consequently r (the radius of curvature of the cornea) is an inverse function of the chord $M\,M'$. The length of this chord is read from the graduation on the arc. The radius of curvature of the cornea in different meridians

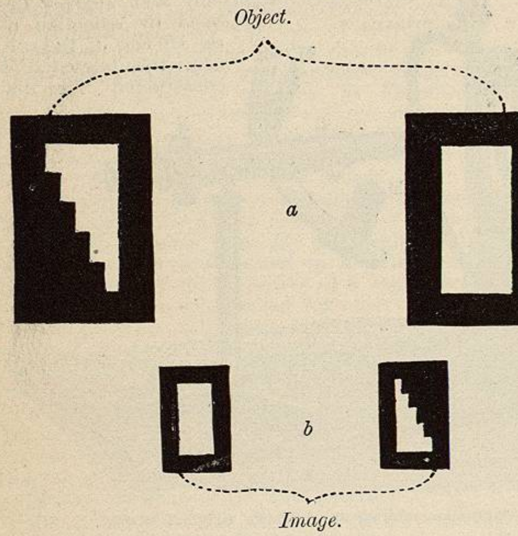


FIG. 3638.—*a*, The Targets; *b*, their corneal images as seen through the telescope without intervention of the prism of Iceland spar.

may be calculated from measurements of the chord $M\,M'$, made after turning the telescope, with the arc and targets, about its axis.

The great value of the Javal-Schiötz ophthalmometer is in its remarkable adaptation to the detection and measurement of corneal astigmatism, and for such examination it has won general recognition as indispensable to the ophthalmic practitioner. In astigmatism the essential thing to be considered is the difference in refraction in the two principal meridians, and it is for the measurement of such differences in the corneal curvature that the instrument has been especially designed. In the use of the ophthalmometer the length of the object (chord $M\,M'$) remains unchanged throughout the observation of the eye in its two principal meridians, and it is only the difference in the length of the image when the arc is adjusted successively for the corneal meridians of greatest and least curvature that is regarded. The observation consists in simply noting the amount of overlapping of the two images in the second position of the arc, after having first brought them into exact contact in the first position.

The device for reading the amount of overlapping of the images is shown in Fig. 3638, *a*. The outer side of one

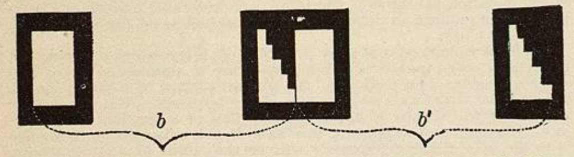


FIG. 3639.—Corneal Images as Seen Through Telescope and Prism. Double images in touching position.

of the rectangular targets is cut in the form of steps of such width that each step approximately represents a difference of corneal curvature corresponding to 1 D of ocular refraction.* The number of overlapping steps is taken as the number of dioptries of astigmatism attributable to inequality of curvature of the cornea in its two principal meridians.

Fig. 3639 shows the doubled images of the targets in the position of contact; in Fig. 3640 the same images are shown with two steps overlapping, indicating 2 D of corneal astigmatism. It will be observed that in both these positions the images are rectangular, also that they lie exactly in the same line.

This rectangular form and linear direction of the images of the four targets is seen whenever the curvature of the cornea is symmetrical with reference to the plane of the arc. When the cornea is a surface of revolution, with its axis passing through the centre of the arc, this condition is fulfilled for all positions of the targets; but when the cornea is of a configuration approaching an ellipsoid of three unequal axes, the position of the arc

FIG. 3640.—Overlapping of Double Images — As = 2 D.

must be such that its plane shall bisect the ellipsoid in one or the other of its two principal planes. In all other positions of the arc the images of the four targets appear more or less distorted, and the images of the two pairs of targets are not in the same line (see Fig. 3641).*

This distortion and oblique displacement of the two images, in all but two positions of the arc, reveals at a glance the presence of corneal astigmatism. To find the meridian of greatest corneal curvature, the arc is turned until the images are seen in a line and most widely separated.† The two targets are then moved inward or outward on the arc until the images are brought into the position of contact. Lastly, the arc is turned through an angle of 90°, or until the images are again seen in a line, and the number of overlapping steps, which repre-

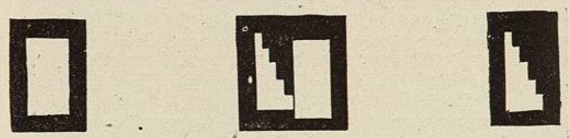


FIG. 3641.—Double Images not on a Level—Astigmatism Present. Arc not in a principal meridian.

sents the number of dioptries of corneal astigmatism, is noted. The examination of the two eyes need not consume more than two or three minutes.

The measurements of corneal astigmatism as made with the ophthalmometer agree remarkably, in most cases, with the results obtained by the use of methods which show the total astigmatism of the eye. The agreement in the direction of the principal meridians is especially close, so that in by far the greater number of cases the direction of the axis of the correcting cylindrical glass may be taken directly from the reading of the instru-

* Inasmuch as different eyes present considerable variation in corneal curvature, necessitating a corresponding variation in the separation of the targets in order to bring their images into exact contact, it is evident that a step on the target does not always represent the same fractional part of the chord $M\,M'$. In the case of a relatively flat cornea the targets must be set nearer together, and each step will then represent a larger fractional part of the chord $M\,M'$; conversely, when the cornea is of greater than average curvature the targets must be set wider apart, and each step will then represent a smaller fractional part of the same chord. It follows that in the former case each overlapping step in the image must represent somewhat more, and in the latter case, somewhat less, than 1 D of corneal astigmatism. It is well, therefore, always to note the length of the chord $M\,M'$, so that a correction can be made for it if deemed necessary.

* For an analysis of the phenomenon of distortion of the image formed by a mirror of asymmetrical curvature, also of the same phenomenon as it occurs in the case of a lens of asymmetrical refraction, see a paper by the writer: "Ein Beitrag zur Theorie der Cylinderlinsen," Graefe's Archiv, 1887.

† By interchanging the targets the images may be brought into the position of contact when the arc is set in the meridian of least corneal curvature, and the overlapping steps counted in the second position of the arc; in practice this is found to be more convenient, for the reason that the meridian of least curvature is, as a rule, approximately horizontal, and it is easier to adjust the targets in the horizontal and to observe the overlapping of the images in the vertical meridian.

ment. In respect to the grade of astigmatism the agreement is less exact, for the reason that the observed corneal astigmatism is often modified by an astigmatism attributable to an oblique position of the crystalline lens. As a rule, the meridian of greatest corneal curvature is

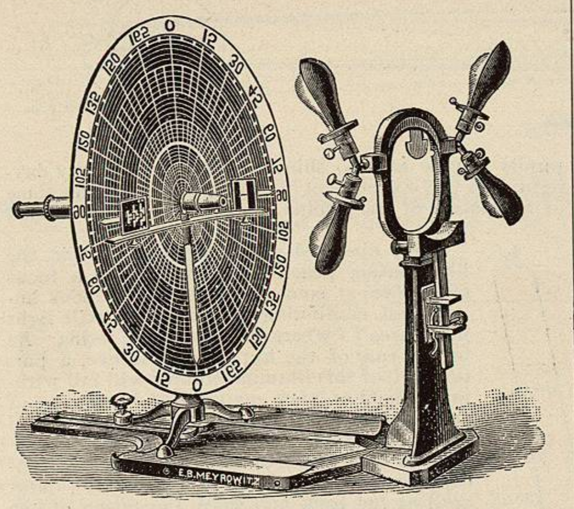


FIG. 3642.—Javal's Ophthalmometer with Attachment for Electrical Illumination of the Targets.

approximately vertical, and the meridian of greatest lenticular refraction is approximately horizontal; the total astigmatism is therefore generally somewhat less than the corneal astigmatism when the meridian of greatest corneal curvature is approximately vertical, and greater when, contrary to the rule, it is approximately horizontal.

In a comparatively small number of instances the total astigmatism is found to vary very widely from the corneal. For example, a relatively high grade of lenticular astigmatism may so far dominate a corneal astigmatism as largely to control both the direction of the principal meridians and the grade of the total astigmatism. Again, it is not uncommon to find a low grade of astigmatism, oftenest with the meridian of greatest refraction horizontal or nearly horizontal, in the absence of corneal asymmetry. Lastly, the ophthalmometer occasionally reveals an anomalous condition in which the corneal meridians of greatest and least curvatures are not at right angles to each other.

Not only has the Javal-Schiötz ophthalmometer greatly advanced our knowledge of astigmatism, but it affords, also, most important special information in every case of investigation of the refraction of the eye.

The instrument-maker Kagenaar (Utrecht, 1887)[11] has somewhat cheapened the original Javal-Schiötz ophthalmometer by substituting a pair of weak glass prisms, turned in opposite directions, for the doubly refracting prism of Iceland spar. Leroy and Dubois (1888)[12] have also produced a low-priced ophthalmometer, in which the doubling of the image is effected by means of two plates of thick glass as used by Helmholtz. In a second and newer model[13] (see Fig. 3642) the shape of the targets has been somewhat altered; and the direction of the meridians of greatest and least corneal curvature is read on the reflected image of the darge disc which now constitutes the most conspicuous feature of the instrument.

Carl Koller.

BIBLIOGRAPHY.

1 Philosophical Transactions, 1801.
2 Oken's Isis, 1840.
3 Wagner's Handwörterbuch der Physiologie, iii., 1.
4 Archiv für Ophthalmologie, 1, 2.
5 Astronomische Nachrichten, No. 414.
6 Archiv für Ophthalmologie, vi., 2.
7 Archiv für Ophthalmologie, viii., 2.
8 Middelburg: De Zitplaats van het astigmatisme, Utrecht, 1863.
9 Coccius: Ueber den Mechanismus der Akkommodation des menschlichen Auges, Leipzig, 1867.
10 Annales d'Oculistique, lxxxvi., Juillet-Août, 1881.
11 Nederlandsch Tijdschrift voor Geneeskunde, 1889.
12 Revue générale d'Ophtalmologie, vii., 2.
13 Bulletin de l'Academie de Médecine de Paris, 27 Août, 1889.

OPHTHALMOSCOPE; OPHTHALMOSCOPY,—from *ὀφθαλμός*, eye, and *σκοπέω*, to view. The ophthalmoscope, German, *der Augenspiegel*, is an optical device by means of which the interior of the eyeball is rendered visible.

Ophthalmoscopy, in its wider meaning, includes whatever pertains to the objective examination of the eye; in a narrower sense, it is restricted to the examination of the interior of the eye by the aid of the ophthalmoscope.

The anterior segment of the eyeball, comprising the cornea, the anterior chamber filled with the aqueous humor, the front of the iris, and so much of the anterior capsule of the crystalline lens as corresponds to the area of the pupil, is accessible to direct inspection by the naked eye, or through a magnifying glass. Even when the pupil is strongly contracted, a central opacity of the

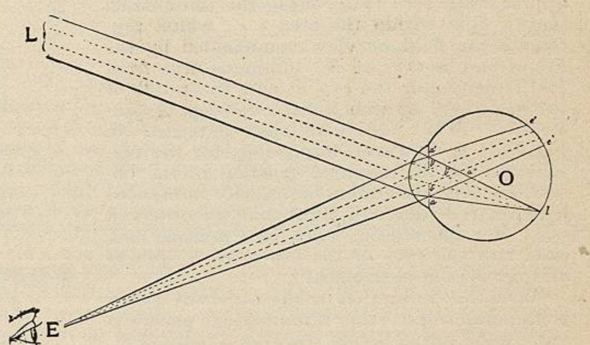


FIG. 3643.

lens capsule or of the immediately subjacent lens substance reveals itself by a characteristic white or gray appearance. When the pupil is widely dilated, we may look deeply into or through the crystalline, and may obtain glimpses of a detached and displaced portion of the

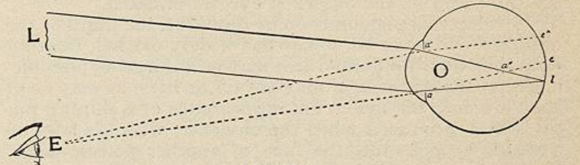


FIG. 3644.

retina, of a blood clot or other large foreign body in the vitreous, or of the surface of a very prominent tumor arising from the retina or choroid.

Let L (Fig. 3643) represent a pencil of parallel rays emanating from a distant source of light and entering the dilated pupil $a\,a'$ of the eye O, so as to light up a

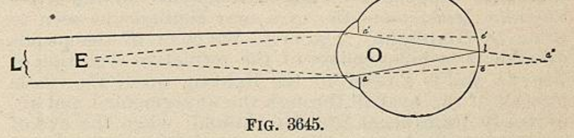


FIG. 3645.

path through the vitreous, indicated by the cone $a\,a'\,l$. The eye of an observer at E will receive rays from any object which may happen to lie within that portion of this cone, near its base, which is bounded by the line $a\,a''$. Outside of the limits $a\,a'\,a''$, the whole interior of the eye is either in comparative darkness or is shut off from view by the iris at a, a'. If the pupil is contracted to the diameter $b\,b'$, only such part of the pencil L as is included within the dotted lines can enter the eye, and only such objects as happen to lie within the smaller

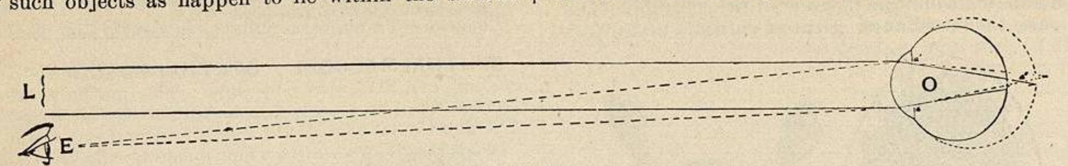


FIG. 3646.

cone $b\,b'\,l$ will be illuminated; of this smaller cone the greater portion is shut off from view by the iris at b, b', so that nothing can be seen outside the narrow limits $b\,b'\,b''$. If we take the angle $L\,O\,E$ smaller (Fig. 3644), the point a'' will fall farther back in the vitreous, and it will be possible to see more deeply into the eye.

When the angle $L\,O\,E$ is taken very small, approaching zero (Fig. 3645), the illuminated point l falls within the area $e\,e'$, which represents the field of view commanded by the eye of an observer at E; luminous rays from l will then enter the eye E, and the pupil of the eye O will be seen lighted up—*das Augenleuchten*. The particular case indicated in Fig. 3645 is, however, impossible, for the reason that, in the assumed position of the observer's eye, his head is necessarily interposed between the source of light and the observed eye. For this reason, when two persons look each into the eyes of the other, the pupils of all four eyes appear black.

When the refraction of the observed eye O is hypermetropic, the illuminating pencil is cut by the retina before reaching a focus (Fig. 3646), thus lighting up an area at the fundus which will be larger or smaller according as the pupil is more or less dilated and the pencil is cut by the retina at a greater or less distance from its focus. An observer looking into the eye, at a very small angle to the axis of the illuminating pencil, may receive rays of light from this illuminated area, and will then see the pupil of the observed eye illuminated. To develop this phenomenon by daylight, the pupil of the observed eye must be somewhat widely dilated, in order both that the illuminated area may be as large as possible, and that the iris at a, a' may cut off as little as may be of the view into the eye. The appearance of a shining pupil is best produced when the observer, with his back to a window, looks into the face of another person, a few feet away, whose eyes are directed toward a strongly illuminated surface, such as a bright cloud in the sky. Shining of the pupils is also very conspicuous, under particular conditions, in animals with eyes of hypermetropic construction whose fundus is clothed by a strongly reflecting layer—the tapetum. A familiar instance is the glowing of the eyes of the cat, when the gaze of the animal, with pupils widely dilated, is encountered by a person entering a dark room with a lighted lamp. In persons with congenital or acquired absence of the iris—*aniridia, irideremia*—the eyes may similarly be seen to shine by lamplight. The vivid red color of the pupils of albinos is independent of the refractive condition of the eye, and is a result of the lighting up of the whole interior of the eyeball through the unpigmented and abnormally translucent iris and choroid; when the eye of an albino is shaded by an opaque card, the pupil, viewed through a hole in the card, appears black, as in a normally pigmented eye (Donders).*

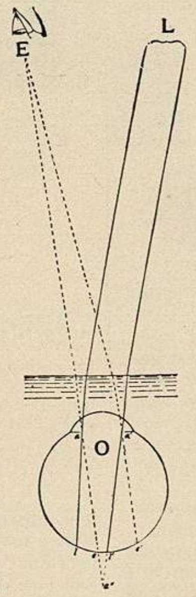


FIG. 3647.

If we annul the refraction at the cornea by plunging the head of an animal under water (Fig. 3647), the eyes will be rendered very strongly hypermetropic, and the pupils may be seen to shine brightly by ordinary daylight. In this experiment it is also possible to see some of the details of the fundus through the widely dilated pupil.*

If the observed eye is strongly myopic, the illuminating pencil will converge to a focus (Fig. 3648) at some point in the vitreous humor, and, continuing on its course, will light up an area $l'\,l$ where it is cut by the retina. As in the case of the hypermetropic eye, a portion, $e'\,l$, of this illuminated area will fall within the field of view commanded by the eye of an observer at E, who will then see the pupil of O lighted up.

If we take as the source of light a small incandescent electric lamp L (Fig. 3649), darkened at the back and sides, the retina of the (unaccommodated) emmetropic eye O will intercept the illuminating pencil before it reaches its focus, and a small area, $l\,l'$, of the fundus will be lighted up. In this case, as in the cases assumed in Figs. 3646 and 3647, a considerable portion, $e\,l$, of the illuminated area, $l\,l'$, falls within the region $e\,e'$, from which rays of light can enter the eye of an observer at E, behind and a little to one side of the lamp. Under these conditions the pupil of O is seen strongly illuminated.†

If we move the lamp L nearer to the eye O, the angle $L\,O\,E$ will become larger and larger, and the portion $e\,l'$ of the illuminated area $l\,l'$, falling within the field $e\,e'$, will become smaller and smaller; whenever the angle $L\,O\,E$ becomes so large that no part of $l\,l'$ coincides with any part of $e\,e'$, the pupil will cease to appear luminous. If, however, we fit a small refracting prism P, to the incandescent lamp (Fig. 3650), we may so change the direction of the illuminating pencil as to turn it upon the eye O, as if emanating from L', thus permitting an observer to look into the eye from E, at a very small angle to the axis of the illuminating pencil, even though he approach to a distance of only a few centimetres from the cornea of the observed eye.

The most convenient and effective way of lighting up the fundus of the eye is by making use of a reflector. This reflector may be made of unsilvered transparent glass, in which case it may be set at an angle of about forty-five degrees to the direction of the axis of the illuminating pencil (Fig. 3651). Of the incident rays, some are

*The shining of the eyes of certain animals in the dark was, for a long time, attributed to a supposed power of generating light. Prevost (1810) showed that the phenomenon is observed only when the eyes are illuminated by light falling directly upon them. Rudolphi (1810) called attention to the fact that it is necessary to look into the eye in a particular direction. In aniridia in the human eye Beer (1839) saw the pupils red and shining when he looked at the eyes in nearly the direction from which the light fell upon them; W. Cumming (1846) and Brücke (1847) discovered, independently of each other, that the pupils of the unmutilated human eye may be made to shine under the same conditions of illumination and inspection (cited from Helmholtz: "Handbuch der physiologischen Optik," first edition, S. 189).

*Mery (1704) first described this experiment, in which probably the first view of the blood-vessels of the retina of a living animal (cat) was obtained. The visibility of the details of the fundus in this experiment was correctly ascribed by La Hire (1709) to the alteration in the conditions of refraction, of which, however, he failed to give an exact explanation (cited from Helmholtz, *op. cit.*, S. 190). By the aid of the orthoscope of Czermak, a little trough of glass, fixed to the cheek and nose with wax, and filled with water, the observation of Mery may be repeated upon the human eye.

†This arrangement of the light represents essentially that employed by Brücke (1847). Brücke used a lamp or a candle as the source of light, and shut off the light from the eye of the observer by means of a small opaque screen.

transmitted by the transparent glass, and lost, while other rays are regularly reflected, and may be directed upon the pupil of the observed eye O, as if they had emanated from

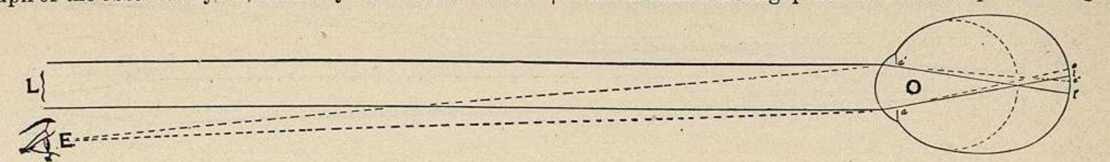


FIG. 3648.

L'. So, also, in the case of the efferent pencils, some of the rays are lost by reflection in the direction of the light L, while others are transmitted by the glass, to be re-

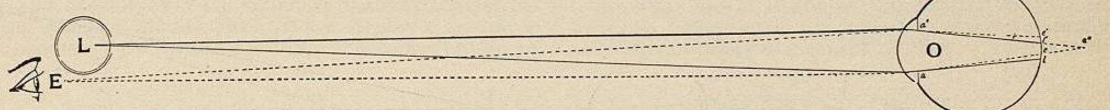


FIG. 3649.

ceived by the eye of an observer looking through the transparent mirror directly in the axis of the illuminating pencil.*

A plane mirror of silvered glass, or of polished metal,

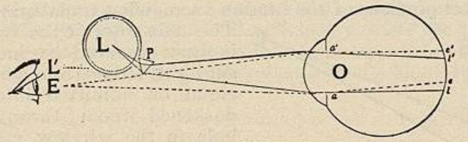


FIG. 3650.

may be substituted for the mirror of transparent glass, with the double advantage of reflecting a much stronger light into the eye and of permitting the lamp to be placed by the side of and at any required distance behind the patient's head (Fig. 3652). An observer looking past the side of the mirror, or, more conveniently, through a small central perforation, sees the pupil of the eye O more strongly illuminated than when an unsilvered glass mirror is used. The farther the plane mirror is held from the observed eye the smaller is the portion of its reflecting surface from which rays of light can enter the pupil and the weaker the illumination (Fig. 3653).

By making use of a concave mirror held near the eye, we may reproduce very nearly the same conditions of illumination as when the plane mirror is used (Fig. 3654), or, increasing the distance of the mirror or of the lamp, we may throw at will a parallel (Fig. 3655) or a convergent pencil (Fig. 3656) into the eye. If we increase still further the distance at which the mirror is held from the eye, and from the lamp (Fig. 3657), a very large convergent pencil, reflected from the entire surface of the mirror, may be thrown into the observed eye, and when the lamp and the pupil of the eye, O, come to lie in conjugate foci of the mirror (Fig. 3658), the size of the illuminating pencil is limited only by the diameter of the mirror, and the illumination at the fundus is correspondingly intense. A concave mirror of very thin, silvered glass, of a diameter of 33 mm. and a focal length of about 23 cm., with a central perforation of about 3.5 mm. diameter, is found to be, on the whole, most convenient, as serving both for such examinations as are required to be made with the mirror held near the eye (Figs. 3654 and 3656) and for those in which it is required to reflect a large convergent pencil from a greater distance (Figs. 3657 and 3658).

If the illuminating pencil is made to pass through a strong convex lens held in front of and at somewhat less than its principal focal distance from the cornea of the observed eye, a very large convergent pencil may be thrown into the eye and focussed at any desired distance behind the cornea. With a convex lens of about 20 dioptries (5 cm. focus), held at a distance of about 4.5 cm. in front of the cornea (Fig. 3659), the focus will lie in the vicinity of the nodal point of the eye, and a large area of the fundus, limited only by the angular diameter of the convex lens, will be strongly illuminated.

If a weaker lens is employed, or if the lens of 5 cm. focus is held nearer to the observed eye (Fig. 3660), the focus of the illuminating pencil will lie at some point in the vitreous humor, and the illuminated area at the fundus will be larger or smaller according as the focus lies farther from or nearer to the retina. When the focus lies at a certain depth in the eye the diameter of the illuminated area is further limited by the size of the pupil, so that only a part of the illuminating pencil, corresponding to a larger or smaller central portion of the convex lens, can gain entrance into the eye.

If a stronger convex lens is used, or if the lens of 5 cm. focus is removed to a little more than its focal distance from the observed eye (Fig. 3661), the focus of the illuminating pencil will lie a little in front of the cornea, and the fundus will be illuminated in an area which, as in the case assumed in Fig. 3659, is limited only by the angular diameter of the convex lens.

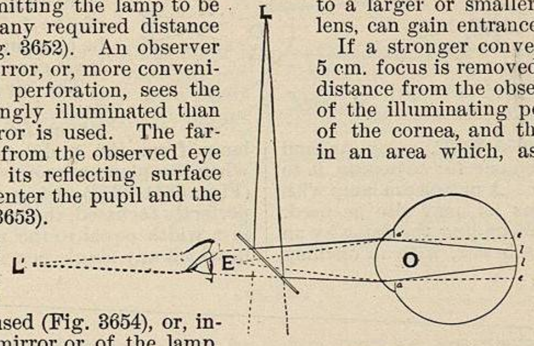


FIG. 3651.

In all three positions, as shown in Figs. 3659 to 3661, nearly the whole of the illuminated area of the fundus falls within the field of view commanded by the eye of an observer at E, so that rays emanating from a large area at the fundus may enter the eye of the observer.

By combining the perforated concave mirror, of about 23 cm. focus, with a convex lens of 5 to 6 cm. focus (Fig.

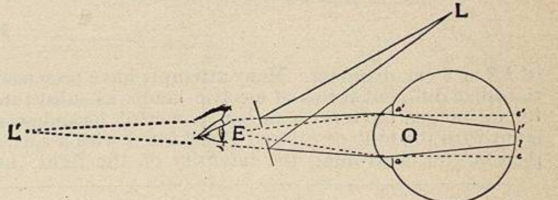


FIG. 3652.

3662), the maximum useful degree of illumination is attained, together with the ability to regulate the diameter of the illuminated area at the fundus by varying the dis-

*The arrangement shown in Fig. 3651 is essentially that originally employed (1851) by Helmholtz, the inventor of the ophthalmoscope.

tance at which the lens is held from the eye. The observer looking through the central perforation in the mirror, directly in the axis of the illuminating pencil, is also in the most favorable position for receiving rays from the illuminated area at the fundus.*

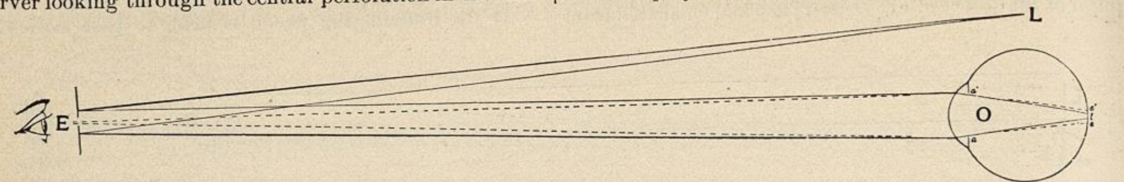


FIG. 3653.

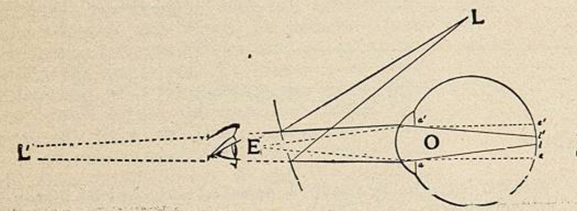


FIG. 3654.

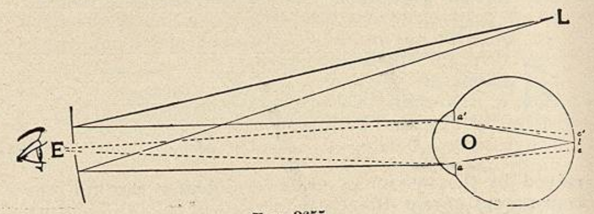


FIG. 3655.

We have thus far, for simplicity of demonstration, considered the source of light as a luminous point, which we have taken either at an infinite distance (Figs. 3643–3648), or at some short distance, as indicated by the position of the small electric lamp (Figs. 3649–3662). In practice, however, we ordinarily make use of an oil lamp or gas burner, in which case the area of illumination at the fundus corresponds to the inverted image of the flame (Fig. 3663). The maximum intensity of illumination is attained when the illuminating pencils are focussed exactly in the retinal image and the pupil is widely dilated.

The lamp ordinarily used in ophthalmoscopic work is an Argand oil lamp (the so-called student's lamp—Figs. 3675–3677), or an Argand gas-burner, with some arrangement for adjusting it to the height of the patient's head. A petroleum lamp with a broad flame, or a bat-wing gas jet, may also be used. There is some advantage in surrounding the flame by an opaque screen, of metal or of asbestos, with an opening of 2.5 or 3 cm. diameter. Many attempts have been made to utilize different forms of electric lamps as substitutes for oil or gas burners; a rather powerful incandescent lamp with the bulb of ground glass, fitted with a special rheostat for controlling the intensity of the light, has found favor with some good observers. Other inventors have employed a very small electric bulb and mirror, both attached to the handle of the ophthalmoscope, or have suppressed the illuminating mirror altogether.

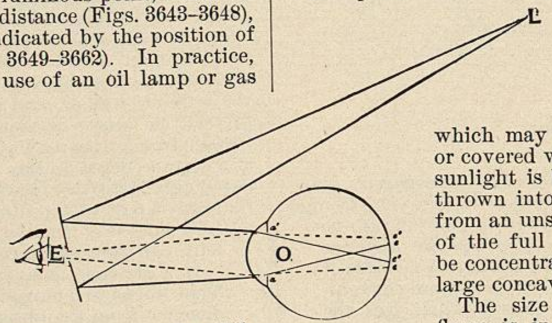


FIG. 3656.

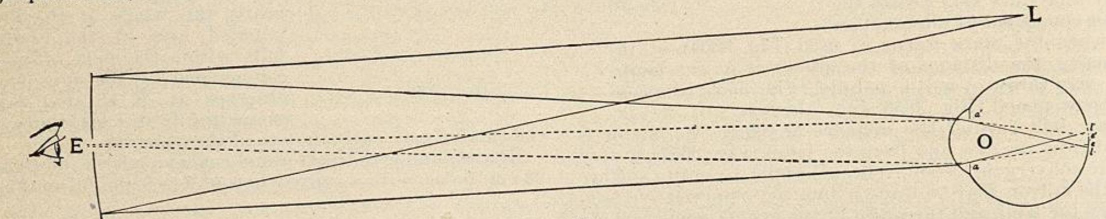


FIG. 3657.

A minor disadvantage in using oil or gas illumination is the yellow color of the flame, which imparts to the whiter portions of the fundus a somewhat unnatural tint. The true color of the fundus is best observed by indirect sunlight, either from a bright cloud or admitted into the darkened room through a hole in the window shutter which may be glazed with ground glass or covered with thin white paper. Direct sunlight is by far too intense to be safely thrown into the eye, even when reflected from an unsilvered glass mirror; the light of the full moon is insufficient, unless it be concentrated by reflection from a very large concave mirror.

The size of the bright image of the flame is in an inverse ratio to the distance (*LO*, *L'O*, *L''O*, Fig. 3663) of the lamp from the nodal point of the observed eye, or, when the plane mirror is used, to the distance $LE + EO$ (Figs. 3651–3653); when the illuminating pencils are imperfectly focussed, the image is spread out, at its borders, in a width equal to the radius of the circle of confusion in which any single pencil is cut by the retina. When a concave mirror is used, and the distance from the observed eye is large (Figs. 3657 and 3658), the illuminated area is practically the image of the mirror.

The extent of the area at the fundus, which falls within the field of view of the observer in the direct method of examination—*i.e.*, without the interposition of the convex lens—varies directly as the size of the pupil of the observed eye, and inversely as the distance from the eye at which the observer is stationed; a fairly large pupil and a near point of observation are therefore essential to the enjoyment of an ample field. To secure a near

* The illumination by means of the perforated concave mirror, conjoined with the employment of the convex lens to form an inverted image of the fundus at or near its anterior focus (Ruete, 1852), constitutes an invention second only in practical importance to that of Helmholtz. Figs. 3659 to 3661 illustrate a development of Brücke's experiment, by Helmholtz (1852).

point of observation, we hold the ophthalmoscopic mirror as near as possible to the observed eye, and to prevent contraction of the pupil under the stimulus of the light reflected into the eye, we may instil a drop of a weak mydriatic solution, or we may make use of a mirror which reflects light of the minimum intensity compatible with sufficient illumination. If we employ a mydriatic we choose, by preference, a solution of cocaine (1 to 50), of euphthalmin (1 to 50), or of cocaine and euphthalmin (1 to 100 each), either of which will sufficiently dilate the pupil in the course of from ten to twenty minutes, without subjecting the patient to the inconvenience incident to the prolonged mydriasis which follows the instillation of a strong solution of atropine, duboisine, or hyoscyamine. To reflect a weak light into the eye, we may use a perforated plane or convex mirror made of darkly tinted glass, or, still better, the original form of mirror devised by Helmholtz, which is made up of three or more plates of thin, unsilvered glass. This compound mirror reflects more light than a single plate of glass, and also polarizes the reflected pencils; by its action as an analyzer, it also extinguishes most of the rays reflected from the surface of the cornea, which often interfere with the view of the parts within the eye.

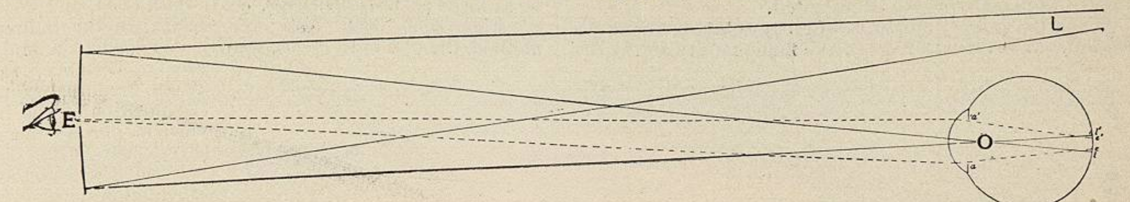


FIG. 3658.

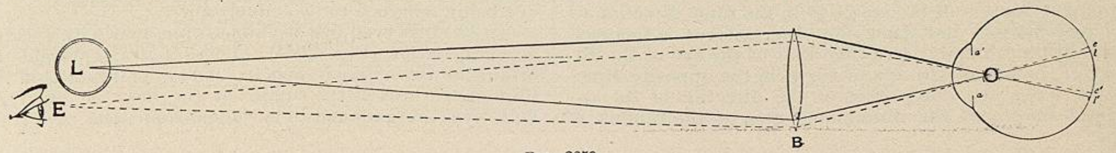


FIG. 3659.

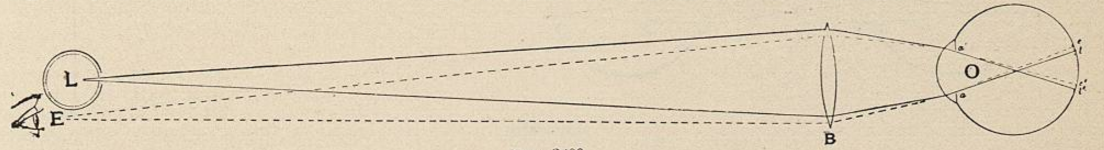


FIG. 3660.

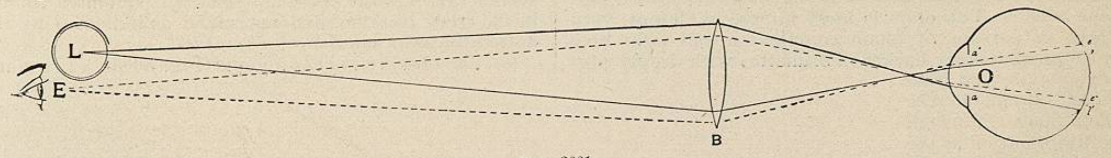


FIG. 3661.

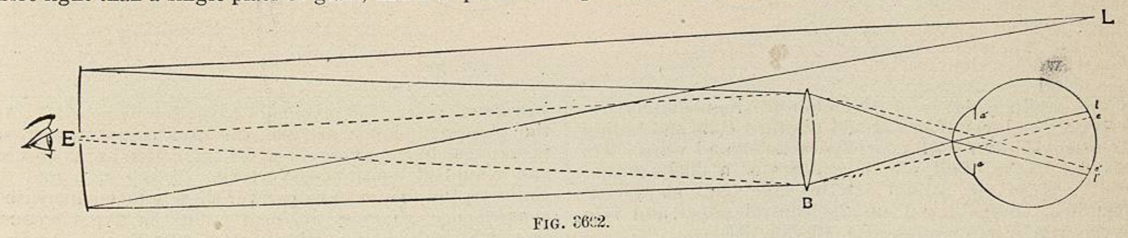


FIG. 3662.

In the indirect method of examination—*i.e.*, by the use of the convex lens of about 5 cm. focus held at about its focal distance in front of the observed eye—the size of the pupil plays a much less important part than in the examination by the direct method, and in certain positions of the lens it is almost completely eliminated as a factor in determining the intensity of the illumination and the amplitude of the field of view. This is practically the case whenever both the focus of the illuminating pencils and the intersection, within the eye, of the lines which defined the limits of the field of view lie in or very near the plane of the pupil (Fig. 3662).

Whenever the inverted image of the flame, at the fundus of the observed eye, is smaller than and lies wholly within the field of view commanded by the eye of the observer, the form of the image may be seen more or less distinctly outlined, according as it is itself sharply defined and as the refractive condition of the observed eye is such as to admit of the efferent pencils being accurately focussed upon the retina of the observer. Outside of the limits of this bright image, the fundus appears dark by contrast, although in fact dimly lighted through the faint general illumination of the interior of the eye by the bright image itself, 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*).

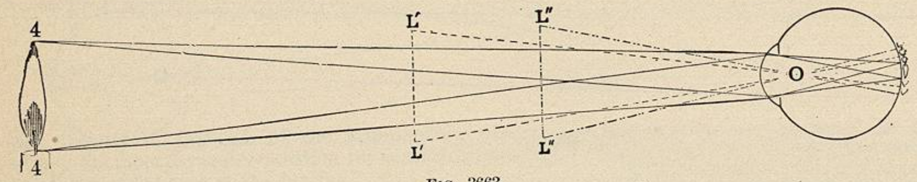


FIG. 3663.

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 direct method of examination the eye of the observer is brought very near to the observed eye, in order that the field of view, as determined by the area of the pupil, may be as large as possible (Figs. 3651, 3652, 3654, and 3656; *cf.* Figs. 3653, 3655, 3657, and 3658). In the indirect method the observer is necessarily stationed at a much greater distance, say 20 cm. or more, beyond the position of the inverted aërial image (Figs. 3667–3672).

In the direct method of examination the visibility of the details of the fundus is affected in different ways according as the refraction of the observed eye is normal (emmetropic) or abnormal (myopic or hypermetropic). These three principal 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. As both eyes are assumed to be emmetropic, the rays composing these pencils become parallel after refraction at 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 in size to *a b*. The observer looking through the pupil of the observed eye sees the portion *a b* of its illuminated fundus in the erect position, and magnified as indicated by the dotted lines drawn toward *a″* and *b″*.

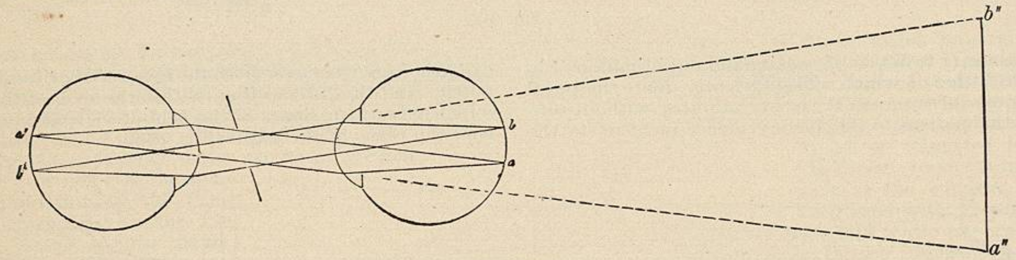


FIG. 3664.

(*b*) The observed eye is myopic (Fig. 3665). Let *a* and *b* again represent the origins of two efferent pencils. As 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 *a* 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 as circles of confusion, thus forming a blurred image. By 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 observer's eye, so that they can be focussed accurately in the points

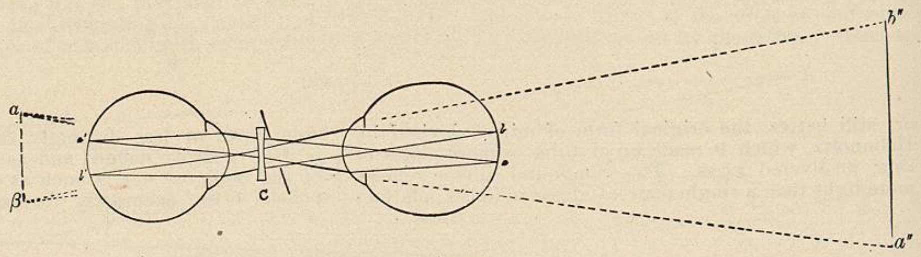
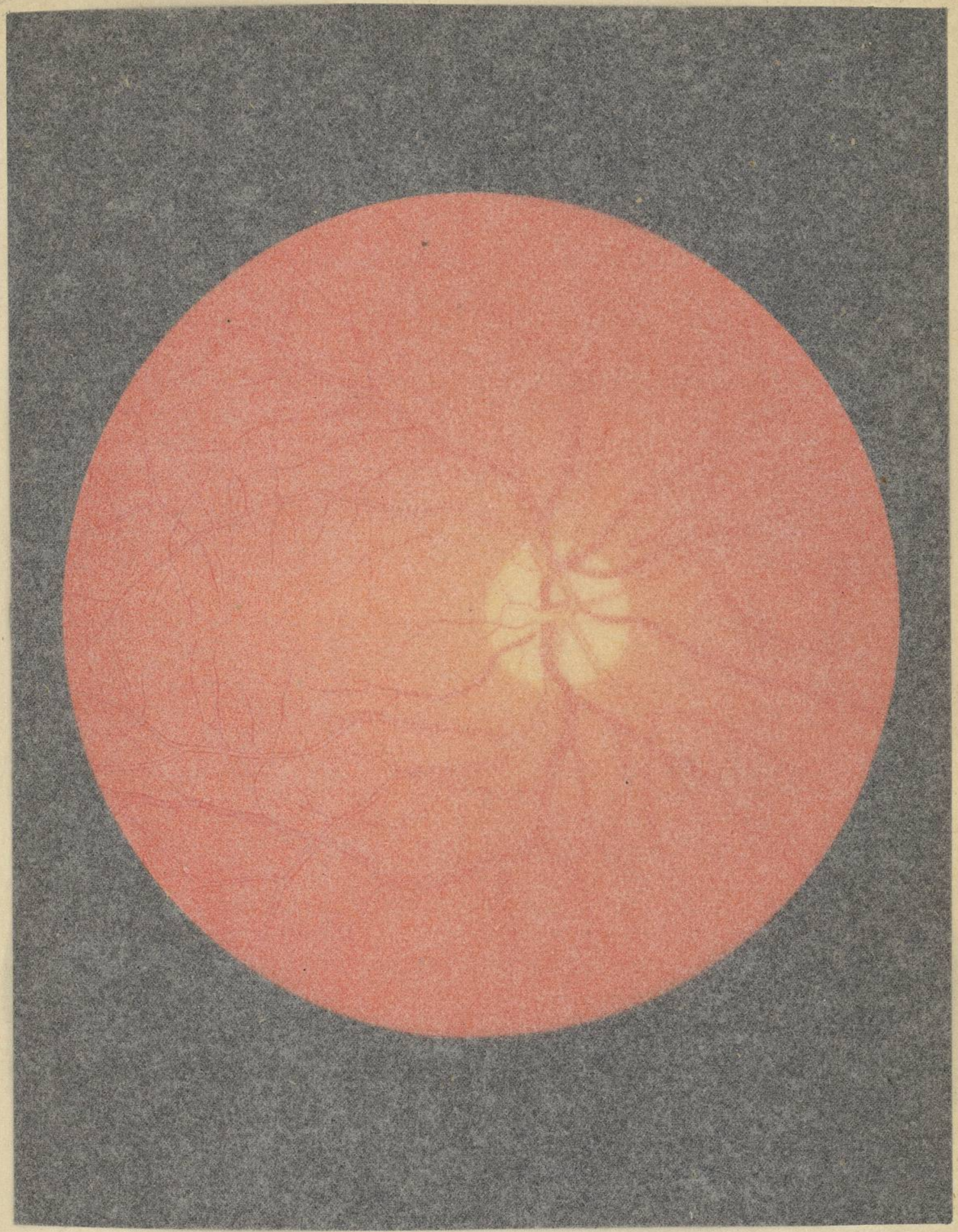


FIG. 3665.

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



OPHTHALMOSCOPIC VIEW OF THE NORMAL FUNDUS OCULI.
(Copied after Jaeger.)