly corrects its hypermetropia; if placed at a greater distance from the eye than its anterior focus, this excess of distance must be subtracted from the focal length of the convex lens. In low grades of hypermetropia small variations in the distance of the convex lens from the eye may be neglected.*

The details of the fundus of the hypermetropic eye, viewed through a convex lens placed behind the ophthalmoscopic mirror, are seen somewhat less magnified than in the case of the emmetropic eye.

In viewing the details of the fundus in the erect image the cornea and lens of the observed eye perform the function of a simple microscope. If we adopt the conventional rule of referring the magnified virtual image to a distance of 8 Paris inches (about 217 mm.), the enlargement will be represented very nearly by the ratio 217 : 15, or about 14.5 diameters, in the case of an emmetropic eye of average dimensions (Helmholtz).

Ametropia in the eye of the observer plays an important part in affecting the distinctness of the view of the fundus in the erect image. Thus a myope who, with the unaided eye, can focus only divergent rays upon his retina, does not see the details of the fundus unless the observed eye is hypermetropic to a degree equivalent to or somewhat in excess of the measure of his own myopia. A hypermetrope, on the other hand, can, with relaxed accommodation, obtain a clear view of the fundus of a

* The principle underlying the method of measuring the refractive condition of any eye, by means of a concave or convex lens placed behind the ophthalmoscopic mirror, is clearly set forth in the first publication of Helmholtz (1851), but the practical employment of the method on an extensive scale began with E. Jaeger (1856). It was also early cultivated by Donders, and especially by Mauthner (1867). Its general adoption, as a part of the daily work of the ophthalmic practitioner, dates from the introduction, by Loring (1869), of an instrument provided with a series of especially selected correcting lenses arranged to admit of easy and rapid changes.

myopic eye in which the myopia does not exceed the measure of his own hypermetropia, and, by exerting his accommodation, he may be able to see the fundus of an emmetropic or even of a hypermetropic eye. A hypermetropic observer enjoys, therefore, a certain advantage in respect of the facility with which he can adjust his accommodation so as to see clearly under different refractive conditions of the observed eye; but he labors under a special disadvantage when he attempts to measure its refraction, and this for the reason that it is generally impossible for him either to estimate the degree to which he exerts his accommodation, or to control its exercise so perfectly as to hold it with even approximate accuracy at the point required to make him virtually emmetropic. To obtain trustworthy measurements of the refraction by means of the ophthalmoscope by the direct method, the hypermetropic observer should first neutralize his manifest hypermetropia by means of the appropriate convex glass, or else should subtract a quantity equal to the measure of his Hm from the value of the strongest convex glass, or add the same quantity to the value of the weakest concave glass through which he is able to see the details of the fundus distinctly. Similarly, the myopic observer should first correct his myopia by means of a neutralizing concave glass, or else should subtract a quantity equal to the measure of his myopia from the value of the weakest concave glass, or add the same quantity to the value of the strongest convex glass, through which he is able to see the details of the fundus. If the observer is astigmatic in any notable degree, he will see the fundus in the erect image under the same imperfect definition as if astigmatism were present in the observed eye. It is, therefore, essential to the highest accuracy, in measuring the refraction by this method, that the observer correct any astigmatism that may exist in his own eye by means of the appropriate cylindrical glass.

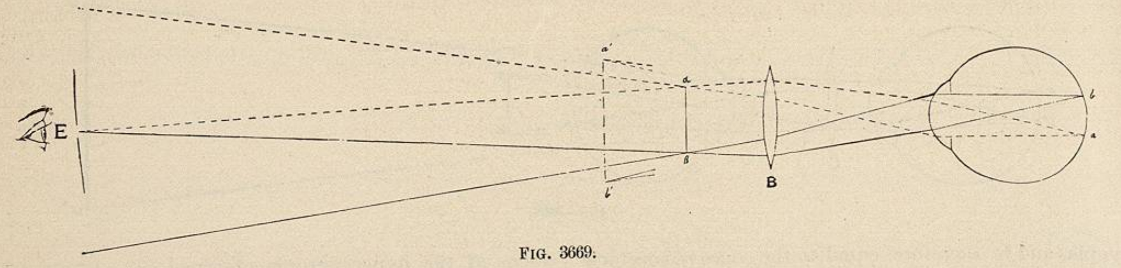


FIG. 3669.

In the indirect method of examination the observer does not view the fundus itself, but an inverted aërial image of the fundus. The myopic eye forms such an image at its far-point (*punctum remotissimum*, *r*). Let *a* and *b* (Fig. 3667) represent two points taken within the illuminated area of a strongly myopic eye, and within the field of view of the observing eye at *E*. Inasmuch as the points *a* and *b* lie behind the principal posterior focus of the observed eye, the pencils originating from these points emerge, respectively, from the eye as pencils of convergent rays, to be focussed at the distance of the far point *r*, where they enter into the formation of an inverted real image β *a*. An observer stationed at *E*, about 20 cm. beyond β *a*, may accommodate for this real image, and see the finest details of the fundus sharply defined and magnified, but in the inverted position. The practical application of this method is greatly restricted by the fact that it is adapted only to cases of myopia of high grade, and that, at the best, the field of view is very small. Moreover, the image is seen under very different degrees of enlargement, according as the myopia is of a lower or a higher grade.

The indirect method is extended to the examination of all eyes, irrespective of the state of the refraction, by making both the illuminating and the efferent pencils pass through a strong convex lens, placed at about its principal focal distance in front of the observed eye (Figs. 3668 to 3670; *cf.* Figs. 3659 to 3662). The efferent pencils, whether parallel (Fig. 3668), convergent (Fig. 3669), or divergent (Fig. 3670), are focussed by the convex lens either at its principal focus (in emmetropia), a little within the principal focus (in myopia), or a little beyond the principal focus (in hypermetropia). An inverted image is thus formed at or near the principal focus of the convex lens, and may be viewed from a station *E*, taken at a distance of from 20 to 25 cm. beyond the position of the principal focus.

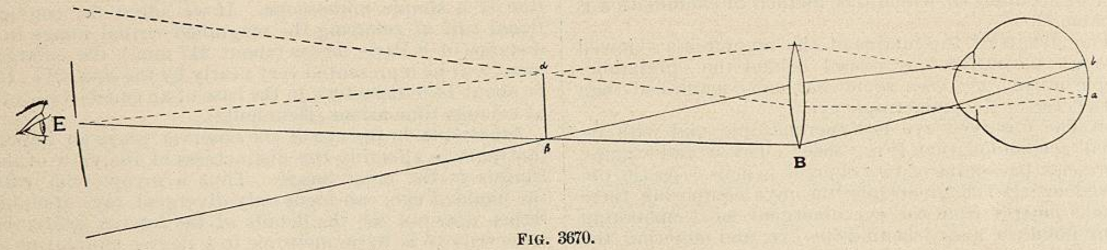


FIG. 3670.

The degree of enlargement of the picture of the fundus in the inverted real image, when the convex lens is placed at exactly its principal focal length in front of the nodal point of the observed eye, is found by dividing the focal length of the lens by the distance of the nodal point of the eye from its retina ($=1.5$ cm. in the emmetropic eye). With a lens of 4 cm. focus the amplification is, therefore, $4:1.5=2.6$; with a lens of 5 cm. focus it is $5:1.5=3.3$; with a lens of 6 cm. focus it is $6:1.5=4$; and with a lens of 8 cm. focus it is $8:1.5=5.3$. In ametropia of the observed eye the second term in these several ratios is either greater (in myopia) or less (in hypermetropia) than the normal measure of 1.5 cm., so that the amplification of the inverted image is less in myopia, and greater in hypermetropia, than it is in emmetropia.

In very high grades of myopia, in which an inverted image of its fundus is formed by the eye at a very short distance in front of its cornea, the convex lens must be held very near the observed eye in order that it may take part in the formation of the image. This implies the use either of an excessively strong lens, in which case the details of the fundus will appear but little magnified in the inverted image, or of a weaker lens, held at a distance notably less than its focal length from the observed eye,

in which case the boundaries of the field of view will be greatly narrowed. In the highest grades of myopia a modification of the indirect method of examination is, therefore, to be preferred.

Fig. 3671 shows a greatly elongated eye, representing a myopia of about 25 dioptries, and, therefore, forming an inverted image of its fundus at a distance of about 4 cm. in front of its nodal point. A convex lens of about 10 dioptries power ($=10$ cm. focus) is held at about its principal focal length in front of the observed eye, and, therefore, at a distance greater than that of the inverted image. The observer, at *E*, views the image β *a* through the convex lens, and consequently sees it magnified by the lens. In this position of the convex lens neither the intensity of the illumination nor the extent of the field of view is materially influenced by the size of the pupil. A convex lens of a focal length a few centimetres greater than the distance of the image from the nodal point of the observed eye, held at about its principal focal distance in front of the cornea, gives a fairly ample field of view, together with a convenient enlargement of the inverted image. If the lens is moved nearer to the observed eye—*i.e.*, nearer to the place of the image—the field of view will be more extensive and the amplification less; if, on the other hand, the lens is moved farther from the eye, the field of view will be less extensive and the amplification greater.

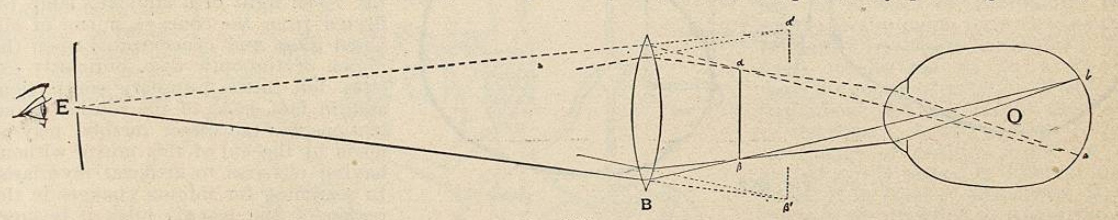


FIG. 3671.

In emmetropia of the observed eye the efferent pencils, of parallel rays, are focussed by the convex lens at its principal focus, irrespective of the distance at which the lens is held in front of the eye. The amplification of the image remains, therefore, constant for any particular lens, whether the distance of the lens from the eye be taken greater or less than its principal focal length. Only the size of the illuminated area at the fundus and the extent of the field of view are affected by the change in the position of the lens.

In ametropia, on the other hand, any change in the distance of the convex lens from the observed eye is attended, also, with some change both in the distance at which the inverted image is formed in front of the lens and in the amplification of the image. In hypermetropia, if we move the lens farther from the eye, the amplification of the image will be somewhat diminished. Conversely, in myopia, any increase in the distance of the convex lens from the eye is attended with some increase in the amplification of the image.

This change in the size of the inverted image in ametropia gives rise to a characteristic phenomenon in astigmatism, namely, a change in the apparent form of the disc of the optic nerve, according as the convex lens is held at a greater or less distance in front of the observed eye. In mixed astigmatism (Ahm or Amh) the eye is virtually myopic in the principal meridian of greatest refraction, and hypermetropic in the principal meridian at right angles to this meridian. It follows that, in moving the convex lens farther from the eye, the size of the inverted image increases in the direction corresponding to the ocular meridian of greatest refraction, and diminishes in the direction of the meridian of least refraction, so that the optic disc is seen as an oval of progressively varying form. In simple hypermetropic astigmatism (Ah) and in simple myopic astigmatism (Am) the change in the form of the inverted image of the disc is the same as in mixed astigmatism, but the variation is confined to the direction corresponding to the ametropic meridian. In compound hypermetropic astigmatism (H + Ah) and in compound myopic astigmatism (M + Am) the same change in form is observed as a result of unequal increase or decrease in the two principal meridians.

This change in the apparent form of the inverted image of the optic disc in astigmatism is necessarily attended with some indistinctness of outline, but this practically adds to, rather than detracts from, the conspicuousness of the phenomenon. In the case of the retinal vessels, the definition varies according as they happen to lie approximately in the direction of one or the other of the principal diameters of the oval. Both the distortion of the inverted image of the disc, and the inequality in the definition of the vessels which lie in the direction of the two principal meridians, may be made to disappear by the simple expedient of rendering the convex lens itself astigmatic by holding it more or less obliquely to the visual axis, according to the grade of astigmatism to be overcome.

The ample field of view, conjoined with as strong an illumination as can be utilized, the convenient degree of enlargement of the retinal picture, the fact that the conditions of visibility of the fundus are not materially affected by hypermetropia, or by any but the highest grades of myopia, and the facility with which the disturbing influence of astigmatism may be annulled by giving an oblique position to the lens, all combine to render the indirect method particularly available whenever we wish to obtain a general view of a large area of the fundus. On the other hand, for the examination of the details of the fundus under a greater magnifying power, and especially for measuring the refraction of the observed eye, the direct method offers advantages which are entirely its own. The two methods are, therefore, to be cultivated side by side, each supplementing the other; the two together affording the means of studying the fundus with a thoroughness not so perfectly attainable by the use of either method alone.

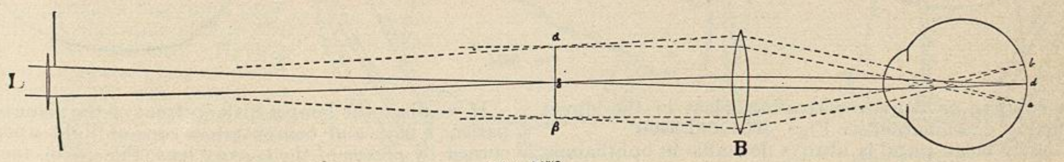


FIG. 3672.

In order to be able to use both methods equally well, so as to obtain from each the best service of which it is capable, it is of the first importance that the observer eliminate any sources of error growing out of the uncontrolled exercise of his own accommodation. This can be attained only by the observer training himself to make all examinations, as well by the indirect as by the direct method, under the uniform condition of complete accommodative relaxation. And here the learner has, first of all, to suppress an instinctive tendency to accommodate for the short distance at which he knows that the object,

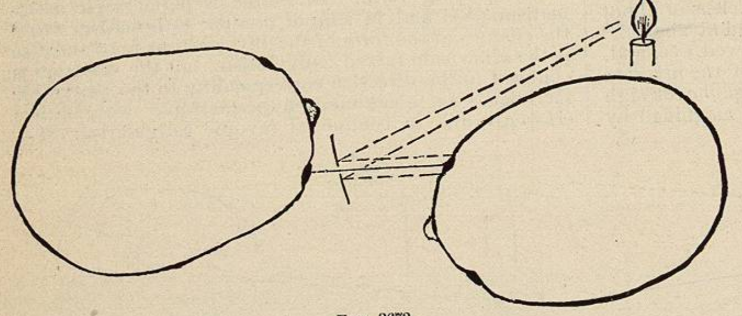


FIG. 3673.

or its image, actually lies. Hence, in practising the direct method, the learner should be made to feel that he must look not so much into the observed eye as through it, as if viewing an object lying far away. If myopic, he should accustom himself always to use the weakest concave correcting glass, or if hypermetropic, to use the strongest convex correcting glass through which he can obtain a distinct view of the details of the fundus; if emmetropic, he should learn to observe the fundus of an emmetropic eye without a correcting glass, and, in examining a myopic or a hypermetropic eye, to find and make use of the particular concave or convex correcting glass which exaclty measures its myopia or hypermetropia. In practising the indirect method the learner should also acquire the habit of viewing the inverted image with relaxed accommodation, which he will accomplish, if emmetropic, by looking through a convex lens of about 5 dioptries power (20 cm. focus) placed immediately behind the hole in the mirror; or, if hypermetropic, by substituting for this lens such other lens, of greater power, as shall, in addition, correct his manifest hypermetropia; if myopic, he should similarly employ the convex or concave lens which accurately adjusts his own far point (*r*) for the distance of 20 cm.; and only in the particular case in which his far point lies at this distance (M = 5 dioptries) should he practise the indirect method without a correcting glass.

The use of a convex correcting glass in the indirect method of examination is shown in Fig. 3672; for the use

aminations in a completely darkened room of considerable size, and preferably with walls of a dark color. The general darkness of the room is favorable to the dilatation of the pupils, and the consciousness that he is in a room of some size makes it easier for the patient to relax his accommodation when he is asked to direct his gaze toward a large and faintly lighted object upon the opposite wall. By observing these precautions the causes which incite to contraction of the pupils are in a great measure eliminated, with the exception of the direct influence of the light reflected into the eye by the mirror. The light of a student's lamp, reflected from the concave mirror of silvered glass and concentrated upon the region of the optic disc, ordinarily excites but little pupillary contraction, and, in fact, most of the routine examinations by the direct method may be made by the aid of this mirror without having recourse to artificial mydriasis. In searching for minute changes in the region of the macula lutea it is, however, not infrequently advisable to make use of a weak mydriatic, such as cocaine or euphthalmin. If, for any reason, it is judged inexpedient to instil a mydriatic solution into the eye, the plane mirror of Helmholtz, made up of several layers of unsilvered glass, may often be made to render excellent service.

In order to permit the patient to direct his gaze upon a somewhat distant large object, it is important that his view, with the eye not under examination, be not cut off by the head of the observer. Hence the very useful rule, of general application, that the observer accustom himself always to use his right eye in examining the right, and his left in examining the left eye (Figs. 3673 and 3674).

The ophthalmoscopic armamentarium, in its simplest effective form, includes (1) a perforated concave mirror, of about 33 mm. diameter and 23 cm. focus, mounted on a handle of about 13 cm. length, and fitted with a rotating disc or other mechanism by which any required concave or convex correcting glass may be easily brought into place behind the hole in the mirror; (2) a convex lens, of a diameter of about 3.5 cm. and a focal length of 5 or 6 cm.; and (3) a good lamp, which should be so mounted as to admit of the easy adjustment of the flame to about the height of the observed and of the observer's eye. This simple apparatus, used in a well darkened room, affords the means of exploring the eye, from the anterior epithelium of the cornea back to the retina and optic disc.

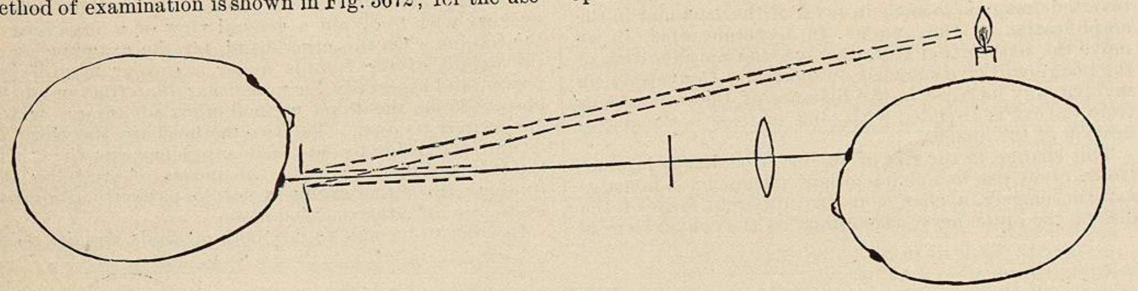


FIG. 3674.

of a concave or convex correcting glass in the direct method of examination see Figs. 3665 and 3666.

A fairly large pupil is always desirable in ophthalmoscopic examination, and in employing the direct method it is often indispensable. Nevertheless, it is not always either necessary or advisable to make use of a mydriatic. As the pupils contract both under the stimulus of strong light and in connection with the exercise of the accommodation, it is best to conduct all ophthalmoscopic ex-

If we place the lamp a little in front of the plane of the patient's face, and concentrate a cone of light upon the cornea by means of the convex lens (Fig. 3675), the conditions of illumination are very favorable to the detection and observation of any slight irregularities or opacities in the cornea, whether superficial or more deeply seated, and also of finely punctate deposits such as often occur in or upon the lining membrane of the cornea (membrane of Descemet). If we change very slightly the

position of the lens, so that the cone of light shall fall upon the iris, we may note slight changes in its texture, and also any irregularities in the contour and pigmentation of the pupillary margin. By concentrating the light upon the region of the pupil, we may similarly detect thin deposits of lymph obscuring the anterior capsule of the crystalline lens in the pupillary field, specks of brown pigment detached from the posterior surface of the iris and adherent to the lens capsule, and also such opacities as have their seat in the capsule or in the anterior layers of the crystalline. If we have previously brought the

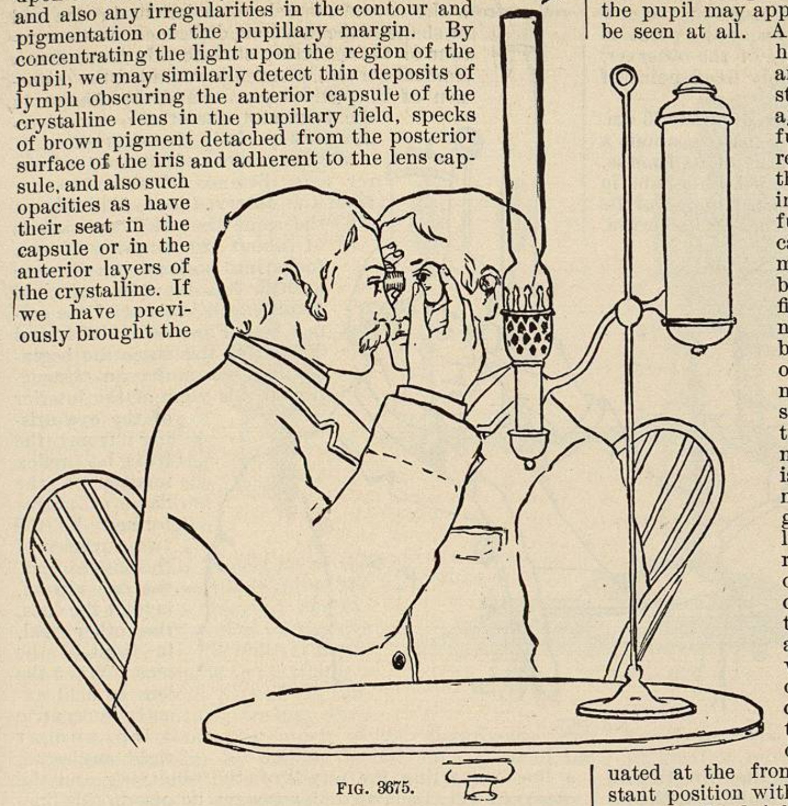


FIG. 3675.

eye under the influence of a mydriatic, we may detect and carefully study any adhesions (synechiæ) which may have been formed between any part of the pupillary border and the lens capsule, whether recent or of indefinitely long standing. If the pupil is widely dilated, we may look deeply into the crystalline lens (*cf.* Fig. 3643) and thus detect and observe the various forms of opacity incident to different types of cataract, or we may even look through the crystalline into the vitreous, and obtain glimpses of a mass of effused blood or lymph, or of a very prominent tumor growing from the fundus. In many cases it is desirable to make use of a magnifying glass in connection with this lateral or oblique focal illumination, for which purpose there is nothing better than an ordinary doublet of about 3.5 cm. focal length. By the method of lateral illumination all objects are seen by the light which they reflect from their surface, and, therefore, in their actual color.

In using the mirror, the lamp is placed a little behind the plane of the patient's face, and, preferably, on the same side as the eye to be examined. Having placed a convex glass of about 5 dioptries (20 cm. focus) behind the mirror, we throw the light upon the eye from a distance somewhat less than the focal length of the lens. Looking through the mirror, we see the field of the pupil brightly illuminated, and of a vivid red color, whenever the media are of unimpaired transparency and the fundus is of its normal hue. In the presence of diffuse cloud-

ing of the cornea or crystalline lens, or a turbid condition of the aqueous or vitreous humor, the red color of the pupil may appear conspicuously dulled, or may not be seen at all. A circumscribed opacity, on the other hand, whether in the cornea, on the anterior lens capsule, or in the substance of the crystalline, appears black against the red background of the fundus. Motes and shreds in the vitreous appear, also, as a rule, under the aspect of black specks or threads, intercepting the red light from the fundus, but in rare instances, as in the case of crystals of cholesterin, they may reflect so much light as to sparkle brilliantly (*synchysis scintillans*). If a fixed opacity has its seat at or very near the centre of rotation of the eyeball (about 13.5 mm. behind the vertex of the cornea), it will undergo little or no change of position when the observed eye is turned in different directions; if in front of this centre, it will move in the direction in which the eye is turned; if behind the centre, it will move in the opposite direction. The greater the distance at which the body lies in front of or behind the centre of rotation, the greater will be the range of its excursions. Thus a spot in the cornea will move through a larger arc than an opacity at the depth of the anterior lens capsule, and this in turn will move through a larger arc than one situated at or near the posterior capsule. Inasmuch as the pupil and the anterior lens capsule lie at the same depth within the eye, an opacity situated at the front of the lens maintains a nearly constant position with reference to the bright field of the pupil, while a spot on the cornea, or in the deeper layers of the lens,

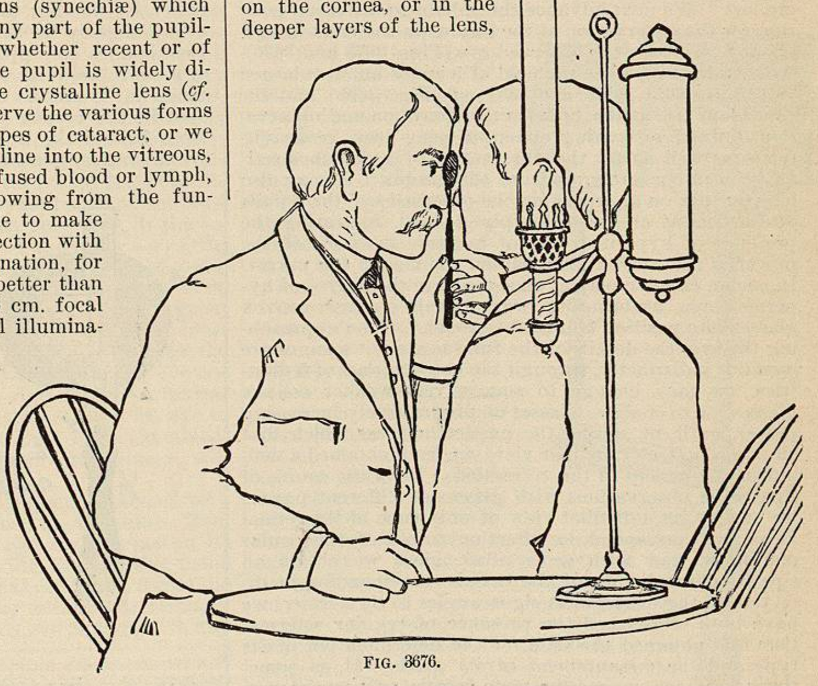


FIG. 3676.

makes conspicuous excursions across this field; in the one case the movement is in the direction in which the eye is turned, in the other case in the opposite direction.