Retinoscopy (or shadow test) in the determination of refraction at one meter distance, with the plane mirror / by James Thorington.

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RETINOSCOPY

THORINGTON

RETINOSCOPY

(OR SHADOW TEST)

IN THE

DETERMINATION OF REFRACTION AT ONE METER DISTANCE, WITH THE PLANE MIRROR

BY
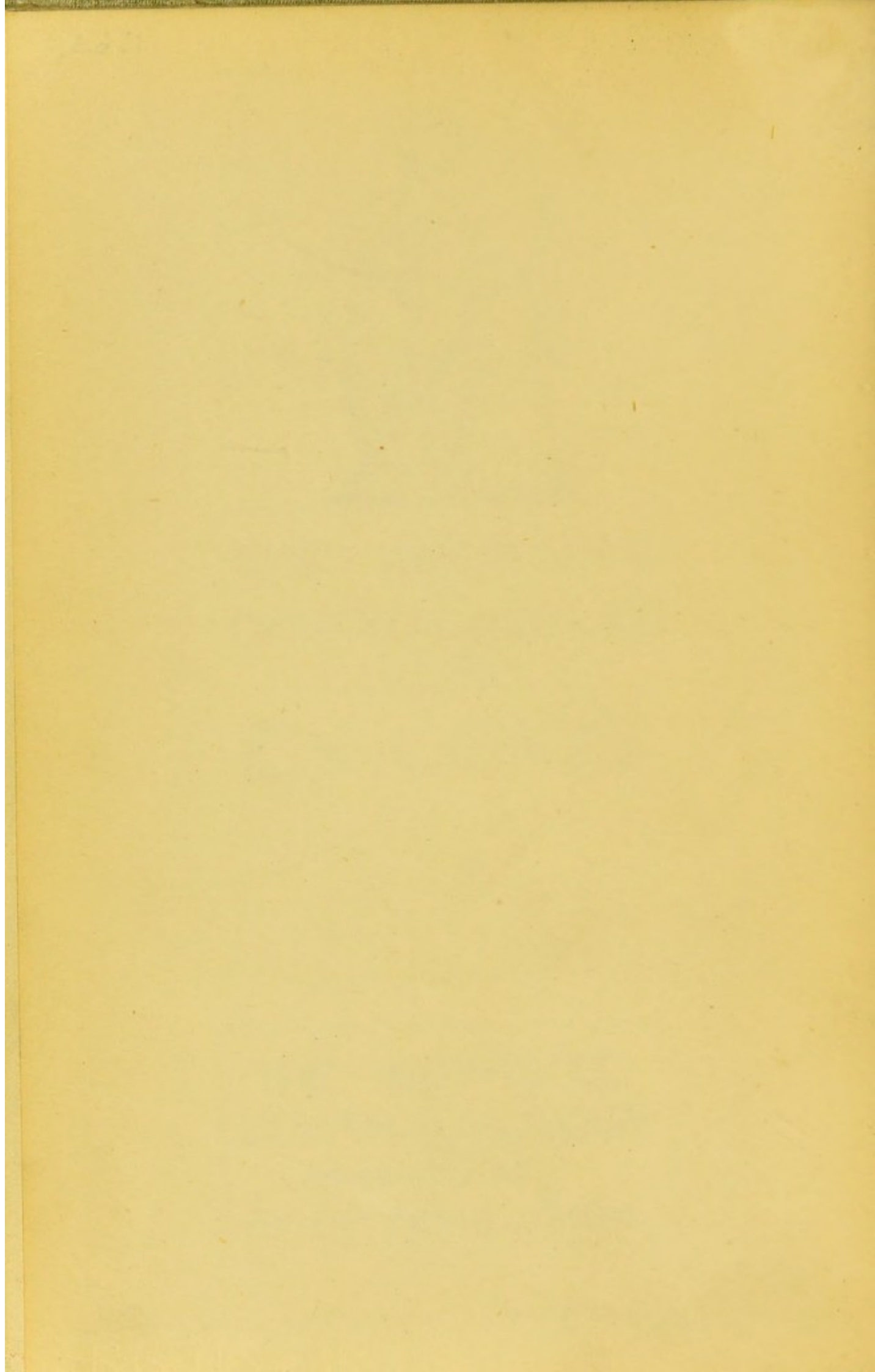
JAMES THORINGTON, A. M., M. D.

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HOW TO USE IT"; PROFESSOR OF DISEASES OF THE EYE IN THE PHILADELPHIA
POLYCLINIC AND COLLEGE FOR GRADUATES IN MEDICINE; OPHTHALMIC
SURGEON TO THE PRESBYTERIAN HOSPITAL; OPHTHALMOLOGIST
TO THE ELWYN AND VINELAND TRAINING SCHOOLS FOR
FEEBLE-MINDED CHILDREN.

SIXTH EDITION, REVISED AND ENLARGED

SIXTY-ONE ILLUSTRATIONS
TEN OF WHICH ARE COLORED
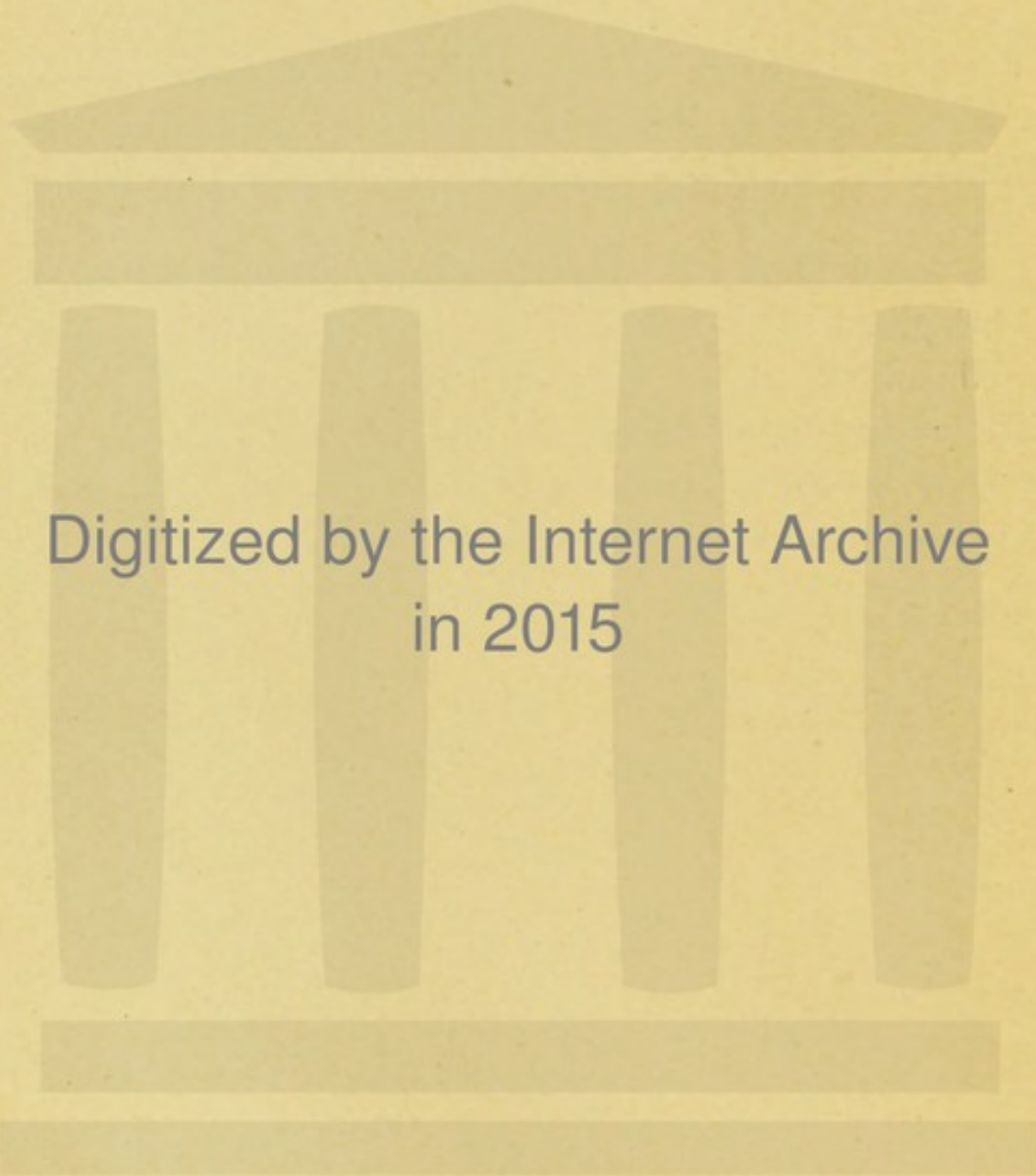
PREFACE TO THE SIXTH EDITION.

The proof of the growing popularity of Retinoscopy as the most valuable objective method of estimating the refraction of an eye is attested by the demand for another edition.

The writer takes pleasure in carefully revising the work and bringing it up to date by the addition of new illustrations as well as illustrations of new apparatus.

The author wishes to express his deep appreciation for the many favorable criticisms of the work and trusts that this edition may receive continued favor.

2031 CHESTNUT STREET,
PHILADELPHIA, PA.

PREFACE TO THE FIRST EDITION.

At the earnest solicitation of many students and friends, this book is presented as an abstract of the author's previous writings and lectures on Retinoscopy, delivered during the winter course on Ophthalmology, at the Philadelphia Polyclinic.

In presenting a manual of this kind the writer does not presume to detract from the writings or teachings of others, or the excellent work on Skiascopy, by his friend and colleague, Dr. E. Jackson; but wishes to elucidate in as concise a manner and few words as possible the method of applying retinoscopy, which has given most satisfaction at his hands.

While intended for college students and post-graduates, yet there is ample material given whereby the ophthalmologist at a distance may acquire a working knowledge of the method, by study and practice in his office.

For three reasons Retinoscopy, in preference to Skiascopy, has been chosen as the title:

First, that it may not be confounded with Skiagraphy.

Second, that it is the name by which the test is universally known; and—

Third, that it is the retina in its relative position to the dioptric media which we study.

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RETINOSCOPY.

CHAPTER I.

DEFINITION.—NAMES.—PRINCIPLE AND VALUE OF RETINOSCOPY.—SUGGESTIONS TO THE BEGINNER.

Definition.—Retinoscopy (see preface to the first edition) may be defined as the method of estimating the refraction of an eye by reflecting into it rays of light from a plane or concave mirror, and observing the movement which the retinal illumination makes when tilting the mirror and reflecting the light through the different meridians.

Names.—Shadow test, dioptroscopy, fundus-reflex test, keratoscopy, fantoscopy, pupilloscopy, retinophotoscopy, retinoskiascopy, skiascopy, umbrascopy, koroscopy, etc., are some of the other names given to this method of estimating the refraction, and their number and greater or less inappropriateness have had much to do, no doubt, with keeping retinoscopy in the background of ophthalmology instead of giving it the prominence which it more justly deserved and is now receiving from ophthalmologists in all parts of the world.

The principle of retinoscopy is the finding of the point of reversal (the far-point of a myopic eye), and to do this, if an eye is not already sufficiently myopic, it will be necessary to place in front of it such a lens, or series of lenses, as will bring the emergent rays of light to a focus at a certain definite distance, usually at one meter (see Point of Reversal, Chap. IV).

Value of Retinoscopy.—Those who would criticize retinoscopy because "we see nothing and think nothing of the condition of the fundus," base their criticism apparently on the name retinoscopy, rather than from any great amount of practical experience with the method. While admitting that the ophthalmoscope in front of a well-trained eye will often give a close estimate of the refractive error of the eye under examination, yet only to the few does such skill obtain, and even then there is that uncertainty which does not attach itself to the retinoscope in competent hands. The ophthalmologist who knows how to use the retinoscopic mirror accurately has the advantage of his confrères who are ignorant of the test; it gives him a position decidedly independent of his patient, and puts him above the common level of those who are tied to the trial-lenses and the patient's uncertain answers. Furthermore, when it is remembered that from fifty to eighty per cent. of the patients consulting the ophthalmologist do so for an error of refraction, it is well that he be most capable in this important branch of the subject.

The wonderful advantage of retinoscopy over other methods needs no argument to uphold it; the rapidly increasing number of retinoscopists testify to its merits.

The writer, from his constant use of the mirror, would suggest the following axiom: That, *with an eye otherwise normal except for its refractive error, and being under the influence of a reliable cycloplegic, there is no more accurate objective method of obtaining its exact correction than by retinoscopy.*

Retinoscopy gives the following advantages:

The character of the refraction is quickly diagnosed.

The exact refraction is obtained without questioning the patient.

Little time is required to make the test.

No expensive apparatus is necessarily required.

Its great value can never be overestimated in cases of nystagmus, young children, amblyopia, aphakia, illiterates, and the feeble-minded.

From what has just been written, it must not be under-
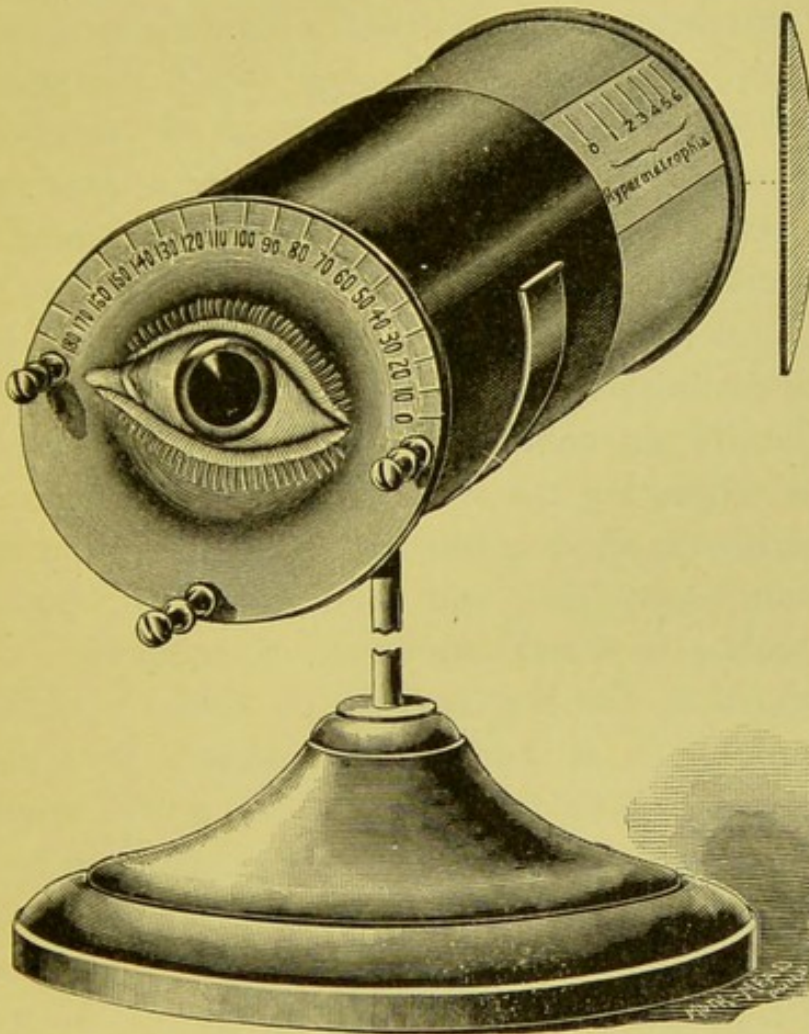
FIG. I.—THE AUTHOR'S SCHEMATIC EYE FOR STUDYING RETINOSCOPY.
(*For description, see Chapt. VI.*)

stood that the patient's glasses are ordered immediately from the findings obtained by retinoscopy; for, on the contrary, all retinoscopic work, like ophthalmometry in general, should, when possible, be confirmed at the trial-case.

It is only in the feeble-minded, in young children, and

in cases of amblyopia that glasses are ordered direct from the findings obtained in the dark room.

The subjective method of placing lenses before the patient's eyes and letting him decide by asking "is this better?" or "is this worse?" only too often fatigues the examiner and worries the patient, giving him or her a dread or fear of inaccuracy that does not satisfy the surgeon or tend to inspire the patient. Whereas, when the neutralizing lenses found by retinoscopy are placed before the patient's eyes and he obtains a visual acuity of $\frac{6}{6}$ or $\frac{20}{20}$ or more, it is easy, if there is any doubt, to hold up a plus and a minus quarter diopter glass respectively in front of this correction, and let the patient tell at once if either glass improves or diminishes the vision.

The writer is not condemning the subjective or other methods of estimating the refraction, nor is he trying to extol too highly the shadow test, yet he would remind those who try retinoscopy, fail, and then ridicule it, that the fault with them is *back* and not in front of the mirror.

Suggestions to the Beginner.—To obtain proficiency in retinoscopy there is much to be understood. Careful attention to details *must* be given, and not a little patience possessed, as it is not a method that is acquired in a day, and it is only after weeks of constant application that accuracy is acquired. Therefore the beginner is strongly advised to learn the major points from one of the many schematic eyes in the market before attempting the human eye. At the same time he should be perfectly familiar with the action of the different cycloplegics and the laws of refraction and dioptrics, as an understanding of conjugate foci is really the underlying principle of the method—*i.e.*, a point on the retina being one focus and the myopic or artificially-made far-point the other focus.

What is meant by major points applies more particularly

to the study of the retinal illumination, its direction and apparent rate of movement when the mirror is tilted, also the form or shape of the illumination, the distance between the observer and the patient, how to handle the mirror, etc., all of which are referred to under their special headings.

CHAPTER II.

RETINOSCOPE. — LIGHT. — LIGHT-SCREEN BRACKET. — DARK ROOM.—SOURCE OF LIGHT AND POSITION OF MIRROR. — OBSERVER AND PATIENT. — LUMINOUS RETINOSCOPE.

The Retinoscope, or Mirror.—Two forms of the plane mirror are in use—the one large, four centimeters in diameter, with a four- or five-millimeter sight-hole often cut through the glass; and the other small, two centimeters in diameter, on a four-centimeter metal disc, with sight-hole two millimeters in diameter, *not* cut through the glass, the quicksilver or plating alone being removed. By thus leaving the glass at the sight-hole, additional reflecting surface is obtained at this point, which assists materially in exact work, as it diminishes the dark central shadow that shows so conspicuously at times, and particularly when the sight-hole is cut through the glass. The small mirror has an advantage over the large by reducing the area of reflected light, as only a one-centimeter area on each side of the sight-hole is of particular use. The small plane mirror[1] is the one recommended, and is made with either a straight or folding handle (see Figs. 2, 3, 4, 18); the latter is for the purpose of protecting the mirror when carried in the pocket. The purpose of the metal disc on which the small mirror is secured is to keep the light out of the observer's eye, and enable him to rest the instrument against the brow and side of the nose; but if its size should appear small, the observer can easily have a larger one made to suit his convenience. The white letters H. C. N.

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[1] *Philadelphia Polyclinic*, November, 1893 Another form is described by Dr. E. Jackson, *American Journal of Ophthalmology*, April, 1896.

on the metal disc are for the patient to look at while the
eye is being examined and the lenses changed before his
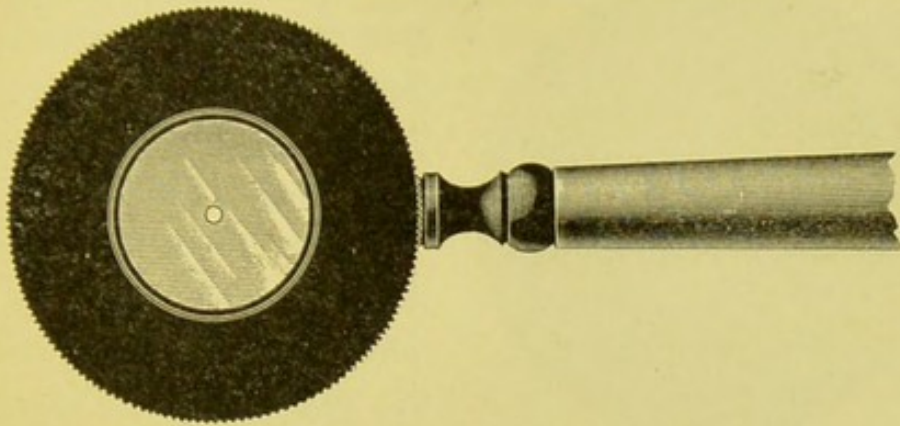
FIG. 2.—THE AUTHOR'S RETINOSCOPE.[1]

eye. The plating or silvering on the mirror should be of
the best, and free from any flaws or imperfections, for on
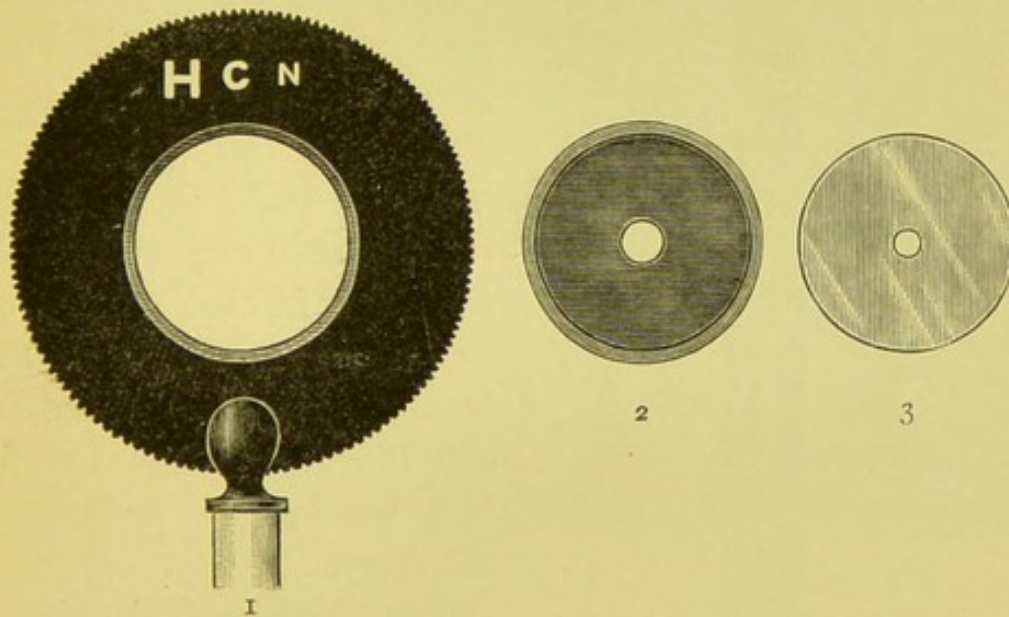
FIG 3.—AUTHOR'S LATEST MODEL RETINOSCOPE. IN THREE PARTS.
(1) Metal Disc and Handle, Straight or Folding; (2) Metal Back for the
Mirror; (3) Plane Mirror with Sight Hole made by removing the Silver-
ing. (See text.)

its quality depends, in part, the good reflecting power of
the mirror, which is very important.

The central shadow just referred to as the result of the
sight-hole had best be seen by the beginner by reflecting

[1] See foot-note on preceding page.

the light from the mirror onto a white surface, before he begins any study, as this dark area may annoy him later if he does not understand its origin. The Author's latest model retinoscope is shown in Fig. 3. This retinoscope comes in three parts, *i.e.*, (1) the metal disc and handle, (3) the plane mirror and (2) the metal back for the mirror. These are put together by placing the mirror (3) on the metal back (2) and then pressing the metal disc into the opening of the large metal disc (1). The purpose of this new model is to supply the oculist with any number of mirrors in case of breakage or defective silvering. The handle (1) can be used indefinitely. Number (2) fits into number (1) with great accuracy.
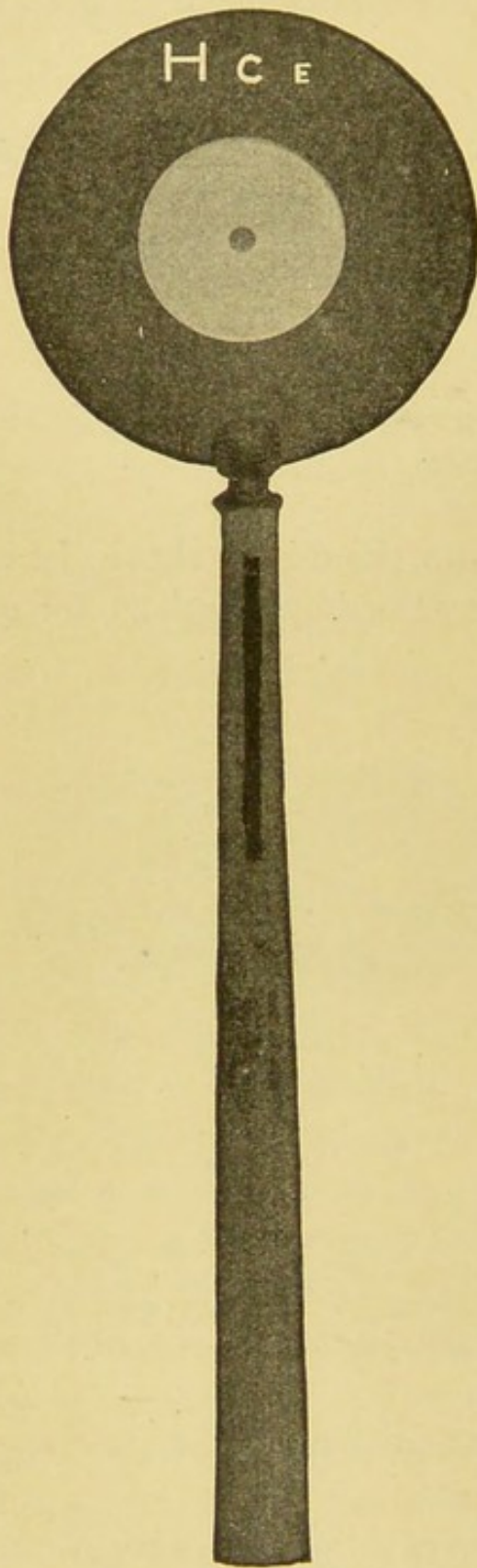
The Light.—This should be steady, clear, and white. The Welsbach possesses all these qualities, but unfortunately its delicate mantle will not stand much jarring, and, as a consequence, is easily broken, causing much

FIG. 4.

loss of time and annoyance. The electric light made with

a twisted carbon and ground-glass covering having a round
center of clear glass is becoming quite popular. For con-
stant service, however, the Argand burner is decidedly
the best, when the asbestos light-screen is used to intercept
the heat. Whatever light is employed, it is well to have
it on an extension bracket, so that the observer may raise
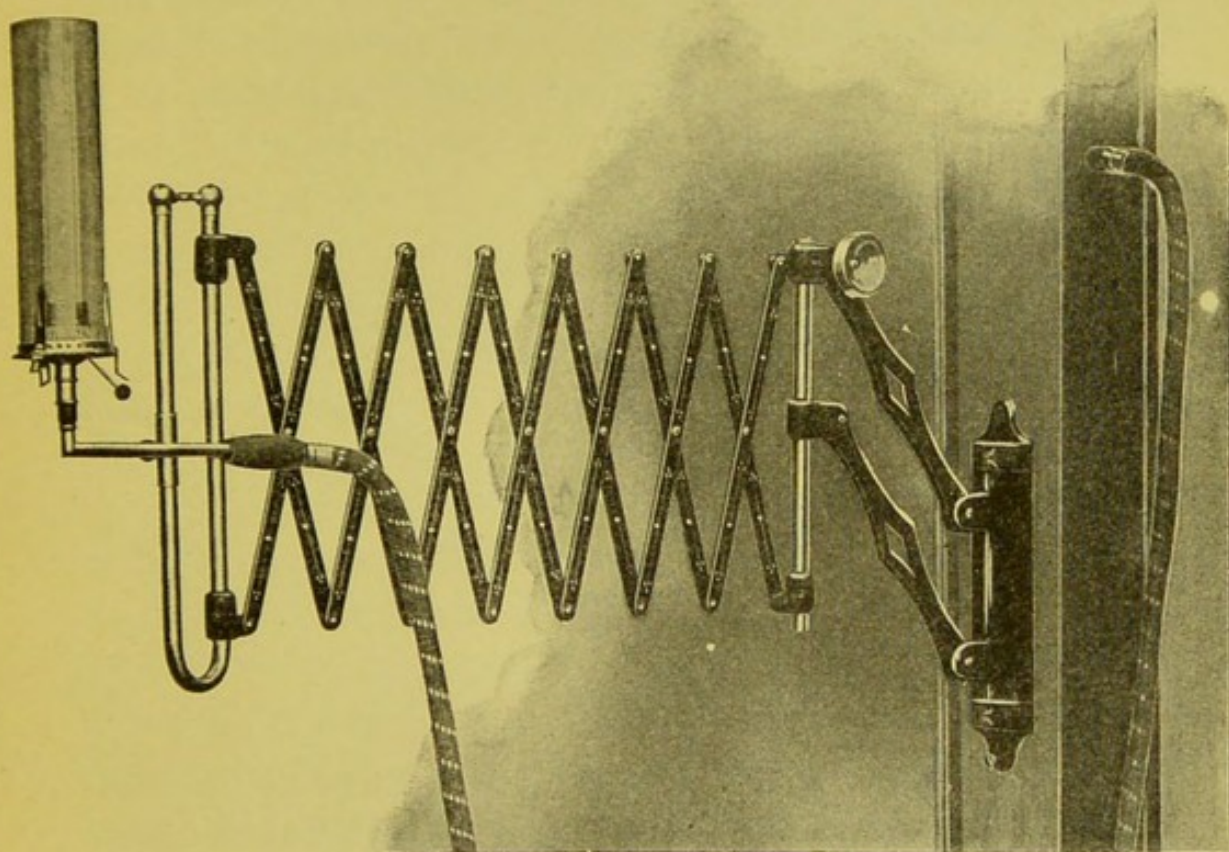
FIG. 5.

or lower it or move it toward or away from the patient,
as necessary (see Fig. 5).

When gas or electric light is not at hand, a student's
oil-lamp, with a suitable light-screen, will answer every
purpose (see Fig. 6).

The light-screen, or cover chimney, is made of one-
eight inch asbestos, and of sufficient size (six centimeters

in diameter by twenty-one in height) to fit over the glass chimney of the Argand burner (see Figs. 7 and 8).

Attached to the screen are two superimposed revolving discs that furnish four round openings, respectively five, ten, twenty, and thirty millimeters, any one of which may be turned into place as occasion may require. Care should be taken that the opening used is placed opposite to the brightest, and never opposite to the edge of the blue part of the flame. Formerly these screens were made of sheet-iron, but the asbestos has been found preferable, as it
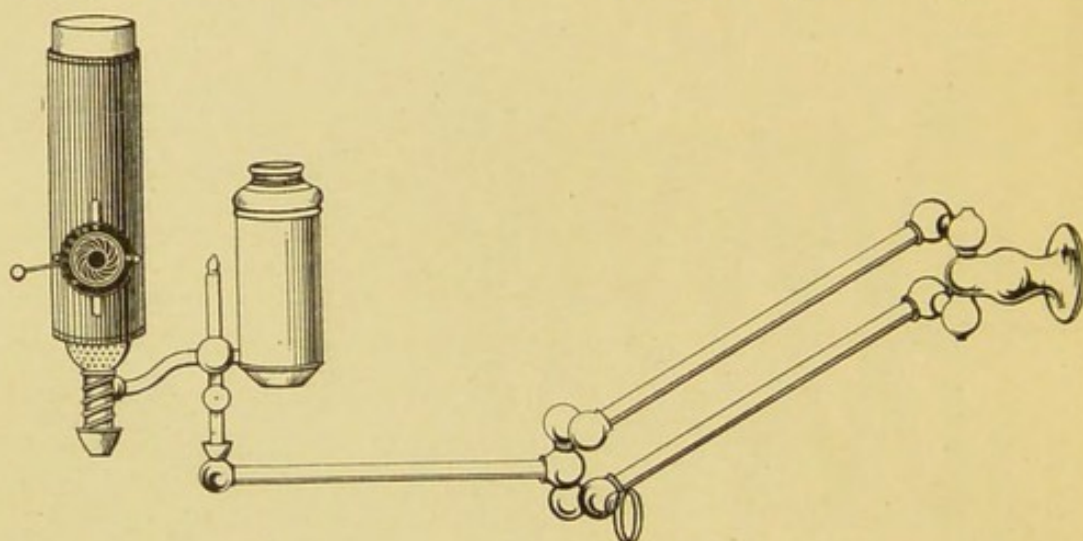
FIG. 6.

does not radiate the heat to the same extent as the iron. The purpose of the light-screen is to cover all of the flame except the portion which presents at the opening in the disc. Figure 8 shows the author's new light-screen, which was described on page 1378 in the "Journal of the American Medical Association," December 3, 1898. This is a more convenient screen for retinoscopy than the one shown in Figure 7. It is made by attaching an iris diaphragm to an asbestos chimney. The amount of light passing through the diaphragm is easily controlled by an ivory-tipped lever at the left hand side; and an index on the periphery records the diameter of the opening in use, from one to thirty millimeters.

Ten-millimeter Opening.—This will be used in most all retinoscopic work by the beginner.

Five-millimeter Opening.—This is used to the best advantage and with no small amount of satisfaction by the expert when working close to the point of reversal.

The room must be darkened—and the darker the better; all other sources of light except the one in use should be excluded. It must not be supposed from this that the room must have its walls and ceiling blackened; on the contrary, if the shades are drawn, the room will be sufficiently dark, though of course a room with walls painted black or draped in black felt would be best, as giving a greater contrast to the condition to be studied. The exclusion of other lights, or beams of light, must be insisted upon, as the principal use of the darkened room is to keep all light except the light in use out of the eye to be examined, and also not to have other lights reflected from the mirror.

As the method of using the concave mirror with source of light (twenty or thirty mm. opening in screen) beyond its principal focus (usually over and beyond the patient's head) has been superseded by the simpler and easier method of using the small plane mirror with source of light (one-half or one cm. opening in light-screen) brought as close to the mirror as possible, the description of retinoscopy which follows will refer to the latter.

The Source of Light and Position of the Mirror.— The rays of light coming out of the round opening in the light-screen should be five or six inches to the left and front of the observer, so that they may pass *in front* of the left eye and fall upon the mirror held before the right, thus leaving the observer's left eye in comparative darkness; or the observer may use the mirror before the left eye in case he is left-handed and has the light to his right. It is always best for the observer to keep both eyes wide open

and to avoid having any light fall into the unused eye, which would cause him much annoyance. Some observers hold the mirror before the eye next to the screen, but this is not recommended, for the reasons just mentioned.

The observer need not make any note of his accommodation, as in using the ophthalmoscope, but, as he requires very acute vision, he should wear any necessary correcting glasses. *Any observer whose vision does not*
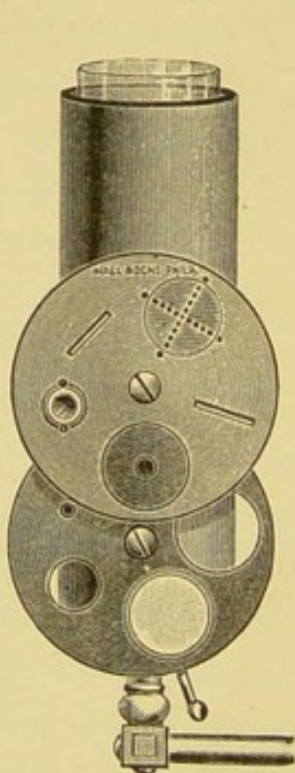
FIG. 7.—THE AUTHOR'S LIGHT-
SCREEN, OR COVER CHIMNEY.
(*For a further description, see Chap. VI.*)
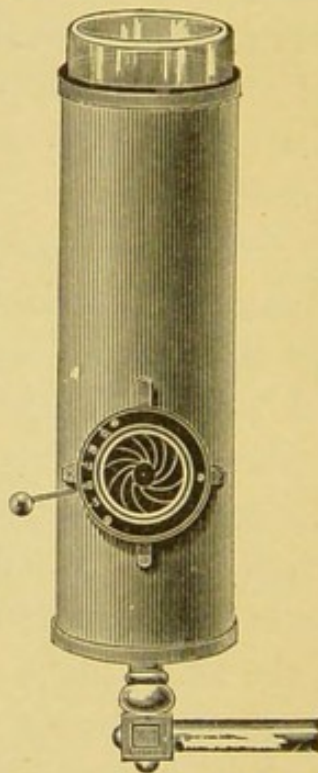
FIG. 8.—THE AUTHOR'S NEW LIGHT-
SCREEN.

approximate $\frac{6}{9}$ in the eye which he uses will not get much satisfaction from retinoscopy.

He should take his seat facing the patient, and, as the strength or brilliancy of the reflected light rapidly weakens as the distance between the mirror and the light-screen is increased, he should have the light-screen close to his face (not farther away than six inches) if he wishes to get the fullest possible strength of light on the mirror.

As the light appears just as far back in the mirror as it is in front of it, then the nearer these two objects are brought together, the more nearly do they become as one. When
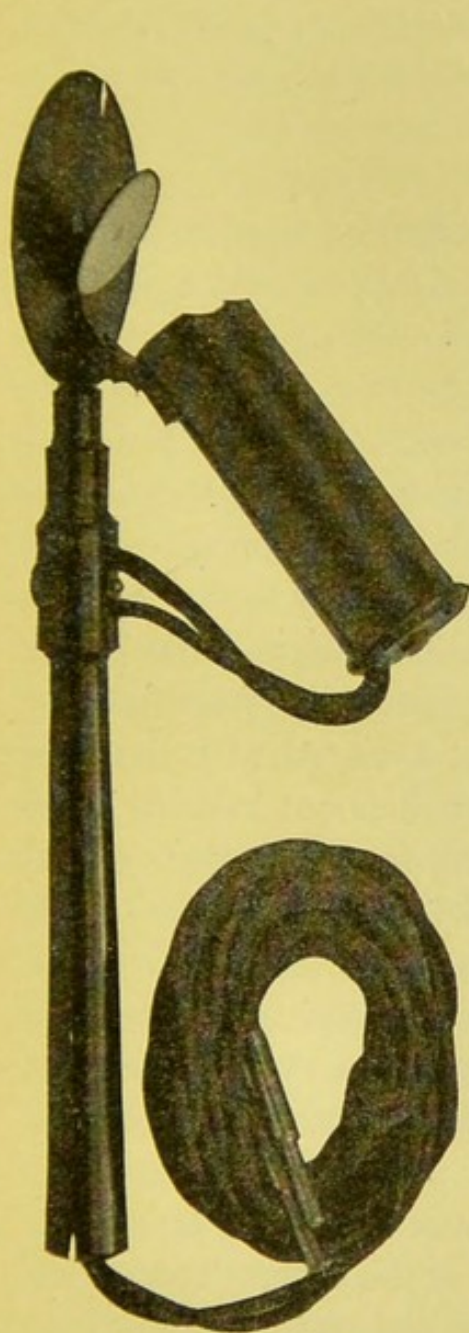
FIG. 9
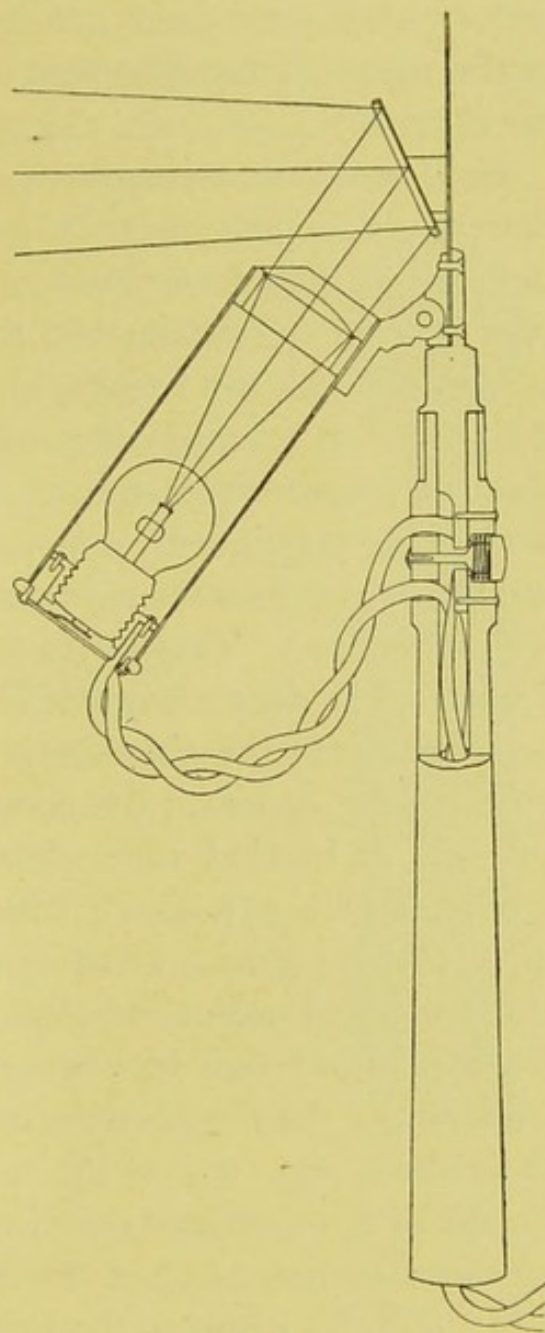
FIG. 10.

working close to the point of reversal, more exact work will be accomplished if this distance between the light and mirror is very short. The nearer together the light and mirror, the brighter the retinal illumination, and greater

contrast, or sharper cut edge between illumination and surrounding shadow. The further the light from the mirror, the dimmer the retinal illumination, and there will appear, under certain conditions, a very conspicuous central shadow as the result of the sight-hole in the mirror—*two very serious objections.*

The Luminous Retinoscope (Figs. 9 and 10). —DeZeng Patent.—This instrument is the author's plane mirror with the electric light attachment. A 5-volt electric light with tiny filament is contained in a tube placed at an angle of 45 degrees with the handle, and the mirror is correspondingly tilted to an angle of 22 degrees. The light from the filament passes divergently to a strong convex lens which renders the rays less divergent as they fall upon the mirror, and from the mirror the rays pass divergently to the patient's eye. (Fig. 10.) This instrument has innumerable points of merit: It does away with any use of gas or lamp or cover chimney; the observer is not annoyed with the heat from the gas or lamp; the observer does not have to move the light or bracket when changing from one distance to another as when working with the gas-light close to the mirror; the electric wires (cords) carrying the current to the filament are of sufficient length to give the observer two meters of space in which to practice the method; the brilliancy of the illumination can be made most intense or diminished very materially with a convenient rheostat; the size of the divergent pencil may be controlled by adjusting the condensing lens at the end of the tube. The writer is in the habit of using the mirror and gas flame until he has obtained an approximate point of reversal and then substitutes the luminous instrument to obtain the more delicate findings; he does this for the reason that if the electric light is used for any great length of time to find the point of reversal a temporary scotoma is produced

that some nervous patients occasionally object to. This luminous instrument will also bring to the notice of the careful observer some fine changes in the lens fibers if present, that he might otherwise overlook.

The DeZeng Ideal Electric Retinoscope (Fig. 11).—This instrument does away with electric wires, therefore giving it portability. The handle is made of aluminum and designed to hold a two-cell battery of regular stock size. This handle is convenient to hold and has a compressible circuit breaker conveniently located for the thumb of the operator. It is arranged for either a touch or a fixing contact, the lamp being lighted either by pressing the extending arm against the handle or swinging it around in contact with the clip on the top of the cap as desired.

The mirror is the author's small plane mirror with sighthole made by removing the silvering only. The Fixation Letters on the disc are those suggested and described in the Author's work "Refraction and How to Refract." These letters are quite cleverly illuminated by the light from the lamp passing through an opening in the tube. Tiny Tungsten lamps are supplied for this retinoscope.

The patient *must have his accommodation thoroughly relaxed with a reliable cycloplegic,* and should be seated comfortably, one meter distant, in front of the observer, with his vision steadily fixed on the observer's forehead, just above the mirror. Or, what is even better, the patient may concentrate his vision on the letters at the edge of the metal disc of the mirror (Figs. 3, 4, 11) or on the observer's forehead, but
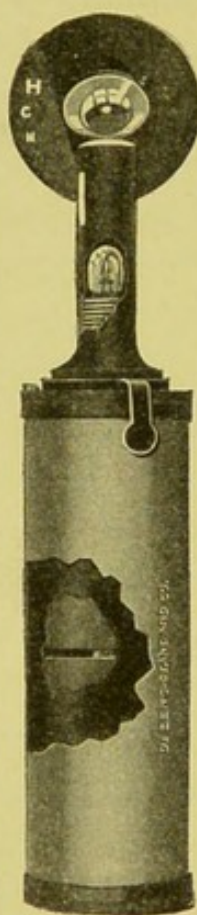
FIG. 11.—
THE DEZENG
IDEAL ELEC-
TRIC RETINO-
SCOPE.

never directly into the mirror, as that would soon irritate and compel him to close his eye.

In this way the patient avoids the strain of looking into the bright reflexed light, and at the same time the *macular region* is refracted (see Fig. 32). It is customary to cover the patient's *other* eye while its fellow is being refracted; for obvious reasons this is specially important in cases of "squint." The axonometer placed before the eye being examined is a decided advantage in any instance (see p. 52 and Fig. 44).

CHAPTER III.

Distance of Surgeon from Patient.—There is no fixed rule for this, and each surgeon may select his own distance. It might be well for the beginner to try different distances and then choose for himself. The writer prefers a one-meter distance, and with few exceptions adheres to it. Some prefer six meters, others two meters, etc. The distance of one meter has important advantages: There is no necessity for getting up to place lenses in front of the patient's eye, as the patient or surgeon, or both, may lean forward for this purpose, if necessary. Another advantage is that at one-meter distance there is a uniform allowance of one diopter in the estimate, which will be explained more fully under Rules for Retinoscopy at One Meter. To get the patient's eye and the observer's forehead just one meter apart, the distance may be marked off on the wall of the dark room on the side where the light is secured (see Fig. 13), or a meter stick for the purpose may be held in the hand of the observer or his assistant.

The method of obtaining the point of reversal at points other than the regulation one meter requires such an amount of extra measuring and computing that it does not meet with the general favor and satisfaction accorded to that found by producing an artificial myopia of one diopter. This can best be explained by reference to Figure
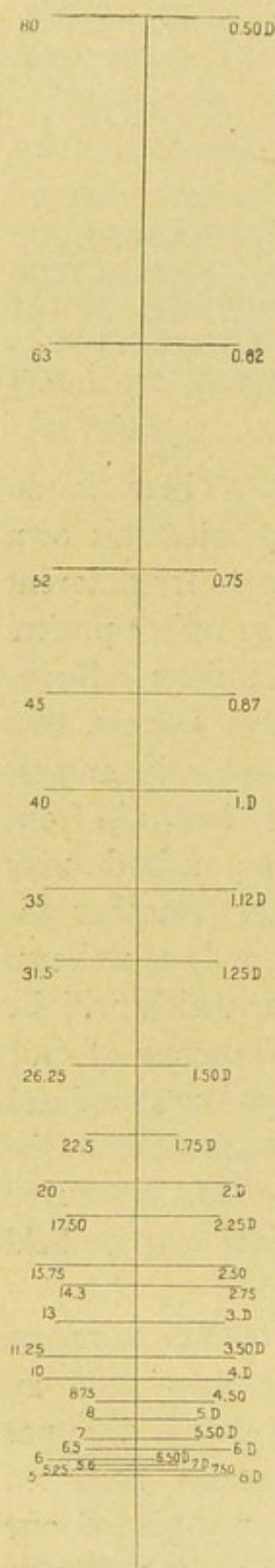
FIG. 12.—SHOWING DISTANCE FROM PATIENT'S EYES IN INCHES AND THE EQUIVALENT IN DIOPTERS.

12, where, if the observer is at one-meter distance, and the neutralizing lens in front of the patient's eye focuses the emergent rays *about* that distance, he may have the liberty of moving forward or back five inches (a play of ten inches) in looking for the point of reversal, and not make a possible error in his result of more than twelve one-hundredths (0.12) of a diopter; *whereas* if he was working closer than this, say at half a meter, and was moved forward or backward five inches to find the point of reversal, he would likely make an error of 0.5 D., or even more, if he was not extremely careful in measuring the distance at which he found the reversal point.

Arrangement of Patient, Light, and Observer.—This has already been described in great part, but reference to the accompanying sketch may give the student a more exact appreciation of the arrangement than any lengthy description could do.

For the convenience of the beginner in using the mirror, it is best, as here shown, to keep the surgeon's eye, the light, and the patient's eye on a horizontal line, and to accomplish this in children they will either have to stand, sit on a high stool, or on the parent's lap. The beginner will find it suffi-

ciently difficult at first to reflect and keep the light on the patient's eye with the mirror held perpendicularly, without inclining it up or down, as he would have to do if the arrangement suggested is not carried out. Placing the light to one side of the patient's head, or above it (Fig. 14), and the observer seated at one-meter distance from the patient, is a convenient way of working retinoscopy. It has
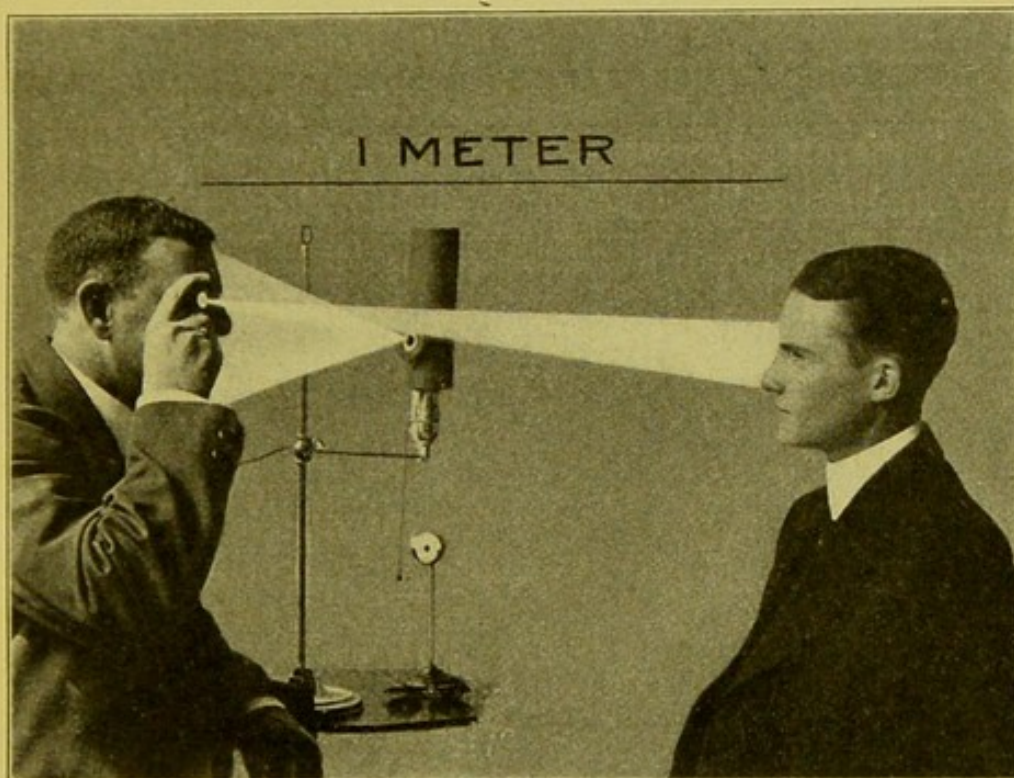
FIG. 13.—ARRANGEMENT OF PATIENT, LIGHT AND OCULIST.

two advantages: the observer avoids the heat of the flame, and at the same time does not have to move the light. But the writer is not partial to this mode of procedure, for various reasons of precision, explained in the text.

Reflection from the Mirror.—The rays of light coming from the round opening in the screen to the p'ane mirror are reflected divergently, as if they came from the opening in the screen situated just as far back in the mirror as they originally started from in front (see Figs. 29, 31 and 33),

and the patient, looking into the mirror, sees a round, bright spot of light, corresponding to the opening in the screen. Fig. 18.

How to Use the Mirror.—It should be held firmly before the right eye (Figs. 15 and 16) so that the sight-hole is opposite to the observer's pupil; and that it may be steady, the second phalanx of the thumb should rest on the cheek
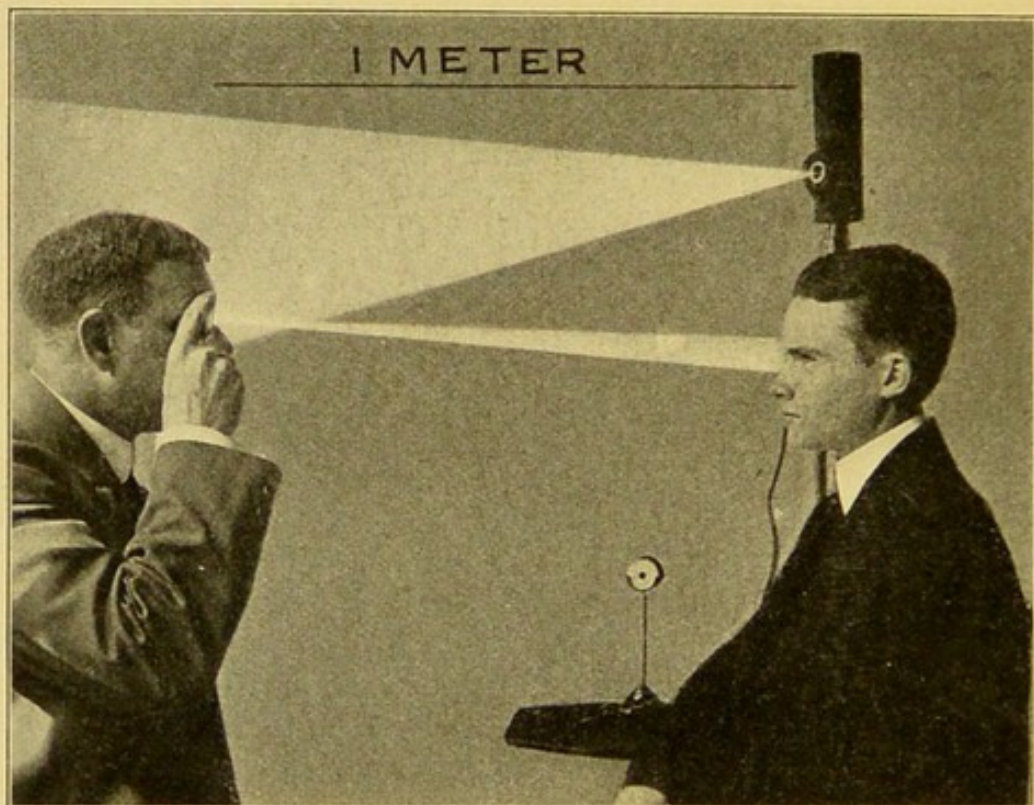
Fig. 14.—Light above Patient's Head and Oculist at One Meter Distance.

just below the eye, the edge of the metal d'sc even touching the side of the nose if the observer's interpupillary distance is not too great. Thus held in position, its movements should be very limited, though they may be slow or quick, but *never*, at any time, should it be tilted more than one, two, or even three millimeters; for if inclined *more* than this the light is lost from the pat'ent's eye. If the light, the patient's, and the observer's eyes are on a horizontal line,

then to find the patient's eye with the reflected light all the observer has to do is to reflect the light back into the light-screen, and by rotating the mirror to his right, carry the reflected light around on the same horizontal line until the patient's eye is reached. This may seem like a super-abundance of instruction, but the finding of the patient's
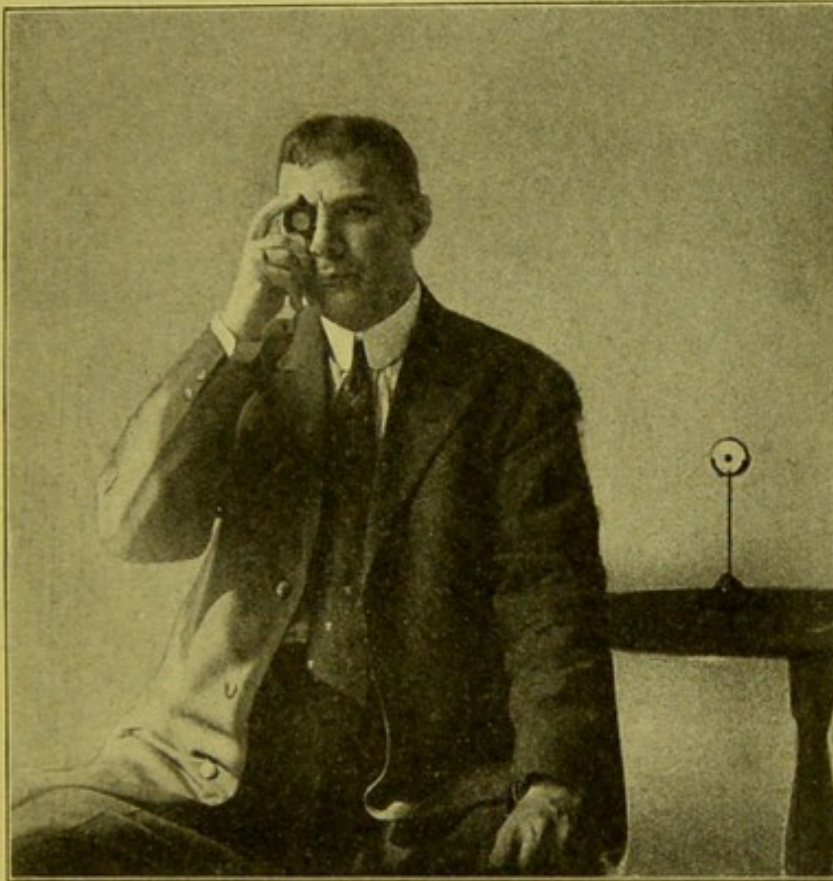
FIG. 15.—MIRROR HELD CORRECTLY BEFORE RIGHT EYE AND OCULIST KEEPS BOTH EYES OPEN.

eye, which appears so easy, is an immense stumbling-block, at the beginning, to most students. Another way to find the eye is for the observer to hold his left hand up between his and the patient's eye and reflect the light on to it, and when this is done to drop his hand and let the light pass into the observed eye. Having succeeded in finding the patient's eye, the observer, if he is not very careful in his limited

movements of the mirror and himself, will turn the light
from the eye almost before he knows it, and so be compelled
to start and find it again; this causes much loss of time.   A
little practice on the schematic eye will assist the beginner
wonderfully and give him courage, for if he hastens to the
human eye, and then has to stop every minute or so to try
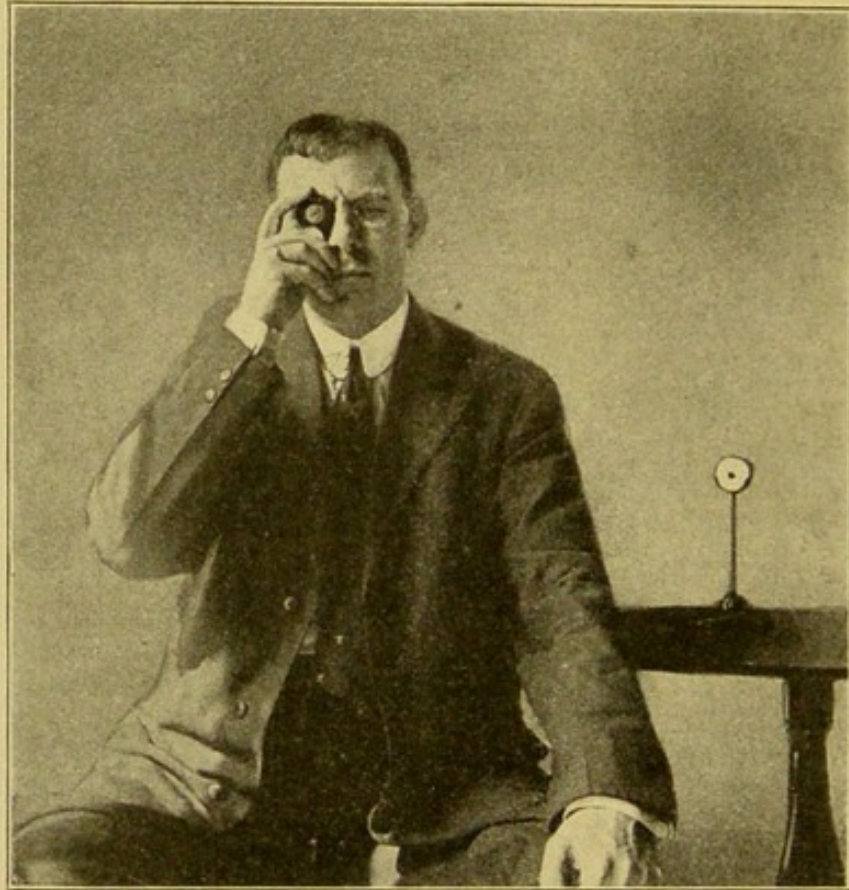
Fig. 16.—Correct Position for Mirror but there is no Necessity
for the Oculist to Squeeze the Left Eye Shut after having Lo-
cated the Patient's Eye.

and get the light on the eye, he soon becomes discouraged
and shows his want of experience to the patient.

What the Observer Sees or the General Appearance
of the Reflection from the Eye.—With the mirror held before
his eye, and close up to the bright light coming from the
ten-millimeter opening in the light-screen, the observer
will obtain a reflection from the pupillary area of the

patient's eye which varies in different patients, and is subject to certain changes in the same patient as the refraction is altered by correcting lenses, or it may be changed by the turning of the patient's eye, or lengthening the distance between the mirror and the light, or increasing or diminishing the strength of the light, or increasing the
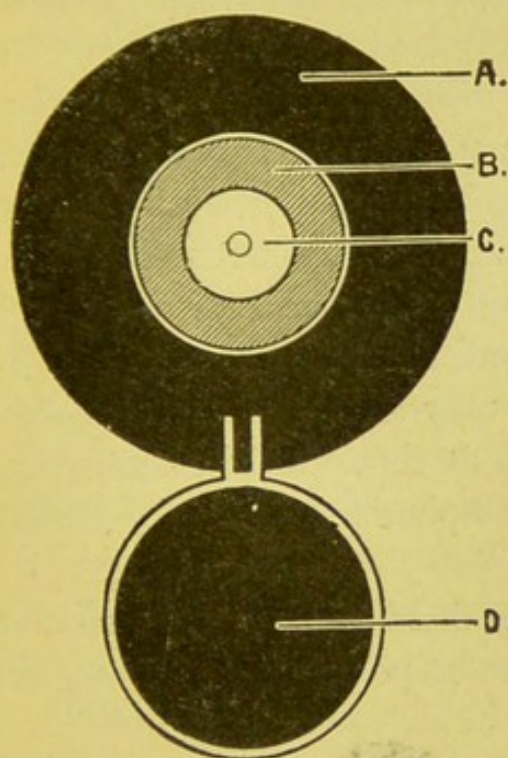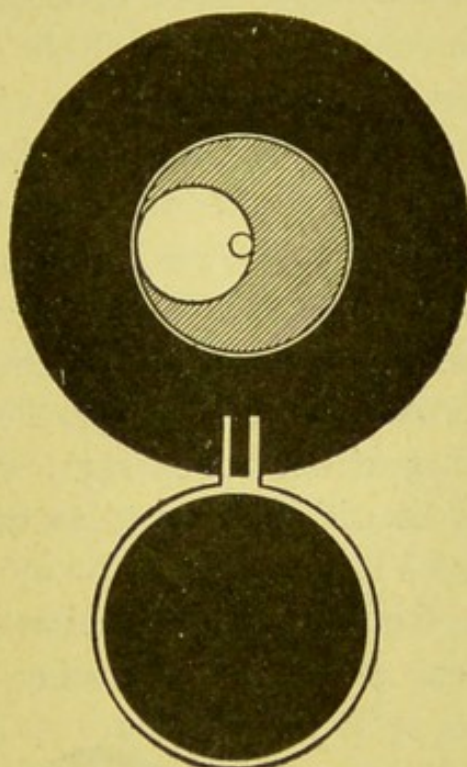
FIG. 17.   · FIG. 18.

AUTHOR'S MIRROR WITH FOLDING HANDLE.

FIG. 17.—Showing central light C, on small mirror B. This is the light the patient sees when looking into the mirror, and corresponds in size to the one-centimeter opening in screen. D is the folding cap handle to protect B when not in use. A is the metal disc.

FIG. 18.—Shows the light moved to one side as a result of tilting the mirror.

distance between the observer and the patient. The reflection from the eye of the albino or blond is much brighter than from the brunette or mulatto, in whom it is not so bright, even dim. This character of the reflex is controlled, of course, in great part by the amount of pigment in the eye ground; however, in most instances, there is more or less of a yellowish-red color to the reflex, and this

is especially so as the point of reversal is approached; at the point of reversal, however, the reflex becomes less brilliant and possesses something of the color of a piece of newly coined silver. Cases of high errors of refraction give a dull reflex (see Fig. 27) as compared to low errors, where the reflex is usually *very* bright (see Fig. 19). Should the media be irregular or not perfectly clear, the reflex is altered accordingly; this will be referred to under the head of Irregular Astigmatism. The observer will also notice on the cornea and lens bright pin-point catoptric images, and at the inner edge of the iris, in many eyes, a very bright ring of light (see Fig. 19) about one millimeter in width, which is due to the very strong peripheral refraction; and as the eye is being refracted and the point of reversal approached, this peripheral ring may develop into a broader ring of aberration rays, which at times will be annoying. This will be referred to under Spheric Aberration, Chapter VI.

Retinal Illumination.—By holding a strong convex lens closer to or further from a plane surface than its

FIG. 19.   FIG. 20.

FIG. 19.—UNIFORM ILLUMINATION IN AN EMMETROPIC EYE WITH SLIGHT SPHERIC ABERRATION.

FIG. 20.—UNIFORM ILLUMINATION AS IN FIG. 13, PASSED TO THE LEFT BY ROTATING THE MIRROR, DARKNESS OR SHADOW FOLLOWING.

principal focus, or at the distance of its principal focus, and letting the sun's rays pass through it, there will be seen on the plane surface a round area of light; it is this light area which corresponds to the illumination on the retina, seen in retinoscopy by reflecting the light from the mirror

into the patient's eye, and hence it is spoken of as the retinal illumination, the "illuminated area," "the area of light," "the image," etc.

Of course, the form of this illumination is controlled, in great part, by the refraction of the patient's eye.

Shadow.—This is the non-illuminated portion of the retina immediately surrounding the illumination. The retinal illumination and shadow are, therefore, in contact, and the contrast is most marked and easily recognized when the refractive error is a moderately high one, two or three diopters. It is by this combination of the illumination and non-illumination (shadow) that we study and give the "shadow test" its name. In the dark room, the patient keeping his eye fixed, the retina is stationary and in total darkness, except the portion illuminated by the light from the mirror (see Fig. 19). If the mirror be tilted the retinal illumination changes its place (see Fig. 20) and darkness, or shadow, appears in its stead. It is by this change of shadow (darkness) for illumination that we often speak of a movement of the shadow.

Where to Look and What to Look For.—With the patient, the observer, and the source of light in position as directed, the rays of light are reflected into the eye from the mirror as it is gently tilted in various meridians, and the (1) *form*, (2) *direction, and* (3) *rate of movement* of the retinal illumination are carefully noted through a four- or five-millimeter area *at the apex of the cornea*, as *this* is the part of the refractive media in the normal eye that the patient will use *when* the effects of the cycloplegic pass away and the pupil regains its normal size.

The one- or two-millimeter area at the edge of the pupil should be avoided by the beginner, except in special instances, as only too frequently it contains a bright ring of light which may or may not give a stronger refraction than

the 4-millimeter area about the apex of the cornea (see Spheric Aberration, Chap. VI).

The beginner will do good work with the retinoscope if he observes closely the illumination at the center of the pupil and *avoids* looking for shadows.

CHAPTER IV.

**POINT OF REVERSAL.—TO FIND THE POINT OF REVER-
SAL.—WHAT TO AVOID.—DIRECTION OF MOVEMENT
OF RETINAL ILLUMINATION.—RATE OF MOVEMENT
AND FORM OF ILLUMINATION.—RULES FOR LENSES.
—MOVEMENT OF MIRROR AND APPARATUS.**

Point of Reversal.—This may be defined in several
ways—namely: It is the far-point of a myopic eye, or

The artificial focal point of the emergent rays of light
(Fig. 30), or

The point where the emergent rays cease to converge
and commence to diverge, or

The point conjugate to a point on the retina (Fig. 34), or

The point where the erect image ceases and the inverted
image begins, or

The point distant from the eye under examination, where
the retinal illumination cannot be seen to move, when
the mirror is being tilted.

The point of magnification.

To Find the Point of Reversal.—The recognition of
the point of reversal is *the principle* of retinoscopy. It
is what is sought for, and, when obtained under certain
definite arrangements, is the correct solution of the test.
During the test it is easy to tell when the illumination
moves with or opposite to the movement of the light on
the face, but to get the exact point where there is no apparent
movement is not always easy, and the ability to quickly
find this point of reversal is only acquired after careful
practice.

For example, having determined at one meter that the
retinal illumination with a $+ 1.50$ D. in front of the observed

eye just moves with the light on the face, and against with a +1.75 D., we know that the reversal point must be obtained with the lens numbered between the strength of these two lenses, *i.e.*, +1.62 D. This demonstrates how we arrive at the exact correction, and also the capability and accuracy of retinoscopy.

Emmetropic and hyperopic eyes, in a state of rest, emit parallel and divergent rays, respectively, and to give such eyes a point of reversal, or a focus for the emergent rays, it will be necessary to intercept these rays with a convex lens as they leave the eye. In other words, emmetropic and hyperopic eyes must be made (artificially) myopic. In myopic eyes, however, the emergent rays always focus at some point inside of infinity, and the observer may, therefore, if he is so disposed, by moving his light and mirror toward or away from the patient's eye, as the case may be, find a point where the retinal illumination ceases to move. If this should be at two meters, the patient would have a myopia of 0.50 D.; if at four meters, a myopia of 0.25 D.; if at one meter, a myopia of one diopter, if at half a meter, a myopia of two diopters, if at ten inches, a myopia of four diopters, etc.

It is well for the beginner to remember, when using the plane mirror, that the illumination *on the patient's face always moves in the same direction the mirror is tilted*, but *not* necessarily so in the pupillary area, where it may appear to move opposite; and *here* it is that we speak of the retinal illumination moving with or against (opposite to) the movement of the mirror, as the case may be, and make our diagnosis accordingly.

As the rays of light from the mirror proceed divergently to the patient's eye, as if they came from a point back in the mirror equal to the distance of the light (opening in light-screen) in front of it and working at one metre's

distance, with source of light five inches in front of the mirror, the rays appear to emerge from a point five inches back of the mirror, or a total distance of 45 inches from the patient's eye, thus giving the rays of light a divergence equal to 0.87 of a diopter before they reach the patient's eye, and this point may be made conjugate to the retina. The observer will do good work if he reduces the retinal illumination to the utmost limit where it can be faintly seen moving with the movement of the mirror, and *if* this is done, the observer's eye and mirror will be just inside of the point of reversal where the erect image can still be recognized. In doing this, however, he must allow 0.87 in his estimate and not 1.00 D.

At the point of reversal no definite movement of the retinal illumination is made out and the pupillary area is seen to be uniformly illuminated, but not so brilliantly as when within or beyond the point of reversal.

If the observer's eye is, at this point, exactly conjugate to the retina, then the movement of the reflected light on the retina cannot be perceived (though it does move), and the retinal illumination will occupy the entire pupil and the shadow will be absent.

Instead, however, of reducing the retinal illumination to the utmost limit (as just mentioned), where it can be faintly seen moving with the movement of the mirror, the writer prefers and recommends placing before the eye under examination such a lens or series of lenses that will bring the emergent rays of light to a focus on his own retina, so that no movement of the retinal illumination can be recognized.

When the point of reversal is approached, the uniform color of the retinal illumination occupies so much of the pupillary area that the student may think he has reached the point of reversal, and if he is not careful to pass the

retinal illumination slowly across the pupil and get the shadow, he will find his result deficient, and possibly may also fail to recognize or may miss seeing some small amount of astigmatism.

To make sure that the point of reversal has been obtained, it is always best, especially for the beginner, to keep putting on stronger neutralizing lenses until he gets a *reversal* of movement, when he knows at once that the point of focus of the emergent rays has passed in between the mirror and eye under examination.

The lenses which control the rays of light emerging from the patient's eye are spoken of as neutralizing lenses.

What to Avoid.—It occasionally happens that a retinal vessel or vessels or a remnant of a hyaloid artery, if present, or even the nerve head, may be seen when the light is reflected into the eye; if so, they are to be ignored, as they are not parts of the test. If the patient's eye is turned, or the rays from the mirror fall obliquely, or the neutralizing lens in front of the eye is inclined instead of being perpendicular, there will be seen reflections of light and images upon the neutralizing lens or cornea, or both, and, in consequence, the retinal illumination is more or less hidden or obscured; these images and reflections can be easily corrected by removing the cause. The catoptric images cannot be removed, but as they are very small, the beginner soon learns to ignore them. The retinal illumination may occasionally contain a small dark center, which will disturb the beginner unless he remembers that it is caused by the sight-hole in the mirror, and is most likely to occur when the sight-hole is large and cut through the mirror. This same dark center in the illumination is also seen at times when the light is removed some distance from the mirror, and the correcting lens almost neutralizes the refraction. The neutralizing lens should never be so

close to the eye that the lashes touch, and, in warm weather especially, moisture from the patient's face may condense on the trial-lens, and temporarily, until it is removed, obscure the reflex.

Retinoscopy with a Plane Mirror at One Meter's Distance and Source of Light Close to the Mirror.— Direction of Movement of Retinal Illumination.— Apparent Rate of Movement and Form of Illumination. —These important points in reference to the retinal illumination should be decided promptly and without any prolonged examination. This proficiency, of course, will only come by practice, and if, on first examination, the observer cannot decide whether the retinal illumination is moving with or opposite to the movement of the reflected light on the face, he may approach the eye until this point is determined. At the distance of one meter the three important essentials may be stated in the following order and in the form of rules:

Direction of Movement of Retinal Illumination.— The recognition of the direction that the retinal illumination takes when tilting the mirror is a most important point in the study of retinoscopy.

The movement of the retinal illumination, when rotating the mirror, going *with* the movement of the light on the patient's face, signifies emmetropia, hyperopia, or myopia, if the myopia is *less* than one diopter.

The apparent movement of the retinal illumination going *opposite* to the movement of the light on the face always signifies myopia of *more* than one diopter.

Rate of Movement.—This, of course, is under the control and is influenced in great part by the rate of movement of the mirror itself; yet after a little practice the observer will recognize the fact that there is a certain slowness in the apparent rate of movement of the illumi-

nation when the refractive error is a high one and requires
a strong lens for its neutralization, whereas when the ret-
inal illumination appears to move fast, the refractive error
is bu slight, and requires a weak lens for its correction.

Form of Illumination.—A large, round illumination,
while it *may* signify hyperopia or myopia alone, yet it
does not preclude astigmatism in combination.

When the illumination appears to move *faster* in one
meridian than the meridian at right angles to it, astig-
matism will be in the meridian of *slow* movement. If the
retinal illumination is a band of light extending across
the pupil, it signifies astigmatism.

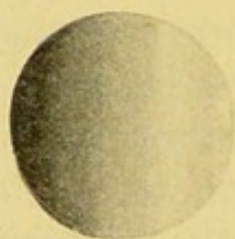The width of the band of light does not indicate so

FIG. 21.—STRAIGHT EDGE, INDICAT- FIG. 22.—CRESCENT EDGE, INDICAT-
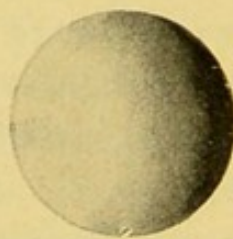   ING ASTIGMATISM.   ING SPHERIC CORRECTION.

much the strength of the correcting cylinder required for
its neutralization as does the apparent rate of movement·
if slow, a strong, if fast, a weak, cylinder is required.

The meridian subtended by the band of light that is seen
when a spheric lens of one diopter or more corrects one meri-
dian and the meridian at right angles remains partly cor-
rected, indicates the axis of the cylinder in the prescription.

Rules for Placing Neutralizing Lenses.—A *plus* lens
is required when the retinal illumination moves *with* the
illumination on the face, and a *minus* lens is required when
it moves *opposite* to the light on the face.

Movement of the Mirror.—There are times when
a quick movement of the mirror, and, at other times, a slow

or gradual movement is required. A substitution of the quick when the slow movement is necessary, then the refraction cannot always be accurately determined. This is explained under "slow movement."

A quick movement of the mirror may be used when looking into the eye before any correcting lens has been placed *in situ*. It often tells the character of the refraction.

The slow movement of the mirror and the five-millimeter opening in light-screen come into use and are of the *utmost* importance when the eye has been corrected to within 0.75 D. or less, as it is generally at this point that so many, by a *quick* movement, hasten the peripheral rays and mask the central illumination, giving the idea at once of over-correction (see Spheric Aberration, Chap. VI). This is a most common error with the beginner, the inexperienced, and with those who fail to get good results and who ridicule retinoscopy as "not exact," or as "not agreeing with the subjective method." It is well in *every* instance, when the point of reversal is approached, to pass the retinal illumination (not the light area on the face) well across the pupillary area to make *sure* in regard to the character of shadow which follows or precedes it. This movement, at such

Fig. 23.—Würde-mann's Disc.

a point in neutralization, will often give a hint as to the presence of astigmatism or not, as a reference to Figures 21 and 22 will show. The presence of astigmatism is known by the straight edge of the illumination, or, in its place, a crescent edge would mean a spheric correction.
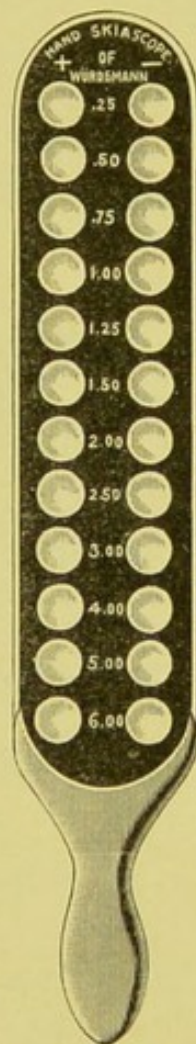
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Apparatus for Placing Lenses in Front of the Patient's Eye.—There are several different forms in the market, their purpose being twofold—to save time and any extra movements on the part of the surgeon. Of these, that of Würdemann (*American Journal of Ophthalmology*, p. 223, 1891) seems the best hand skiascope. A reference to the sketch (Fig. 23) shows this instrument with its convenient handle
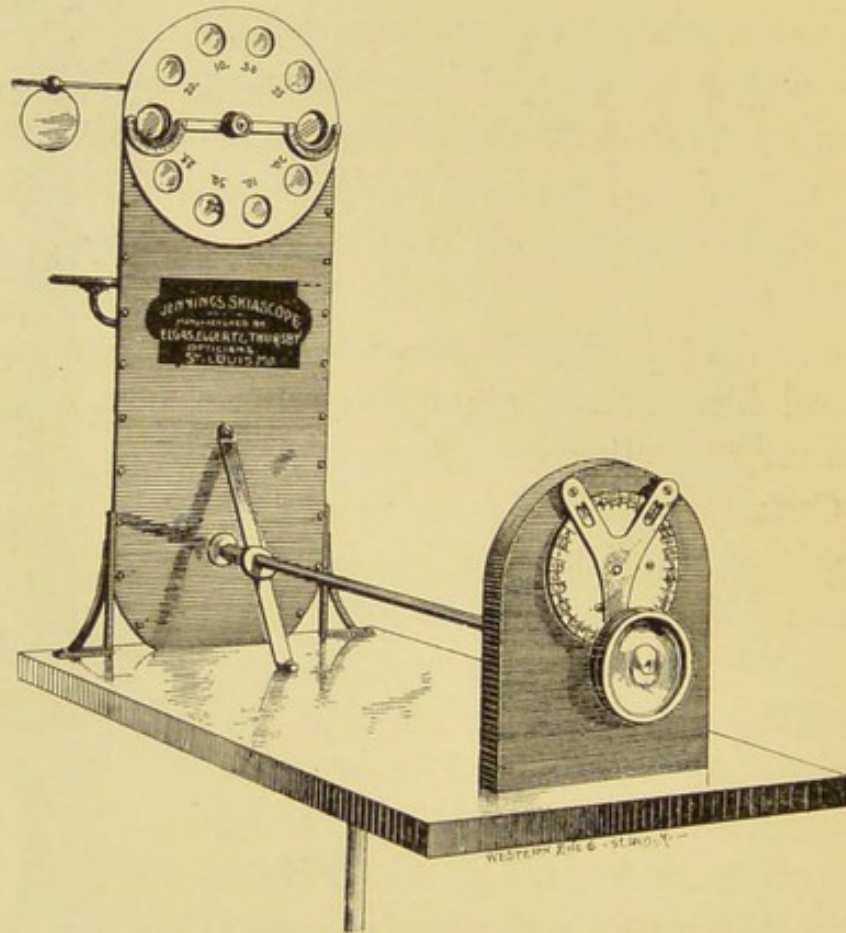

FIG. 24.—JENNINGS' SKIASCOPIC DISC.

wherewith the patient, being instructed, raises or lowers the disc in front of the eye, with its smooth broad edge resting against the side of the nose.

One column contains plus and the other minus lenses, and as it is reversible, these may be placed in front of the eye, as the surgeon directs.

The most modern and complete revolving skiascopic

disc is that of Jennings (Fig. 24) (*American Journal of Oph-thalmology*, November, 1896, and April, 1899), and may be best understood from his own description: "It consists of an upright metal frame, 18 inches high and 7 inches wide, placed at the end of a table 26 1/2 inches long and 12 inches wide. In the upright frame is an endless groove containing 39 lenses and 1 open cell. At the lower end of the frame is a strong driving wheel connected with a hori-zontal rod running the length of the table to a handle with which the operator rotates the lenses. Facing the operator and close to his hand is a large disc, on which is indicated
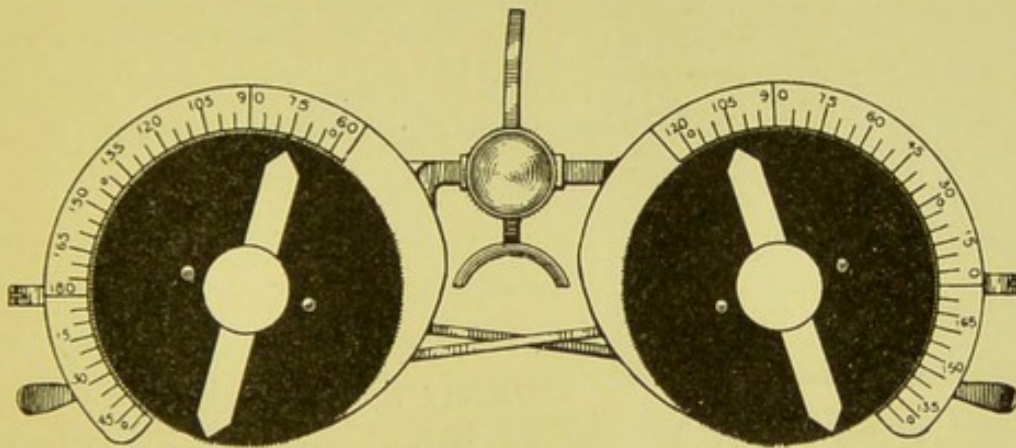

FIG. 25.—AUTHOR'S TRIAL-FRAME WITH AXONOMETERS ATTACHED.
(*Drawing reduced in size.*)

the strength of the lens presenting at the sight-hole. The white numbers on a black ground represent convex, and the black numbers on the white ground concave, lenses. The lenses range from 0.25 D. to 9 D. plus, and from 0.25 D. to 9 D. minus. The sight-holes are 7/8 of an inch in diameter, and are placed about five inches from the top of the upright frame. In front of each sight-hole is a cell marked in degrees to hold stronger spheres or cy inders. The central portion of the upright is cut away, leaving a space for the face of the patient. A movable blinder is hung from the top, while the chin-rest moves up and down

on two parallel rods and is held in place by a thumb-screw. The whole is mounted on a strong adjustable stand, which is raised or lowered by means of a rack and pinion." The essential advantages of this skiascope are as follows:

1. It saves time and fatigue in changing lenses.

2. It is *under the immediate control of the operator*, and indicates the lens in front of the sight-hole without his getting up.

3. The mechanism is simple, durable, and easy to operate.

4. The cornea is accurately centered and the lens perpendicular to the front of the eye (a very important consideration, and one not possible with *every* kind of trial frame).
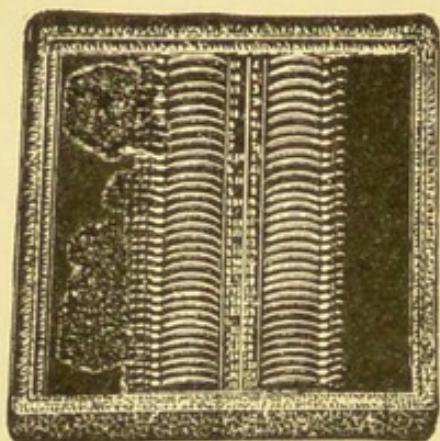
5. The instrument is of such length that the operator is always one meter distant from the patient.

FIG. 26.—AUTHOR'S TRIAL-CASE FOR RETINOSCOPY.

While either the hand or the revolving disc is recommended, yet the writer is partial to an accurately fitting trial frame (Fig. 25), using the lenses from the trail-case, which should be conveniently at hand. The following suggestions in the selection and use of the trial-frame are offered: The temples should rest easily on the ears, the nose-piece (bridge) to have a sufficiently long post to permit the eye-pieces to fit high and accurately over any pair of eyes, especially those of children, and have the cornea occupy the center of each eye-piece. Correct results cannot be expected or quickly obtained unless the neutralizing lenses be placed with their centers corresponding to corneal centers, and at the same time perpendicular to the front of the eye. A convenient and small trial-case containing a row of plus and minus spheres, from 0.12 to 10 D., is shown in Figure 26.

CHAPTER V.

RETINOSCOPY IN EMMETROPIA AND THE VARIOUS FORMS OF REGULAR AMETROPIA.—AXONOMETER.

Hyperopia.—In this variety of refraction the direction of the movement of the retinal illumination is *with* the movement of the light on the patient's face. By reflecting the light through the various meridians and observing the rate of movement, a strong or weak plus sphere, according to

FIG. 27.   FIG. 28.

FIG. 27.—GRAY REFLEX AS SEEN IN HIGH HYPEROPIA, EVEN DARKER THAN THE PICTURE SHOWS IT.

FIG. 28.—GRAY REFLEX, WITH CRESCENT EDGE BY TILTING MIRROR TO LEFT, DARKNESS OR SHADOW FOLLOWING.

the apparent rate of movement, is placed before the eye, and the rate of movement of the retinal illumination is again noted.

Practice alone will guide the observer in a quick appreciation of the approximate strength of neutralizing lens to thus employ.

If the movement of the illumination appears slow, and the observer places a $+2.75$ D. before the eye for its neutralization, and the illumination then becomes brilliant and appears to move fast and with the light on the face, the hyperopia is still slightly uncorrected and a stonger lens must be substituted. (At this point in the examination the

37

five-millimeter opening in the light-screen may be used to advantage.)

Removing the $+2.75$ D. and substituting a $+3.25$ D., if the retinal illumination is then found to move *opposite* to the movement of the light on the face, the refraction of the eye will then be represented by the lens numbered between the $+2.75$ D. and the 3.25 D., which is 3 D. (See example, p. 28, Chap. IV). Now, while the $+3$ D. has brought the emergent rays to a focus at one meter, it has made the eye myopic just one diopter, so that in taking the patient from the dark room to test his vision at six meters, or infinity, this one diopter (artificial myopia) must be subtracted from
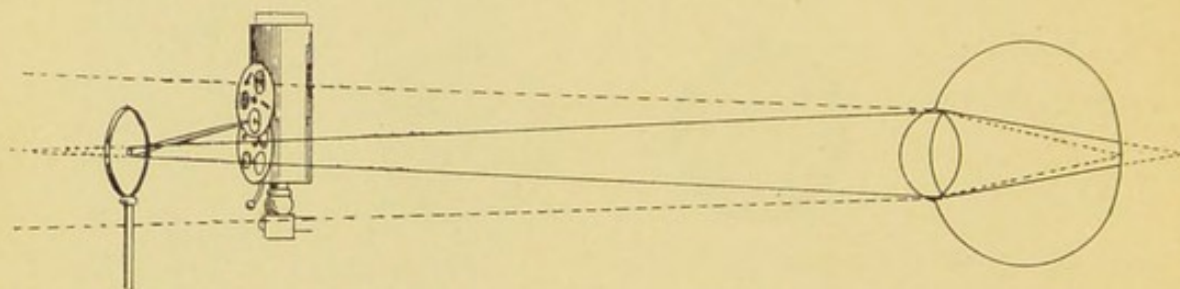
FIG. 29.

the $+3$ D., which would leave $+2$ D., the amount of the hyperopia.

A reference to Figure 30 will illustrate the description just given.

Figure 29 is the hyperopic eye under examination, and shows the mirror at one meter's distance, with the light five inches from the mirror. The dotted lines represent the rays proceeding divergently from the eye under examination; the dark lines show the reflected rays from the mirror, which illuminate the retina and have an imaginary focus (dotted lines) beyond the retina.

Figure 30 is a profile view showing the hyperopic eye with neutralizing lens in position. The dotted lines with arrow-heads indicate the direction the rays would naturally

take coming from the eye. The lens (+ 3 D.) in front of the eye is just sufficiently strong to bend these divergent rays and bring them to a focus at one meter's distance (artificial point of reversal). In other words, + 2 D. of the three diopters thus placed before this hyperopic eye would have bent the divergent rays and made them parallel, or emmetropic, but the additional one diopter bends the rays still more and brings them to a focus (P. R., point of reversal) at one meter. If, now, with the + 3 D. before the eye, the observer approaches the eye thus refracted and observes the retinal illumination closer than one meter, he will be inside of the point of reversal, and consequently
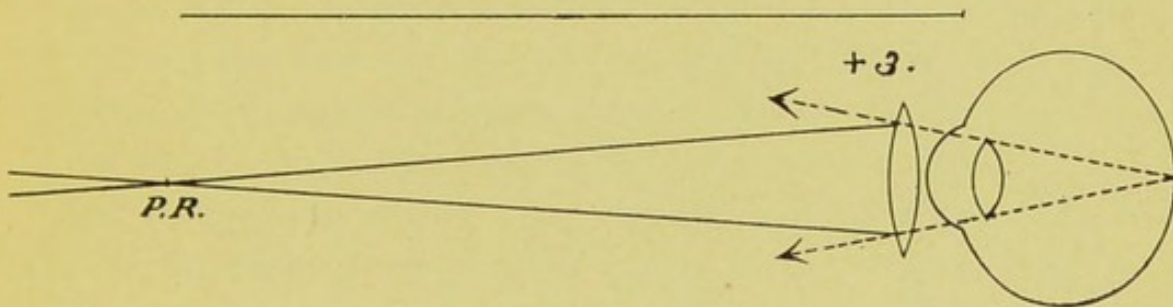
FIG. 30.

see an erect image moving rapidly with the direction of the movement of the mirror. If beyond this point of reversal (P. R.), he would get an inverted image and the retinal illumination moving rapidly in a direction opposite to the movement of the mirror.

Emmetropia.—The emergent rays from an emmetropic eye are always parallel, and the observer seated at one meter sees the pupillary area in such an eye brilliantly illuminated, the illumination moving rapidly with the light on the face as the mirror is slowly tilted.

A reference to Figure 31 shows the emmetropic eye under examination with the position of light, mirror, and eye, as in Figure 29. The dotted lines indicate the parallel emergent rays, and the solid lines the divergent rays from

the mirror with an imaginary focus just beyond the retina.
The purpose is this instance, as in all others of retinoscopy,
is to place such a neutralizing lens before the eye as will
bend the emergent rays and bring them to a focus at a
certain definite distance, making the emergent rays from
a point on the retina come to a focus on the observer's
retina.   Therefore, to change this illumination so that no
movement can be seen to take place in the pupillary area,
and at the same time have the emergent rays focus on the
observer's retina, a $+1$ sphere must be placed before the
eye.

Just here the writer wishes to *impress* upon the beginner
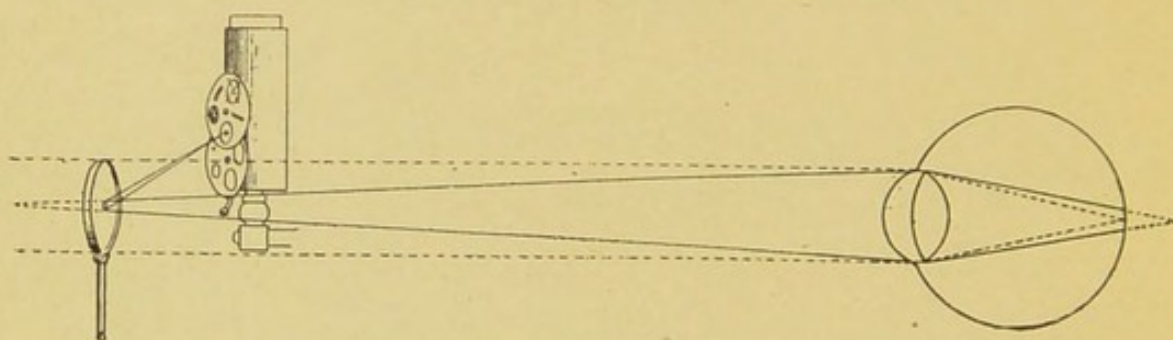
FIG. 31.

the great importance, as mentioned on page 41, of refract-
ing the macular region.   To accomplish this, the patient
must fix his gaze upon the metal disc or letters on the disc of
the mirror.   As the region of the macula is departed from,
the strength of the neutralizing lens grows slightly stronger
in emmetropia and hyperopia, and diminishes in myopia.
A reference to Figure 32 will give an idea of what is meant,
and show that radii drawn from the nodal point are all
shorter than the one to the fovea.

Myopia.—In myopia the emergent rays *always* converge
to the far-point (point of reversal), and the observer, seated
at one meter distant from the eye, will have the apparent
movement of the retinal illumination going opposite to

the light on the face *if* the myopia exceeds one diopter, and *with* the light on the face *if* the myopia is less than one diopter. If the myopia should be *just* one diopter, then the emergent rays would focus on the observer's retina at one meter, and there will not be any neutralizing lens required to accomplish this purpose; but if the emergent rays focus beyond one meter, the observer will be within this point of reversal or focus, and will, therefore, have an erect image, moving fast with the movement of the mirror, and will have to place before the eye a plus lens of less than one diopter to bring the point of reversal up to the distance of one meter. When the myopia is more than one diopter, and observer at one meter, the emergent rays will have focused somewhere between the observer and the patient, and, as a result, the retinal illumination appears to move oppo-site to the light upon the face; more or less rapidly, according to the amount of myopia; and a concave or minus lens must be placed in front of such an eye that will bring the emergent rays to a focus at one meter, or, in other words, will stop all apparent movement of the retinal illumination. If, for example, a
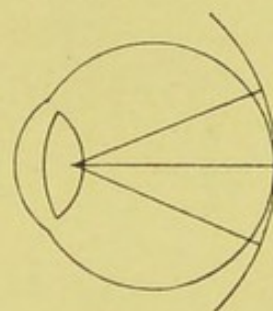
FIG. 32.

−2.75 D. has been so placed, and the movement is still slightly opposite to the movement of the mirror, and a −3.25 D. substituted makes the retinal illumination move *with* the movement of the mirror, then the neutralizing lens for one meter will be numbered between −2.75 D. and −3.25 D., which will be −3 D.

Figure 33 shows the myopic eye just described, with the position of the mirror, light, and eye as in Figures 29 and 31. The solid lines represent the rays reflected diver-gently from the mirror focusing at a point in the vitreous before coming to the retina, and the broken lines show

the rays emerging from a point on the retina and then converging to the focus, far-point, or point of reversal close to the eye, between the eye and the mirror. The observer, seated with the mirror one meter distant, gets an opposite movement in the pupillary area from the direction in which he moves his mirror, and, of course, an inverted image. If the observer had his eye at the point where the emergent rays focused (dotted lines cross), he would not recognize any movement in the pupillary area, and it would have a uniform reflex. The amount of the myopia is equal to the distance measured from this point of reversal to the cornea; for example, if the distance (point of reversal)
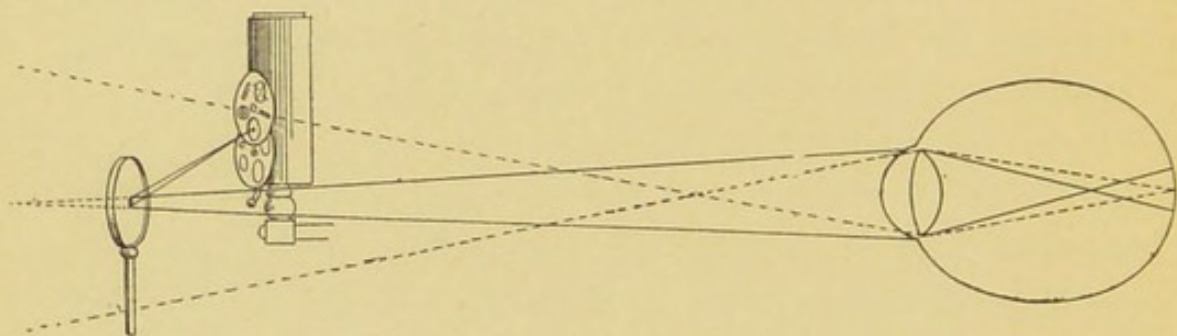
FIG. 33.

was twenty-five cm. from the patient's eye, then the amount of the myopia would be four diopters; if at 33 cm., then 3 D., etc.

Figure 34 is a profile view of the myopic eye. The dotted lines show the rays coming from a point on the retina and focusing at the far-point (F.P.); the solid lines show the emergent rays acted upon or bent by a plano-concave lens of three diopters, which has lessened the convergence of these emergent rays and put the far-point farther from the eye, or at a distance of one meter. The observer at this distance does not appreciate any movement in the pupillary area, but if he moves the light and mirror closer to the eye he is then inside the point of reversal

and gets an erect image moving with the movement of the mirror; if beyond the one meter's distance, an inverted image and movement against the movement of the mirror will be seen. If a −4 D. lens had been placed before this myopic eye, the emergent rays would have proceeded from it parallel, and the observer, at one meter, would have the same conditions as in the refraction of an emmetropic eye, Figure 31; but as only a −3 D. glass was used, the eye has one diopter of its myopia uncorrected. From the description of retinoscopy in hyperopia, emmetropia, and myopia, just given, the student will recognize at once that the hyperopic, emmetropic, and myopic eyes of less
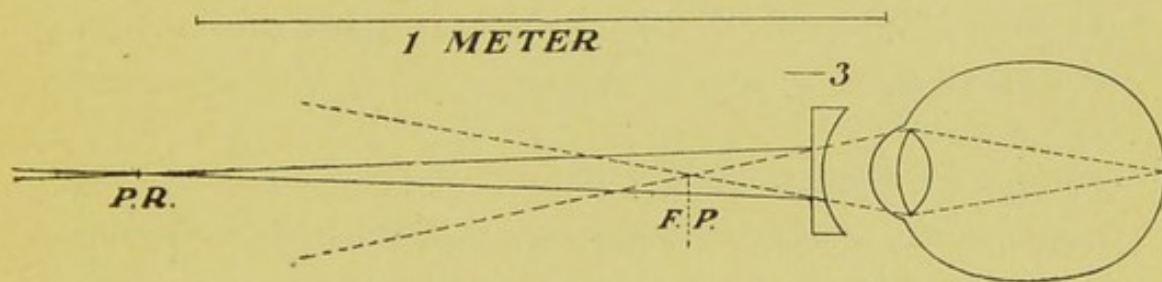
FIG. 34.

than one diopter, working with the plane mirror at one meter's distance, are given a stronger refraction than they naturally call for, or, in other words, are made, artificially, myopic one diopter. And the myopic eye of more than one diopter, under similar conditions, being already myopic, retains one diopter of its myopia. To give a patient thus refracted with the retinoscope his emmetropic correction (correction for parallel rays of light), *an allowance must always be made, in all meridians, of one diopter, no matter what the refraction.* The artificial myopia thus produced at one meter gives the following rules for glasses required for infinity:

Rules.—1. When the neutralizing lens employed is plus, then subtract one diopter.

2. When the neutralizing lens employed is minus, then add a −1 D., or what is more simple, or even a better rule, is, to *always add a −1 sphere to the neutralizing lens obtained in the dark room when working at one meter, and the result will be the emmetropic or infinity correction.*

Examples:

Dark Room, ... +0.50 0.00+1.00+2.00−1.00
Adding, ... : −1.00−1.00−1.00−1.00−1.00
Emmetropic Correction, . . . −0.50−1.00−0.00+1.00−2.00

The main point in all retinoscopic work to remember in changing from the dark room to the six-meter correction, is to always allow for the distance from the patient's eye to the point of reversal—i.e., if working at half a meter, allow two diopters; if at two meters, 0.50 D., if at four meters, 0.25 D., etc.

Regular Astigmatism.—When refracting with the retinoscope, the observer should remember *that he is refracting the meridian in the direction of which he moves the mirror.* Particular attention is called to this important fact on account of the confusion sometimes arising in the student's mind from the use of the ophthalmoscope, where the refractive condition of a certain meridian is estimated by the strength of the lens used to see clearly the vessels at right angles to it. Astigmatism being present in an eye, means a difference in the strength of the glass required for the two principal meridians, which, with few exceptions, are at right angles to each other, and it is to these two principal meridians *only* that the observer pays attention; for example, the eye that takes the following formula,

$$+1.00 \text{ D.} \bigcirc +1.00 \text{ c. axis } 105°,$$

means that in the 105 meridian there is +1 D. and in the 15 meridian a +2 D. In the dark room a +2 sphere in front of such an eye at one meter would correct the 105

meridian and partly correct the 15 meridian; or a +3 D. would correct the 15 and over-correct (movement against) the 105 meridian. When with +2 D. the 105 meridian is corrected and the 15 only partly so, there is seen in the 15 meridian a band of light which stands or extends across the pupil in the 105 meridan and moves across the pupil
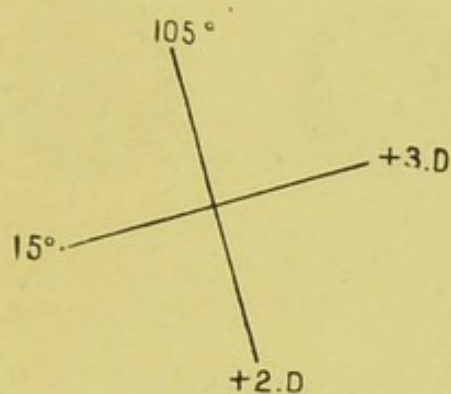
105° °

+3.D

15°.

+2.D

FIG. 35.

from left to right *with* the movement of the mirror as the light is reflected through the 15 meridian.

The presence of this band of light *after* the meridian of least ametropia has been corrected *always* signifies astigmatism, and the axis it subtends—in this case 105° gives the axis of the cylinder in the prescription; and the amount of the astigmatism, or the strength of the cylinder required, is the difference between the strength of the two spheres employed. Figure 35 shows the method of writing such a dark room correction, and adding, according to our rule, a −1 to this dark room work, we get our original formula:

+1.00 D. $\bigcirc$ +1.00 c. axis 105°.

The method of correcting with spheres (Fig. 26) will be found much more satisfactory than by placing a +2 D., as called for in the 105 meridian, then adding and changing cylinders until the correct one is found. It takes much time and care to get the cylinder axis just right, and is most difficult in the dark room. After the result has been

obtained with spheres, the observer may, if he is so disposed, prove it before leaving the dark room with the sphero-cylinder combination.

Astigmatism may or may not be recognized on first inspection of the fundus-reflex, this depending *entirely* on the refraction; if it be a high astigmatism with a small

FIG. 36.   FIG. 37.

FIG. 36.—BAND OF LIGHT AT AXIS 60°, WITH THE 60° MERIDIAN NEUTRAL-IZED. No movement of the illumination can be recognized in the 60° meridian.

FIG. 37.—Shows the same as Figure 36, but the band of light with straight edge has been moved upward and to the left by tilting the mirror in the 150° meridian.

amount of refractive error in the opposite meridian, as in one of the following formulas,

$$+ 1.00 \text{ D.} \bigcirc + 3.00 \text{ c. axis } 45°,$$
$$- 1.00 \text{ D.} \bigcirc - 4.00 \text{ c. axis } 180°,$$

then the band of light so characteristic of astigmatism will be plainly seen on first inspection, extending across the pupil before any neutralizing lens has been placed in position; but if the hyperopia or myopia be high and the cylinder required is low, as in one of the following formulas,

$$+ 3.00 \text{ D.} \bigcirc + 0.75 \text{ c. axis } 105°,$$
$$- 4.00 \text{ D.} \bigcirc - 1.00 \text{ c. axis } 165°,$$

then the band of light is not recognized on first inspection or until an approximate correction has been placed before the eye. To get an idea of what the band of light looks like, the beginner may refer to Figures 36 and 38; or focus rays of light through a strong cylinder; or place a + or − 2 D. cylinder in front of the schematic eye registered at zero and study the retinal illumination. The student should

bear in mind that the axis of the band of light appears on the meridian of least ametropia, and is brightest when this meridian has received its full spheric correction—the opposite meridian being only partly corrected.

The reason for the brightness of the band of light when the meridian of its axis is corrected is that any point on the retina in this meridian is conjugate to the focus on the observer's retina (point of reversal), and any movement of the mirror in this meridian is not recognized, but has a uniform color and occupies the entire meridian of the pupil. To recognize so small an error as a quarterdiopter cylinder —which is *not* easily detected, and the observer, if he is in a hurry, might think the case one of simple hyperopia or myopia—the writer would suggest that when the supposed point of reversal is reached the correcting sphere be increased a quarter of a diopter, and *if* only one meridian is found over-cor-

FIG. 38.—BAND OF LIGHT ASTIGMATISM AXIS 90°.

rected (movement opposite), the other remaining correct (no movement recognized), he *then* knows that a quarter cylinder is required; for example, a + 2 D. is supposed to correct all meridians, and yet by substituting a + 2.25 D., the vertical meridian moves against and the horizontal remains stationary; then a +0.25 D. cylinder is called for at axis 90°.

Cases having a low astigmatic error of 0.50 D. can be recognized when near the point of reversal by the faint shaded area on each side of the band of light, as shown in Figure 39—a condition often overlooked.

Mixed Astigmatism.—In this condition of refraction, where one meridian is myopic and the meridian at right angles to it is hyperopic, the movement of the retinal illumination in the myopic meridian will be controlled by

the *amount* of the myopia. The illumination in the myopic meridian, if the myopia is less than one diopter, moves *with* the mirror, and against the movement of the mirror if it is more than one diopter; in either instance the observer gets a distinct band of light in the meridians alternately as each meridian is neutralized separately with a sphere. Taking the following example (no glass in front of the eye),

$$-2.00 \text{ c. axis } 180° \bigcirc +1.00 \text{ c. axis } 90°,$$

the 90 meridian shows an *opposite* movement up and down, and in the horizontal the movement is *with* the movement

FIG. 39.—BAND OF LIGHT SHOWING HALF A DIOPTER OF ASTIGMATISM.

of the mirror. If, now, a -1 D. sphere be placed before the eye, the 90 meridian is neutralized for one meter distance, and a bright band of light is seen at 90°, moving with the movement of the mirror in the horizontal meridian. Removing the -1 D. and placing a $+2$ D. before the eye, which would neutralize the horizontal meridian for one meter, a bright band will be seen in the horizontal meridian and moving opposite to the movement of the mirror in the 90° meridian. Carrying out the rule of always adding a -1 D. sphere to the correction obtained in the dark room at one meter, we have -1 added to the -1 in the vertical meridian, making -2 D. axis 180°; and adding -1 to the $+2$ D. in the horizontal, we have $+1$ D. axis 90°, or our original formula.

$$-2.00 \text{ axis } 180° \bigcirc +1.00 \text{ c. axis } 90°.$$

The rule for neutralizing lenses in mixed astigmatism is the same as for any other form of refraction; namely, using a plus lens when the movement is with, and a minus

lens when the movement is opposite to, the movement of the light on the face.

To transpose crossed cylinders into a sphero-cylinder combination the writer would advise using the rule of Dr. Harry S. Pearse, of Albany, which is as follows:

"The cylinder is the sum of the two cylinders with the sign and axis of one of the cylinders. The sphere is the strength of the other cylinder with its sign." In the above formula, the sphero-cylinder combination will be

$$- 2 \text{ D. } \bigcirc + 3.00 \text{ c. axis } 90°.$$

Axonometer.—To find the exact axis subtended by the band of light while studying the retinal illumination, when
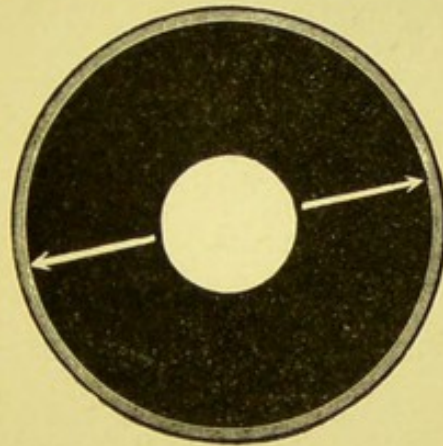
FIG. 40.

the meridian of least ametropia has been corrected, the writer has suggested a small instrument, which, for want of a better name, he has called an axonometer.

Figure 40 shows this instrument, and Figure 41 the axonometer in position.

The original description of this device was published in *The Medical News*, March 3, 1894, as follows: "The direction of the principal meridians of corneal curvature is often difficult to determine, and the statement of the patient must be accepted when confirming the shadow-test correction; or, if there is still uncertainty, the ophthal-

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mometer of Javal may be of service. The axonometer is a black metal disc, with a milled edge, one and one-half mm. in thickness, of the diameter of the ordinary trial-
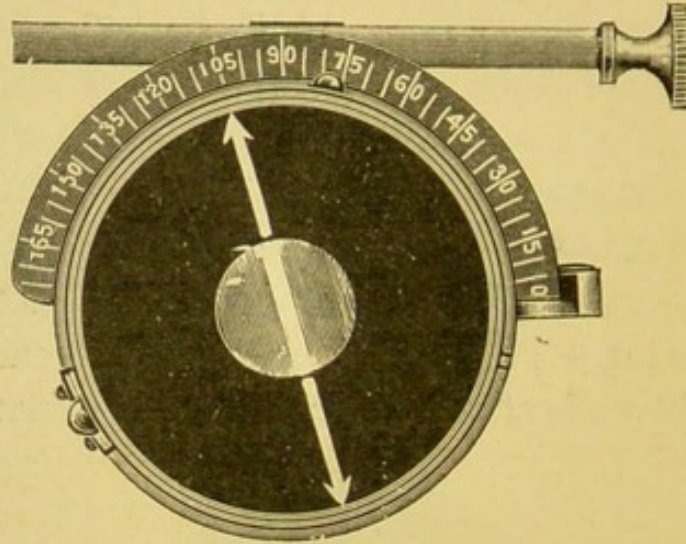
FIG. 41.

lens, and mounted in a cell of the trial-set. It has a central round opening 12 mm. in diameter—the diameter of the average cornea at its base. Two heavy white lines, one on each side, pass from the circumference across to the central
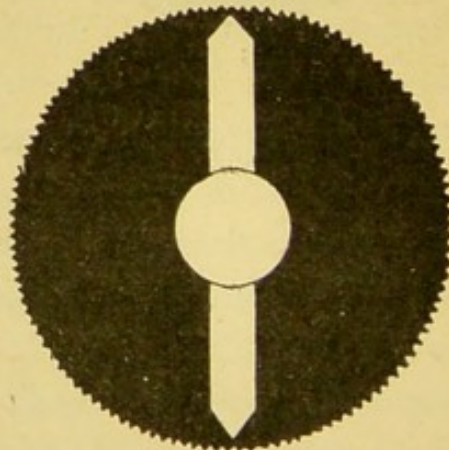
FIG. 42.

opening, bisecting the disc. To use the axonometer, place it in the front opening of the trial-frame, and with the patient seated erect and frame accurately adjusted so that

the cornea of the eye to be refracted occupies the central opening, proceed as in the usual method of making the shadow test. As soon as that lens is found which corrects the meridian of least ametropia, and the band of light appears distinct, turn the axonometer slowly until the two heavy white lines accurately coincide, or appear to make

FIG. 43.—TRIAL-FRAME WITH AXONOMETERS IN POSITION INDICATING SYMMETRIC ASTIGMATISM.

one continuous line with the band of light (see Fig. 41).

"The degree marks on the trial-frame to which the arrow-head at the end of the white lines then points is the exact axis for the cylinder. The axonometer possesses the following points of merit:

"Simplicity.

"Accuracy.

"Small expense.

"It covers an unnecessary part of the trial-lens which too frequently gives annoying reflexes and images.

"It saves time, avoids the statement of the patient, and renders the ophthalmometer unnecessary.

"Its color (black) absorbs the superfluous light rays from the mirror and gives a stronger contrast to the reflex and central illumination.

FIG. 44.—TRIAL-FRAME WITH AXONOMETERS IN POSITION INDICATING ASYMMETRIC ASTIGMATISM.

"Limiting the field of vision in children, it permits of more concentrated attention.

"For children and nervous patients, when it is difficult to use the ophthalmometer, his simple appliance is of great service."

Lately the writer has improved the axonometer by having the white lines broadened to four millimeters, which is a decided advantage over the instrument shown in Figures 40 and 41 as the broad line is easily seen at one meter distance. This axonometer, shown in Figure 42, is made of thick celluloid.

Figure 43 shows the trial frame with axonometers in position indicating symmetric astigmatism.

Figure 44 shows the trail frame with axonometers in position indicating asymmetric astigmatism.

CHAPTER VI.

RETINOSCOPY IN THE VARIOUS FORMS OF IRREGULAR AMETROPIA.—RETINOSCOPY WITHOUT A CYCLOPLE- GIC.—THE CONCAVE MIRROR.—DESCRIPTION OF THE AUTHOR'S SCHEMATIC EYE AND LIGHT-SCREEN.— LENSES FOR THE STUDY OF THE SCISSOR MOVEMENT, CONIC CORNEA, AND SPHERIC ABERRATION.

Irregular Astigmatism.—This condition is either in the cornea or in the lens, or in both structures in one and the same eye; in any instance it is confusing to the beginner, and even the expert must work slowly to obtain a definite result. The corneal form is most difficult to refract as the retinal illumination is more or less obscured by areas of darkness. The illumination between these dark areas appears to move with, in places, and in others against, the movement of the mirror. By moving the mirror so as to make the light describe a circle around the pupillary edge, a most unique kaleidoscopic picture is obtained, which is quite diagnostic of the condition. To refract an eye with this irregularity the observer may have to change his posi- tion several times, going closer to or farther away from the patient. Very often these eyes are astigmatic, and the band of light may be promptly noted by the observer changing his position as suggested, and at the same time placing a neutralizing lens before the eye. Care *must* be taken, also, to refract in the area of the cornea that will correspond to the small pupil when the effect of the cyclo- plegic passes away. It is often best, in these cases of irregular corneal astigmatism, to make a record of the cor- rection found and use it as a guide in a post-cycloplegic manifest refraction.

Irregular astigmatism of the lens is frequently more or less uniform, and not so broken as in the corneal variety. Figures 45 and 46 show two kinds of irregular lenticular astigmatism.

Figure 45 illustrates the spicules pointing in from the periphery, and so long as these do not encroach upon the pupillary area, they do not usually in themselves interfere with vision; they are not often recognized until the pupil is dilated, are then very faint, and not usually made out until the point of reversal is approached. Figure 46 is another form of irregular astigmatism, and a very inter-

FIG. 45.   FIG. 46.
IRREGULAR LENTICULAR ASTIGMATISM.

esting picture as studied with the retinoscope; and, as in Figure 45, *when* very faint, is not made out until close to the point of reversal. These two forms of irregular lenticular astigmatism, when *just* beginning, are very seldom seen with the ophthalmoscope; the striations are too fine to be made out except under the conditions just described, and when recognized are of inestimable value from a point of prophylactic treatment, calling for a change of occupation, rest to the eyes, and carefully selected glasses, the latter often being weak lenses. These lenticular conditions not infrequently accompany the "flannel-red" fundus, the "fluffy eye ground," the "shot-silk retina," the "woolly choroid," etc.

Scissor Movement.—Another form of astigmatism that may be classed as irregular is where there are two areas of light, each with a straight edge, and usually seen on

the horizontal meridian, or inclined a few degrees from the horizontal, and moving toward each other as the mirror is tilted in the opposite meridian; in other words as the observer is seated at one meter he sees an area of light above and an area of light below with a dark interspace (Fig. 48). As the mirror is slowly tilted in the vertical
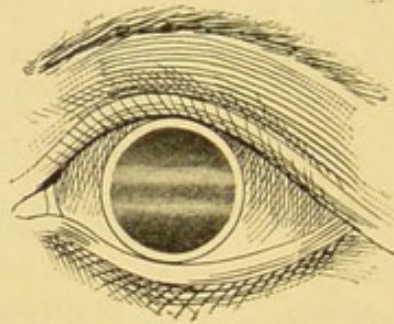
FIG. 47.—LIGHT AREAS COMING TOGETHER AND DARK INTERSPACE FADING.

meridian these light areas approach and are followed by darkness or shadow, and at the same time the dark interspace begins to fade, giving the picture as shown in Figure 47. When the light areas are brought together, they result in a horizontal band of light, as seen in Figure 49, and at this point resemble the ordinary band of light as seen in regular astigmatism. This movement of the light areas is likened to the opening and closing of the scissor blades, and hence the name of scissor movement.

These cases are more or less difficult to refract, but the presence of the two areas of light with the dark interspace will often assist in a correct selection of glasses, for while they are generally of the compound hyperopic variety, calling for a plus sphere and plus cylinder, yet practice and the patient's statement often call for a plus sphere and minus cylinder.

With the following formula,

$$+2.00 \text{ D.} \bigcirc +0.75 \text{ c. axis } 90°,$$

substituting a sphere the strength of the combined values

of the sphere and cylinder, and using a minus cylinder of the same number as the plus cylinder at the opposite axis, the result will be,

$$+2.75 \text{ D.} \bigcirc -0.75 \text{ c. axis } 180°.$$

The vision with the latter formula is much better in many instances than with the former, and though either formula would be correct, yet the latter is practically the better of the two, and should be ordered when so found. The writer's method of procedure when he recognizes the scissor movement is to tilt the mirror until the two light
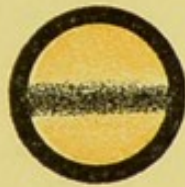
FIG. 48.   FIG. 49.
FIG. 48.—LIGHT AREA ABOVE AND BELOW, WITH DARK INTERSPACE.
FIG. 49.—LIGHT AREAS BROUGHT TOGETHER.

areas are brought into one band of light as shown in Fig. 49 and then to reflect the light through the meridian of this band (in this instance as illustrated, the 180 meridian). Having obtained the lens which neutralizes the movement in this meridian, the writer does not attempt to find the neutralizing lens for the opposite meridian but goes from the dark room to the trial-case and places before the patient's eye that sphere which corrects the refraction in the horizontal meridian. For instance, if $+3.75$ D. corrects the horizontal meridian at one meter, then $+2.75$ D. sphere is placed before the eye, and a minus cylinder (beginning with -0.50 at axis 180 degrees) is placed in front of the sphere and the strength of this minus cylinder is gradually increased so long as the visual acuity improves. In other words the writer does not attempt to estimate the refraction with the retinoscope in the meridian opposite to the bands

of light. The condition which may be the probable cause
of the scissor movement is a slight tilting of the lens (see
Fig. 50)—that is, the antero-posterior axis of the lens is
not at right angles to the plane of the cornea, thus making
one portion of the pupil myopic (area of light moving op-
posite) and the other portion hyperopic (area of light moving
with the movement of the mirror). This condition may be
simulated by placing a convex lens at an angle before the
schematic eye, or reflecting the light into the eye obliquely,
or by using the combination lens in front of the schematic
eye, as suggested on page 66.

What causes the tilting of the lens the writer is not prepared
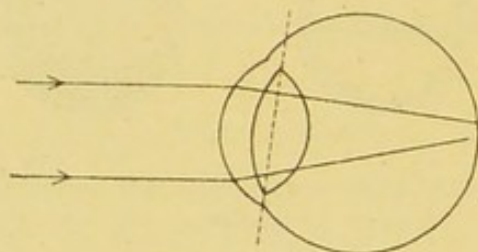
FIG. 50.

to state *positively;* it may be congenital, and yet careful
inquiry of the patients, in many instances, has shown that
it is most likely due to using the eyes to excess in the recum-
bent posture. It may be a coincidence, but most of the
cases of scissor movement seen by the author have been
in adults, and those who were in the habit of reading
while lying down, reading themselves to sleep at night in
bed.[1] Other cases were seen among paper-hangers,
whose occupation compelled them to look upward much
of the time. These do not seem unlikely causes, especially
when the anatomy of the ciliary region is considered, the
strain of the accommodation (possibly spasm) during the

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[1] The writer does not wish to be misunderstood and does *not* say that
every one who uses his eyes in this faulty position *must* develop this form of
irregular astigmatism.

faulty position of the eye tilting the lens as it rests upon the vitreous body.   This form of astigmatism, so far as known, remains a permanent one even after a cessation from the original cause and correcting glasses have been ordered. The retinoscope is the only instrument of precision we have in diagnosing this condition.   The ophthalmoscope may recognize the presence of the astigmatism, but not its character, and the ophthalmometer only records the corneal curvature.   Cases of aphakia (following cataract *extraction*) frequently show the scissor movement *during* the process of retinoscopy.   This is undoubtedly due to the flattening of the cornea corresponding to the section, making one
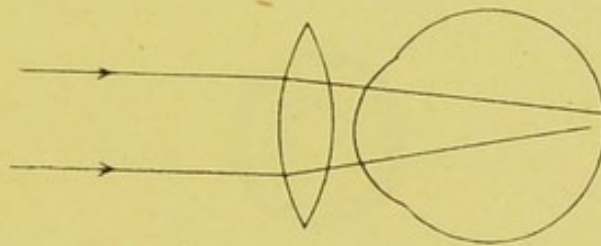
FIG. 51.

portion myopic and the other hyperopic. Figure 51 with correcting sphere in position, shows such a condition, where the upper illumination would move with and the lower, being myopic, would move against the movement of the mirror.

Compound Irregular Astigmatism.—This is a combination of the scissor movement and regular astigmatism, but they are *not* at right angles to each other.   The scissor movement may be at 180°, and the regular astigmatism at some point *away* from 90°, but not at 90°; or the regular astigmatism may be at 90° and the scissor movement at some meridian other than 180°.

A hasty review of the literature of astigmatism does not reveal any reference to this form, and the name for the condition has been suggested by the following picture,

namely: When studying the reflex, a vertical band of
light will be seen passing across the pupillary area from
left to right as the mirror is turned, and then in the vertical
meridian (*not* at right angles) the scissor movement will
be recognized also; there is, therefore, a combination of
regular corneal astigmatism with the scissor movement
at an oblique angle, giving the compound name suggested.
This form of astigmatism is rare, yet not difficult to diagnose
or refract when understood. It is hoped, however, that the
beginner in retinoscopy may not meet one of these on his
first attempt at the human eye. (See page 67.)

Conic Cornea.—Reflecting the light into an eye that
has such a condition, the observer is impressed at once

FIG. 52.—ILLUMINATION SEEN IN CONIC CORNEA.

with the bright central illumination that moves opposite
to the movement of the mirror, the peripheral illumination
moving with, unless perchance the margin should be
myopic also, but of less degree. This form of illumina-
tion is seen in Figure 52, showing the central illumination
faintly separated by a shaded area or ring from the per-
ipheral circle. The best way to refract a case of this kind is
to keep a record of the neutralizing lens or lenses required
for the portion of the pupillary area that will correspond
to the size of the pupil after the effect of the cycloplegic
passes away, and use this record as a guide in a post-cyclo-
plegic manifest correction, as in irregular corneal astig-
matism.

As the apex of the cone is not always central, the observer
must not expect to always find the bright illumination in

the center of the pupillary area, as just mentioned; and it is also well to note the fact that a band of light will often appear during the process of neutralization, as astigmatism is usually present. This is further described on page 66.

Spheric Aberration.—This appears under two forms, positive or negative, and is the condition in which, during the process of neutralization, there are two zones, one central and the other peripheral, where the refraction is not the same. In positive aberration the peripheral refraction is stronger and in negative abberation the peripheral
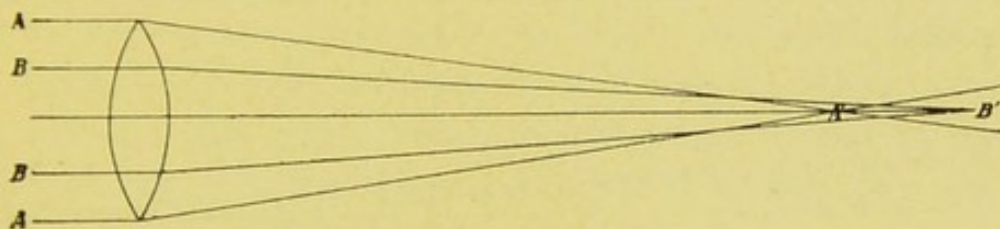
FIG. 53.—POSITIVE ABERRATION.

is weaker than the central area; that is to say, in the positive form, when the point of reversal for the center of the pupil is close to one meter, the peripheral illumination grows broader and has a tendency to, and often will, crowd in upon the small central illumination, giving the idea of neutralization, or even the appearance of over-correction, the illumination in the periphery moving opposite. The observer must be on his guard for this condition, and while giving the mirror a slow and limited rotation must watch carefully the illumination in the center of the pupil and *not* hasten the peripheral movement. (See What to Avoid, p. 30, Chap. IV.) The observer may have to approach the patient's eye closer than one meter if the peripheral illumination appears to move very fast. The negative form is where the peripheral refraction is weak as compared to the central which appears strong, and when the neutralizing lens gives a point of reversal to the center of

the pupil the peripheral illumination still moves with the movement of the mirror. This condition is seen in cases of conic cornea.

Figure 53 illustrates positive abberration where the parallel rays passing through a convex lens in the periphery at *A A* come to a focus at *A'*, much sooner than the parallel rays *B B*, near the center, which comes to a focus back of *A'* at *B'*.

Figure 54 illustrates negative abberation, which is the reverse of positive aberration, and the central rays *B B* are focused at *B'* in front of the peripheral rays *A A* focusing at *A'*.
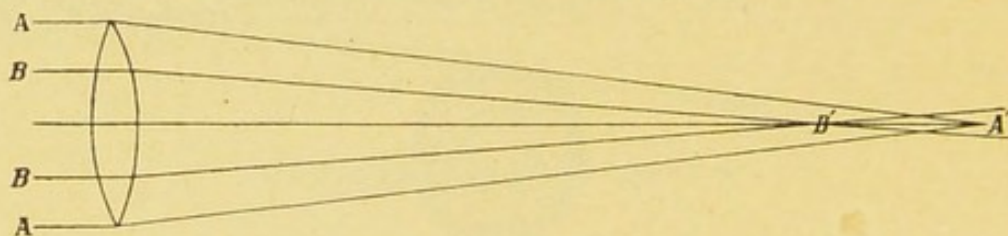
FIG. 54.—NEGATIVE ABERRATION.

Retinoscopy Without a Cycloplegic.—Cases of myopia and mixed astigmatism which have large pupils *can* be quickly and accurately refracted by the shadow test without the use of a cycloplegic. This has been repeatedly proven by comparison of the manifest and cycloplegic results; yet it is not a method to be recommended or pursued, for two reasons: One is that these patients are not annoyed, like hyperopics, by the blurred near-vision incident to the cycloplegic; and, secondly, glasses ordered without the cycloplegic seldom give the comfort that follows from the physiologic rest the eye receives from the drug. The surgeon will obtain much assistance and save time by using the retinoscope in cases of aphakia, in old persons especially who are very slow to answer, and will insist upon a description of what they do and do not see, as also in re-reading

the test-card from the very top each time a change of lens is put in the trial-frame. Presbyopes of fifty or more years of age can be quickly and not inconveniently refracted by the shadow test after having their pupils dilated with a weak (four per cent.) solution of cocain.

Concave Mirror.—While the study of retinoscopy with the concave mirror is not a part of the subject of this book, and allusion to it has been carefully avoided up to this time, yet for the benefit of those who may wish to try it, the writer would suggest that it will be necessary to place the source of light (20 or 30 mm. opening in light-screen) above and beyond the patient's head, one meter distant, or more, so that the convergent rays from the mirror come to a focus and cross before entering the observed eye. Then to estimate the refraction, proceed as with the plane mirror, remembering, however, that the movements of the retinal illumination are just the reverse of those obtained when using the plane mirror.

The Author's Schematic Eye for Studying Retinoscopy.—For illustration see Figure 1 and the *Journal of the American Medical Association*, January 5, 1895. The eye is here shown, slightly reduced in size, is made of two brass cylinders, one somewhat smaller than its fellow, to permit slipping evenly into the other. Both cylinders are well blackened outside. The smaller cylinder is closed at one end (concave surface), and on its inner surface is placed a colored lithograph of the normal eye ground. The larger cylinder is also closed at one end, except for a central round opening 10 mm. in diameter, which is occupied by a +16 D. lens, and on its outer surface is a colored lithograph of the normal eye and its appendages; the pupil is left dilated, and corresponds in size to the central opening just referred to. In addition to the picture of the eye, there is also lithographed on the upper half of the periphery

the degree marks similar to those on a trial-frame. To the lower half of the periphery are secured, at equal distances, three posts with grooves to hold trial-lenses. On the side of the small cylinder is an index which records emmetropia, and the amount of myopia and hyperopia, as it is pushed into or drawn out of the large cylinder. The eye is mounted on a convenient stand and upright, so that it may be moved as required. In using this eye, if the red eye ground and retinal vessels disturb the beginner, then he may substitute a piece of white paper for the retina. To study astigmatism with the model, the beginner will have to place a cylinder of known strength in the groove next to the eye and study the characteristic band of light so diagnostic of this condition, and at the same time he should learn to locate the axis of the band with the axonometer.

The author's light-screen or cover chimney (see Figure 7 and the *Annals of Ophthalmology and Otology*, October, 1896) is made of one-eighth inch asbestos, and of sufficient size to fit easily over the glass chimney of the Argand burner; attached to the asbestos by means of a metal clamp are two superimposed discs, which revolve independently of each other. The lower disc contains a piece of white procelain, 30 mm. in diameter; also four round openings, respectively 5, 10, 20, and 35 mm. in diameter. The upper disc contains a round 35 mm. opening, a round section of blue cobalt glass, a perforated disc, a vertical and a horizontal slit, each 2 1/2 by 25 mm. The several uses of this screen are as follows:

1. For the ophthalmoscope a good light is obtained by superimposing the two 35 mm. openings.

2. Combining the 35 mm. opening in the upper with either the 5 or 10 mm. in the lower disc, a source of light is produced for the small retinoscope; and,

3. By substituting the 20 mm. opening, light is had for the concave mirror.

4. Placing the cobalt glass over the 5, 10, 20, or 35 mm. opening, and the chromo-aberration test for ametropia is given.

5. To test for astigmatism at one meter while using the plane mirror, or for heterophoria at six meters, the perforated disc is to be turned over the porcelain, the latter producing a clear white image.

6. The horizontal slit placed over the porcelain glass, and the operator may exercise the oblique muscles.

7. The vertical slit similarly placed gives the test for paralyzed muscles.

Lenses for the Study of the Scissor Movement, Conic Cornea, Spheric Aberration, and Lenticular Astigmatism.—(Described by the author in the *Journal of the American Medical Association*, December 18, 1897.)

As the scissor movement, conic cornea, spheric aberration, and lenticular astigmatism, as recognized by the retinoscope, are so difficult of demonstration, except in the individual patient, the writer has suggested and had made four lenses which will illustrate these conditions respectively when placed in front of his schematic eye; and thus the beginner in retinoscopy may have the opportunity to see, know, and study these important and interesting manifestations (and at small expense) before prodceeding direct and in comparative ignorance to his patient.

Figures 55 and 56 represent a plano-concave cylinder of two diopters, mounted in a cell of the trial-case, and to one-half of its plane surface is cemented (at the same axis) a plano-convex cylinder of four diopters, thus making a combination lens, one-half of which is a -2 D. and the other half equaling a $+2$ D. Placing this lens, with its axis at 180°, before the schematic eye at emmetropia (zero),

and the observer at one meter distance with his plane mirror, the two light areas characteristic of the scissor movement, with their comparatively straight edges and dark interspace may be seen approaching each other from above and below (and the dark interspace disappearing) as the mirror is tilted in the vertical meridian.

Figures 57 and 58 represent a section of thin plane glass mounted as in Figure 55 and has cemented at its center a small plano-convex sphere of three diopters, whose base
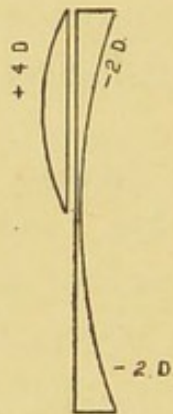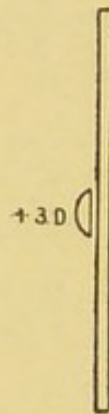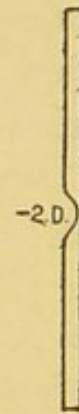
FIG. 55.   FIG. 57.   FIG. 59.

is about four mm. in diameter. Placing this lens in front of the schematic eye at emmetropia, and reflecting the light from the plane mirror at one meter, there will be seen in the pupillary area a small central illumination, which moves against or opposite to the movement of the mirror, and at the same time there will also be seen a peripheral ring (at the edge of the iris) which moves rapidly with the movement of the mirror; between these light areas is a shaded ring of feeble illumination. This is the retinoscopic picture and movement of the light areas, so indicative of conic cornea. It is also an exaggerated picture of negative aberration.

Figures 59 and 60 represent a section similar to that shown in Figures 57 and 58, except that at its center is

ground a — 2 D. sphere of about four mm. in diameter. To produce spheric aberration of the positive form, place this lens in front of the schematic eye at emmetropia, and the observer, seated at one meter distance with the plane mirror, will see in the pupillary area a central illumination which moves slower than the peripheral area or ring (at the edge of the iris), which moves rapidly, both areas moving with the movement of the mirror. Figure 61 shows a lens for studying lenticular astigmatism. This is made by scratching a piece of plane glass with a diamond.
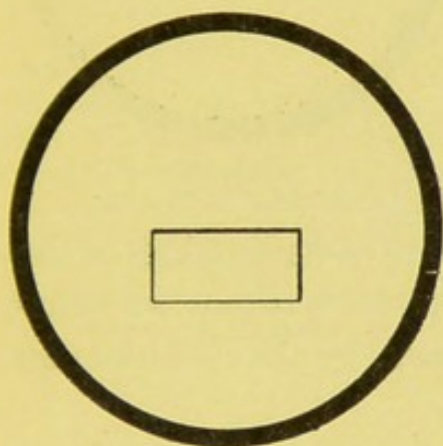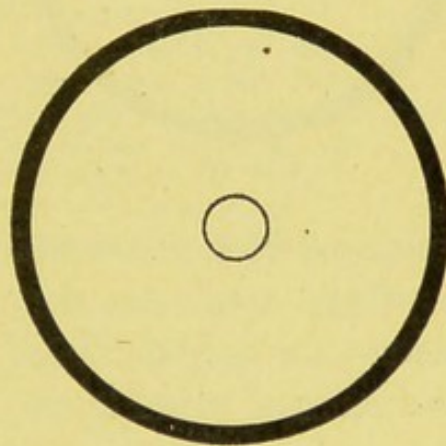
FIG. 56.   FIG. 58.

After the observer has carefully studied these pictures it will be obvious that changes other than those mentioned can be made with these lenses, and he should proceed to note them by—

1. Changing the focus of the schematic eye.

2. By varying his distance from the eye.

3. By placing both the concave and convex spheres in combination.

4. By placing a concave cylinder in front of the double cylinder at an oblique axis, thus getting a picture of compound irregular astigmatism.

5. By placing a concave cylinder in front of the convex sphere and developing astigmatism with the conic cornea,

which is the usual condition; or a convex cylinder might be used in place of the concave cylinder if a higher error is desired.

6. It is obvious, also, that the scissor movement can be
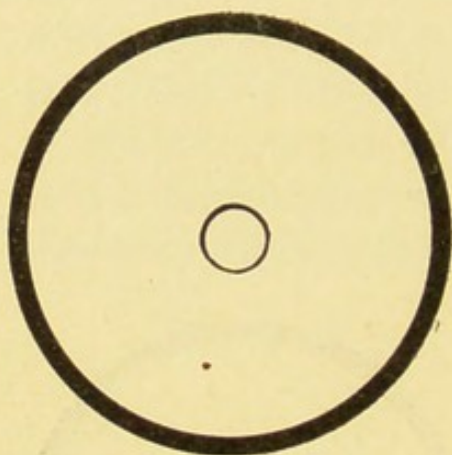
FIG. 60.
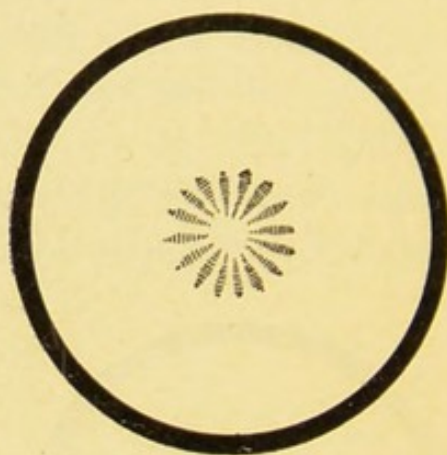
FIG. 61.

produced by a prism which is made to cover one-half of the pupillary area, but the resulting picture is not so satisfactory for demonstration as that given by the combination lens referred to in Figure 55.

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