Not all myopia is physical.
Hyperopic mentality requires no physician.

R. S. Copeland.

Oct. 8/06.

REFRACTION

INCLUDING

MUSCLE IMBALANCE AND THE ADJUSTMENT OF GLASSES

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PREFACE.

With no word of explanation, it would be presumptuous to add to the large and growing list of excellent and exhaustive treatises on the subject of refraction. No student of medicine, we think, will deny that the study of this branch of practical therapeutics is beset with many difficulties, and, when viewed through the meshes of a multiplicity of diagrammatic cobwebs, it appears especially unattractive. We feel safe in adding that any real help in simplifying the teaching of refraction will be welcomed by student and practitioner. An attempt to accomplish this end is our only hope of justification, and if, in a small measure, we succeed in elucidating some of the difficult principles and problems of the subject, we shall feel that our efforts have not been vainly spent.

Refraction is an eminently practical science and we aim to treat it as such, divesting it, so far as possible, of such theoretical demonstrations, logarithmic computations, and minor technicalities as are not deemed absolutely essential to a thorough comprehension of the subject. To strip it of its embellishments is to invite criticism, but the relative importance of what has been omitted is, of course, a matter of judgment. To some of our readers, occasional statements may seem too broad, but if we have failed to limit them sufficiently, or to state all known exceptions, we have acted in the hope of avoiding confusion without sacrifice of essentials. To lead the student along practical lines to an accurate understanding of the applied principles of refraction has been the object of our labor. To this end, it is strongly recommended that the student early acquaint himself with the test-case and, so far as possible, supplement his studies by practical verification of the facts and theories set forth in the text.

University of Michigan, June, 1905.

CONTENTS.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

APPENDIX.

INDEX OF ILLUSTRATIONS.

INDEX OF TABLES.

REFRACTION.

CHAPTER I.

OPTICAL PRINCIPLES.

WAVE THEORY OF LIGHT.

The long-time accepted view regarding light production is based on the theory that all space is pervaded by a medium called the luminiferous ether. In the terms of this hypothesis, the emanations from a luminous source involve the ether in wave-like motion, resulting in the phenomenon of light.

This theory answers very well most of the observed phenomena, but recently it has been considerably revised. The newer view is that the oscillations are of an electrical nature, that electro-magnetic radiations and light radiations are practically identical. The nature of the so-called "electrical displacement" is not thoroughly understood, but in its terms all of the phenomena of light can be explained.

It is believed that the particles constituting the ether are in constant motion. These ethereal waves, according to their length, frequency, form and energy, manifest themselves by stimulation of the organs of special sense. In one instance, their impingement upon the terminal nerves of the body is proved by a sensation of feeling. Again, they manifest themselves as heat producers, or may serve to induce chemical changes. Under other conditions they serve to stimulate the retina of the eye, effecting the sensation of light.

THE LIGHT RAY.

A ray of light may be considered as the path described by the emanation from a single point in the luminous source.

Such a path may be described as a succession of waves proceeding along a straight course. This has been compared to the oscillations of the various points of a rope along which a wave is passing, the vibration of the ether being at right angles to the direction of the wave itself. For the sake of convenience in description, these oscillations may be considered as consisting of "wave fronts," or "wave crests." So long as the optical density of the transmitting medium is constant, the velocity of the oscillations is uniform. As would be expected, their speed is lessened in passing from a rare into a dense medium, as, for instance, from the air into glass or water. Their direction remains unchanged, *provided they enter the denser medium perpendicularly*. This is explained by the fact that the entire transverse vibration, "wave front," or "wave crest," whatever it may be called, enters the denser medium at the same time and, hence, encounters the retarding influence equally at every point.

REFRACTION.

Should a ray of light encounter in its course a transparent medium of greater density and enter it at any angle less than 90° (*i. e.*, not perpendicularly), one end of the "wave front," or "wave crest," will be retarded. while the other end proceeds at the original velocity until it, too, enters the denser medium. (Fig. 1.) In this way the course of the ray is deflected from its straight path and is spoken of as a *Refracted Ray*. The reverse of this takes place when the ray, at any angle less than 90°, emerges from the denser medium to enter one more rare. The end of the "wave front" first liberated immediately increases its velocity and consequently a deflection occurs in its course. When the entire "wave front" has passed out into the new medium, it again proceeds in a straight line.

The ray before its deflection is known as the *Incident Ray*, and the substance causing its change of course is called the *Refracting Medium*. A ray of light entering such a refracting medium perpendicularly, as has been said, will not be deflected, although its velocity will be diminished; neither will the refracted ray alter its course while traversing the refracting medium. It is only in passing from one medium into another of different density that any change of the ray's course is possible, and this deflection takes place at the surface of the refracting medium.

Refraction, then, is the deflection of luminous rays in passing obliquely from one medium into another of different optical density.

The Index of Refraction.—Any transparent substance is a refracting medium. Some media deflect rays of light more

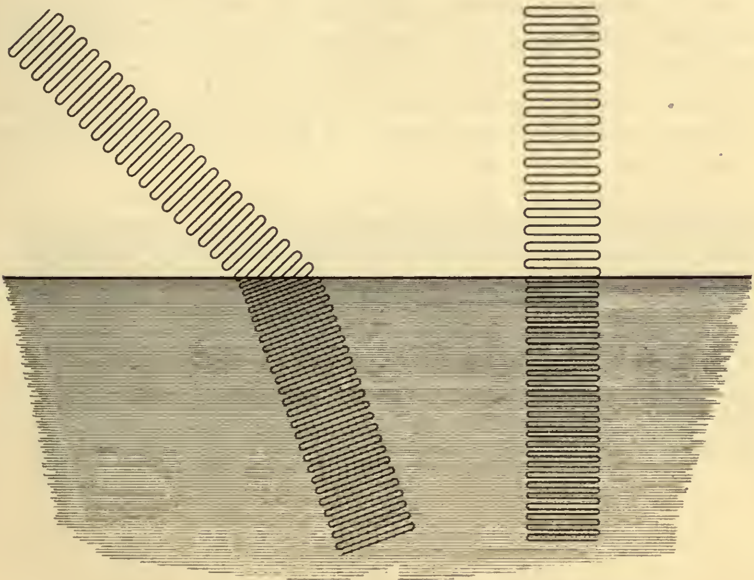

FIG. 1.—Showing the Refraction of a Light Wave.

than does air, the adopted standard. This relative refractive power of a substance, as compared with air, is expressed in figures and is known as the *index of refraction.* It varies directly with the optical density of the medium. Air having an index of 1 and crown glass having half again as much refractive power, because of its greater density, is said to have a refractive index of 1.50.

First Principles.—From what has been said we may deduct the following principles:

1. *From any luminous source, light rays pass out in every direction.*

2. *Light rays always proceed in a straight course, if the medium through which they pass be homogeneous; if deflected from their original direction by passing through an optically denser medium, they resume a straight course upon release.*

3. *The velocity with which the rays proceed varies inversely with the optical density of the medium through which they pass.*

4. *Light rays passing perpendicularly from a rare into an optically dense medium, or vice versa, do not alter their direction.*

5. *In passing obliquely from one medium into another of different optical density, rays of light are deflected from their course.*

6. *The degree* of such deflection *is determined by:*

(a) *The angle of entrance;*

(b) *The difference in optical density (refractive indices) of the two media.*

CHAPTER II.

LENSES.

A Lens.—A lens, named from its resemblance to a lentil, may be any transparent substance, the surfaces of which cause parallel light rays, passing through it, to be diverted from their course. The effect of a lens to change the direction of a light ray, as has been said in a previous chapter (see p. 11), is known as its power of refraction. To understand this it is well to consider the simplest form of a lens, the optical unit, viz., the wedge-shaped lens commonly known as a prism.

FIG. 2.—Showing a Prismatic or Wedge-shaped Lens.

The Prism.—The prism is a transparent substance whose plain surfaces are not parallel to each other. (Fig. 2.) The thick edge of such a lens is spoken of as the *base;* the thin edge towards which the surfaces converge being the *apex.* Rays of light passing through a prism will be deflected *towards its base.* (Fig. 3.) When a light ray strikes the inclined surface of the prism one end of the wave crests is held back while the other proceeds uninterruptedly, until it, too, encounters the more resistent lens surface. The ray proceeds along its new course through the lens until the other surface is reached. One end of the wave crests emerging into the less resistent air advances faster than the other, until the whole wave-front has emerged, when the ray proceeds along its new course.

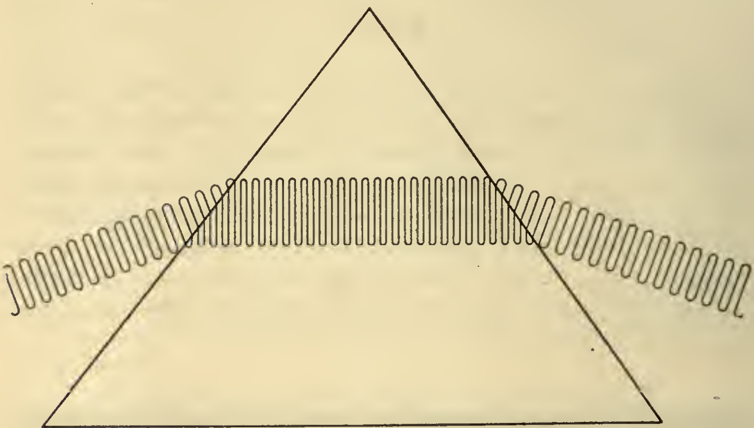

FIG. 3.—Showing the Deflection of a Light Ray Toward the Base of a Prism.

Spherical Lenses.—When the surface of a lens represents a section of a sphere, it is called a *Spherical Lens.* (Figs. 4 and 5.) Such a lens deflects light rays equally in all meridians.

FIG. 4.—Showing Sections of a Sphere to Represent Convex Spherical Lenses.

Spherical lenses may be *Convex* or *Concave*. When thickest at the centre, the lens is convex, commonly called "plus,"

FIG. 5.—Showing a Spherical Concave Surface.

and designated by the sign +. The effect upon a beam of light in passing through a convex spherical lens is to cause it to become a converging cone. (Fig. 6.) The apex of the

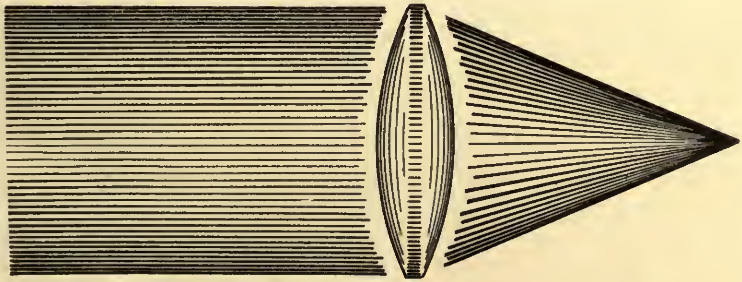

FIG. 6.—Showing the Convergence of a Beam of Light in Passing Through a Spherical Bi-Convex Lens.

cone, the point to which the rays centre, is known as the *Focus* of the lens.

When thickest at its periphery, the lens is concave, commonly called a "minus" lens, designated by the sign —. A beam of light in passing through a concave spherical lens

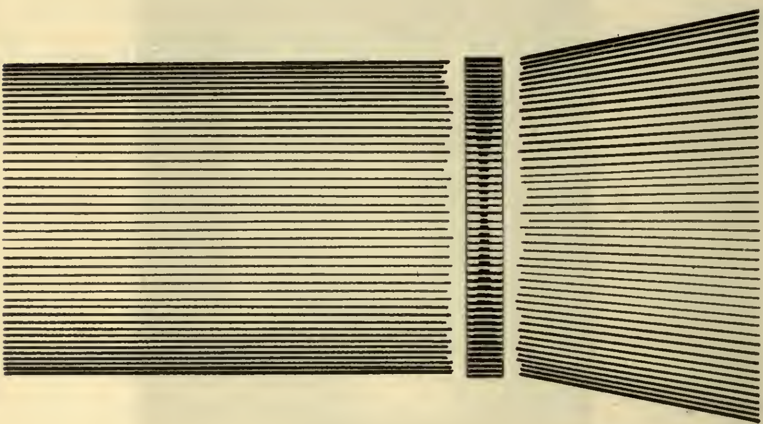

FIG. 7.—Showing the Divergence of a Beam of Light in Passing Through a Spherical Bi-Concave Lens.

becomes shaped like a diverging cone truncated at the surface of the lens. (Fig. 7.) Projected backward through the lens the boundary lines of this cone reach a point on the side

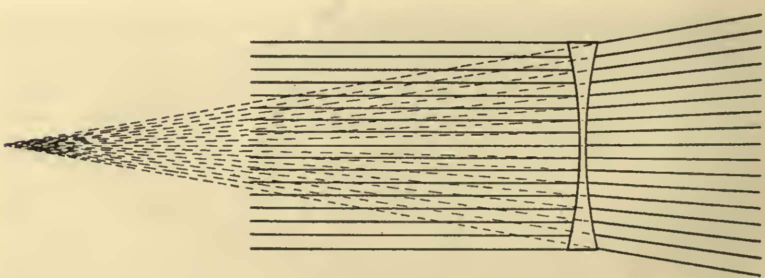

FIG. 8.—Showing the Virtual Focus of a Concave Lens.

from which the light enters. This point is known as the "negative" or "*virtual focus*" of the concave lens. (Fig. 8.)

It has long been customary to consider a convex lens as made up of prisms, placed base to base, and a concave lens as made up of prisms placed apex to apex, (Fig. 9.) Their effect upon rays of light is thus readily explained. But to be more exact, the two surfaces of a spherical lens should be considered as made up of the sides of an infinite number of prism sections. When the bases of these prism sections are directed toward the *centre* of the lens, it is convex; when they are directed toward the *edge* of the lens, it is concave. (Figs. 10 and 11.) In both concave and convex lenses, the

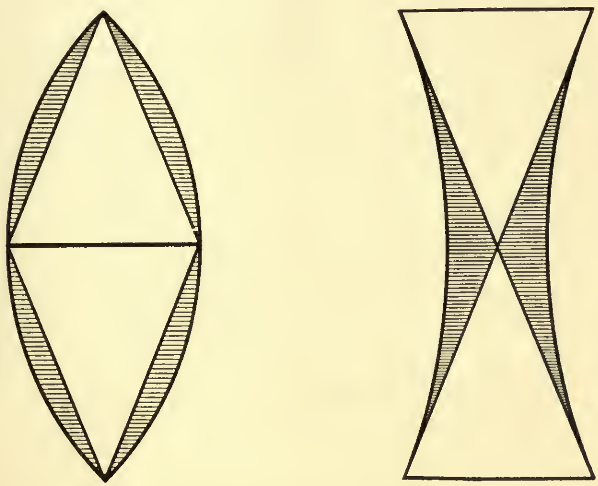

FIG. 9.—Showing How Spherical Lenses may be Considered as made up of Prisms.

angle formed by the two surfaces of the prism sections increases from the centre outward. At the centre the two surfaces are parallel and, therefore, have no refractive effect at that part of the lens, if the light enters perpendicularly. At the periphery the prismatic angle is largest, hence the refractive effect is greatest.

A straight line, perpendicular to both surfaces of the lens and passing through its centre of curvature, is called the *Principal Axis*. The *Focus*, whether it be the real focus of the convex lens, or the virtual focus of the concave lens, is

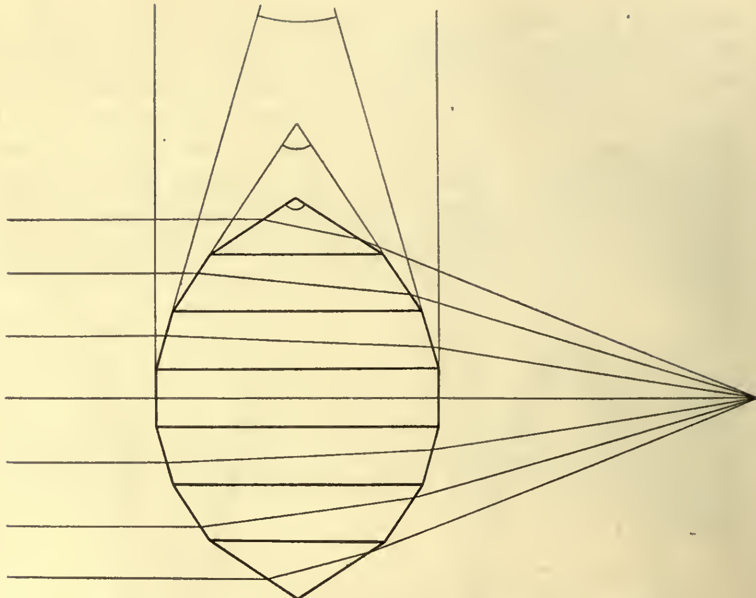

FIG. 10.—Showing Convex Spherical Surfaces as made up of Prism Sides.

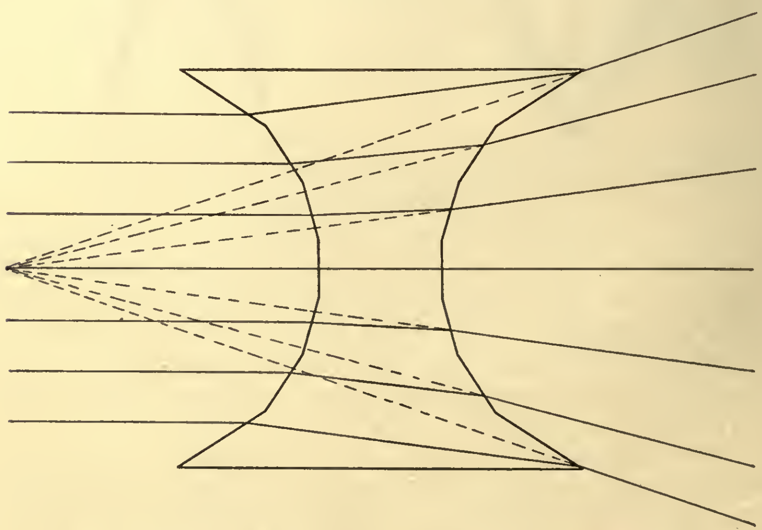

FIG. 11.—Showing Concave Spherical Surfaces as made up of Prism Sides.

found in the Principal Axis. The distance of the focus from the lens is called the *Focal Distance*.

The *Optical Centre* of a lens is that point on the principal

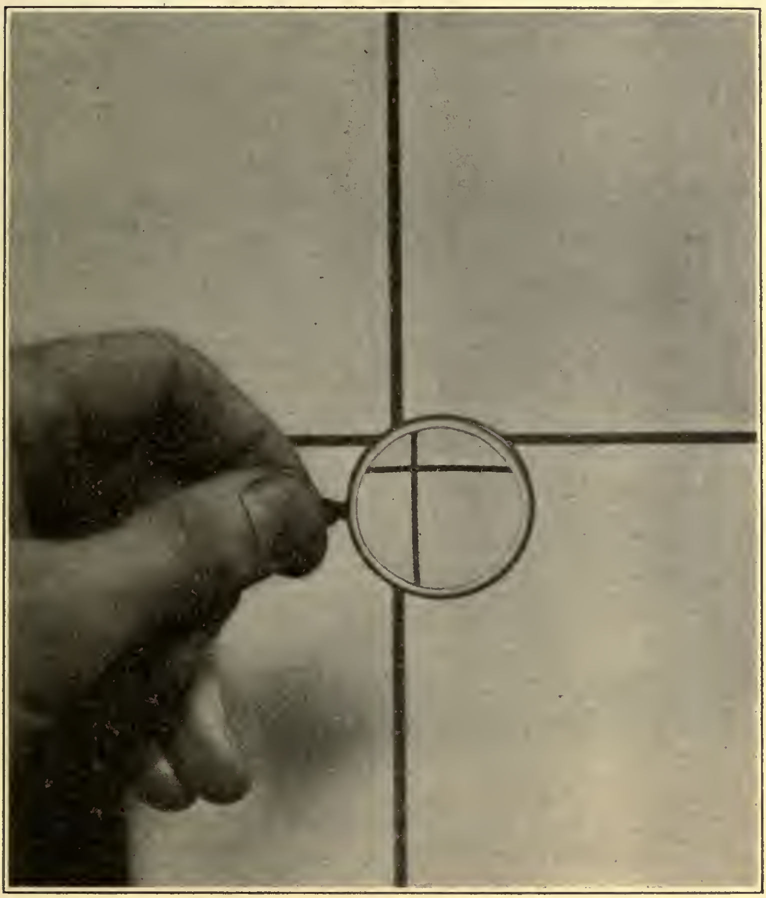

FIG. 12.—Showing Method of Determining the Optical Centre of a Lens.

axis and within the substance of the lens, through which rays coming from all directions pass without altering their course. It may be found by viewing the corner of a test card or other object presenting a right angle. When the two lines seen through the lens are continuous with those outside of it, the point of the angle will coincide with the optical centre of the lens. (Fig. 12.)

Cylindric Lenses.—When a lens diverts light rays in one plane only, it is called a *Cylindric* or *Astigmic Lens*. This is made by cutting lengthwise through a solid cylinder or

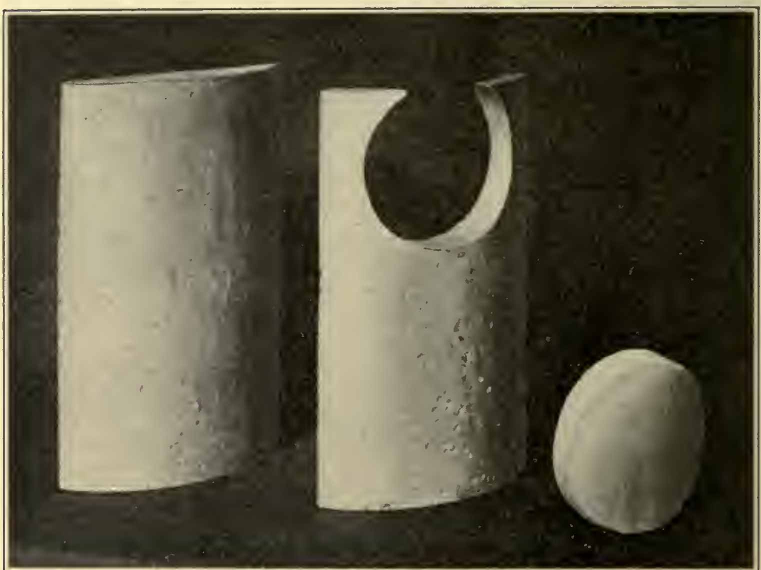

FIG. 13.—Showing Convex Cylindric Lens.

rod of glass, splitting off a shaving, as it were. (Fig. 13.) The resulting segment, of course, will have one plane and one cylindric surface, constituting a plano-cylindric lens. The *axis* of such a lens coincides with the axis of the rod from which it is cut; in other words, it corresponds to the lead of the lead-pencil, were that the cylinder from which the shaving came.

A cylindric lens causes transmitted rays to meet, not at a focal point, as happens with a spherical lens, but in a focal line. A beam of light, after passing through such a lens, becomes wedge-shaped. (Fig. 14.) The sharp edge of the wedge is the focal line and this lies parallel with the axis of the lens. The plane in which light rays are deflected by a

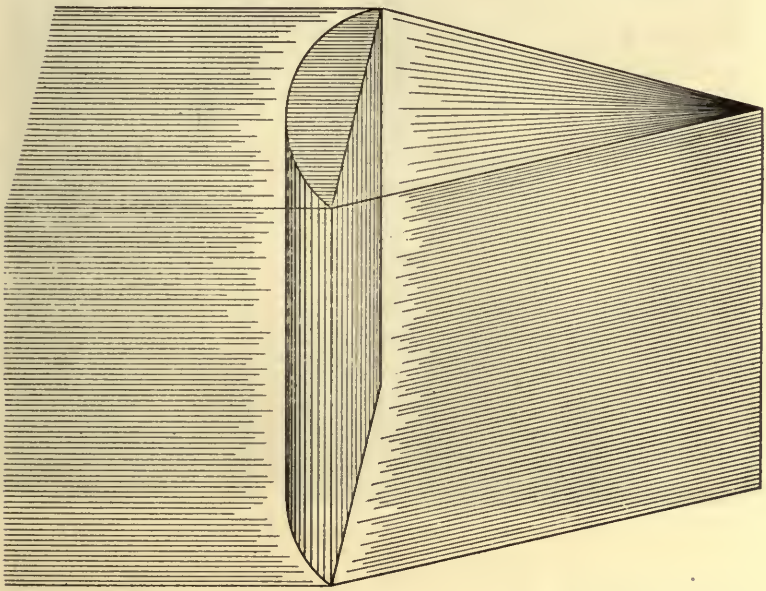

FIG. 14.—Showing Effect on a Beam of Light Passing Through a Cylindric Lens.

cylindric lens is, therefore, at right angles to the axis; the rays lying in a plane with the axis remain unchanged.

Cylindric lenses, or Cylinders, as they are called, may be convex or concaves according as they cause transmitted rays to converge or diverge.

In describing a cylindric lens, it is necessary to indicate its axis (the non-refracting meridian). With the lens in its

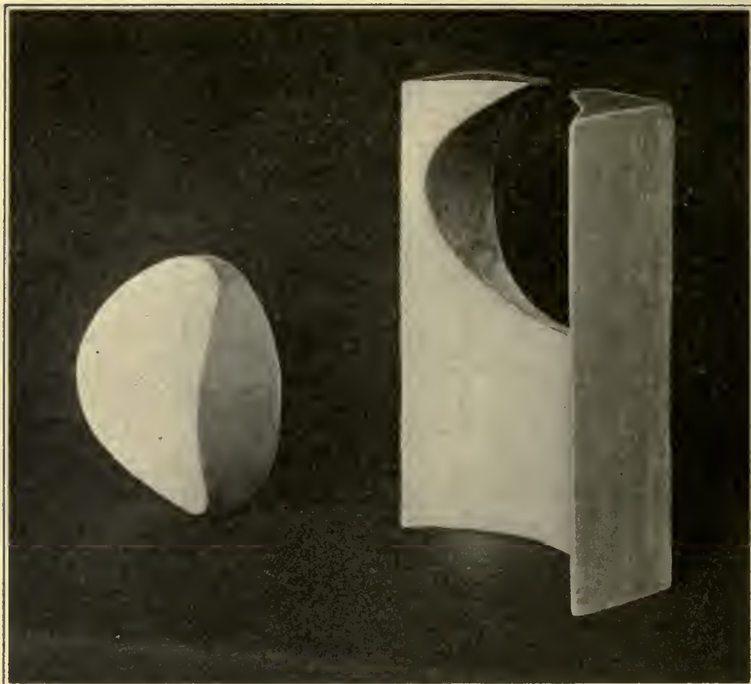

FIG. 15.—Showing a Concave Cylindric Lens.

proper position before the eye, the axis is indicated in degrees of a semi-circle numbered from right to left. If the

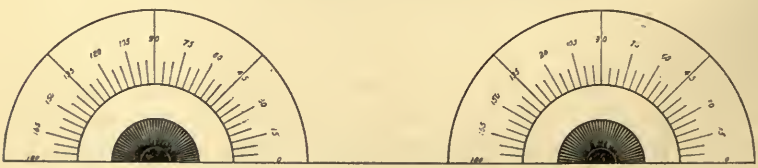

FIG. 16.—Showing How the Axis of a Cylindric Lens is Indicated.

axis lies horizontally, it is denoted as 180°, if vertically, as 90°, etc. (Fig. 16.)

PROPERTIES OF LENSES.

Convex Spherical Lenses.—From what has been said it will be seen that:

1. *Parallel* rays passing through a spherical convex lens are made to converge to a point, or *focus*. The distance of this point from the centre of the lens, measured along the *principal axis*, is called the *focal distance*.

Conversely, rays proceeding from the principal focus of a convex lens are rendered parallel by the action of the lens.

2. *Divergent* rays, after traversing such a lens, unite at a point farther away from the lens than the principal focus.

Conversely, rays proceeding from a point farther from the lens than its principal focus emerge from it as convergent rays.

3. *Convergent* rays, refracted by a convex lens, meet at a point nearer to the lens than its principal focus.

Conversely, rays emanating from this point are, upon refraction, made less divergent.

Concave Spherical Lenses.—Parallel rays after passing through a concave lens diverge as though emitted from a point on the side from which the light emanates. This point is the "virtual" focus of the lens and its distance from the lens is the "negative" focal length.

Rays converging to meet at this point become parallel after passing through the lens.

Cylindrical Lenses.—The same properties characterizing spherical lenses apply to cylinders, but in one meridian only, viz., at right angles to the axis.

VARIETIES OF LENSES.

Every lens has two refracting surfaces, the shape and relative position of these surfaces to each other determining the power and refracting properties of the lens. (Fig. 17.) Both surfaces may be plane, spherical, or cylindrical, or one surface may differ from the other; therefore, a large variety of lenses may be ground. Those in common use are the following:

1. Plano; 2. Prismatic; 3. Plano-convex Spherical; 4. Plano-concave Spherical; 5. Plano-convex Cylindrical; 6. Plano-concave Cylindrical; 7. Biconvex Spherical; 8. Biconcave Spherical; 9. Concavo-convex (two varieties): (a) The Convex surface having a greater radius of curvature than the concave, forming a lens called the Converging Meniscus, (b) The Convex surface having a lesser radius of curvature, forming the Diverging Meniscus; 10. Convex Sphero-cylindrical; 11. Concave Sphero-cylindrical; 12. Biconvex Cylindrical; 13. Biconcave Cylindrical; 14. Concavo-convex Cylindrical (with axes crossed). A prism may

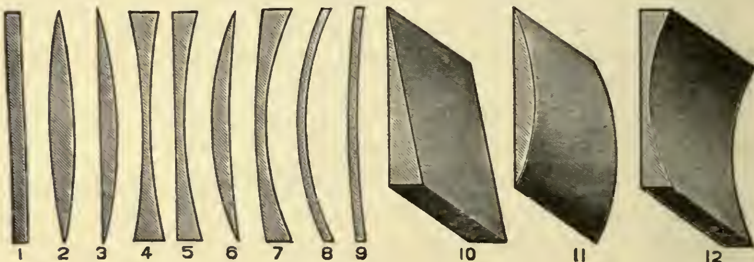

FIG. 17.—Showing Varieties of Lenses, viz.: 1, Plano; 2, Bi-Convex Spherical; 3, Plano-Convex Spherical; 4, Bi-Concave Spherical; 5, Plano-Concave Spherical; 6, Converging Meniscus; 7, Diverging Meniscus; 8, Coquille; 9, M'Coquille; 10, Prism; 11, Convex Cylindrical; 12, Concave Cylindrical.

be introduced as an element in each of the above named lenses, thus doubling the list of possible forms of lenses. And, lastly, we might add the so-called "toric" lenses, mention of which will be made in a subsequent chapter. (See p. 115.)

SYSTEMS OF LENS MEASUREMENTS.

Up to this point we have been dealing with the subject in the abstract. To make the science of Refraction practical, it is necessary to determine exact values. To accomplish this end we must adopt a standard of measurements.

The English System.—Inasmuch as a lens of great refractive power causes the rays of light to converge at a shorter focal distance than does one of less refractivity, the focal distance expresses the strength of a lens. Thus, a spherical lens with a focal distance of ten inches is twice as strong as one with a focal distance of twenty inches. The strength, likewise, of a cylindrical lens signifies the distance of the *focal line* from the optical centre of the lens. The strength of a lens, then, may be expressed in terms of its focal distance in inches. Under the old English system this was the accepted method. Since the strength of a lens is inversely proportional to its focal length, this method necessitates the use of fractions in making deductions. Consequently, it is confusing and laborious. Furthermore, the inch varies in different countries, and measurements under this standard are uncertain and scientifically unreliable.

THE METRIC SYSTEM.

That in common use to-day is a better system, and has almost completely supplanted the inexact and cumbersome methods of the past. It was introduced by Nagel in 1867, and is an adaptation of the metric system of measurement. Instead of computing focal lengths, its values designate the refractive power of a given lens as compared with one of known strength adopted as a standard. This standard is a lens whose focal distance is one meter (39.36 inches), the "Meterlens" of Nagel, and is called a Diopter (Monoyer).

A lens, then, having a focal distance of one meter is said to have the refractive power of one diopter. The strength of any given lens is expressed in terms of decimals or multiples of this standard. For instance, a lens of 2.50 D. (diopters) has two and one-half times the refractive power of the standard lens, or a focal distance two and one-half times shorter; a lens of .50 D. strength has one-half the refractive power of the standard, and, of course, a focal length of two meters.

The following table shows the strength of lenses in diopters and their corresponding focal lengths in English inches and in centimeters:

TABLE I.

Diopters.	Focal length in English inches.	Focal length in centimeters.	Diopters.	Focal length in English inches.	Focal length in centimeters.
0.25	160	400	5.0	8	20
0.50	80	200	5.50	7.50	18
0.75	60	133	6.0	7	16
1.0	40	100	7.0	6	14
1.25	35	80	8.0	5	12.5
1.50	30	66	9.0	4.50	11
1.75	25	57	10.0	4	10
2.0	20	50	11.0	3.75	9
2.25	18	44	12.0	3.50	8.3
2.50	16	40			
2.75	14	36	14.0	2.25	7.1
3.0	12	33	15.0	3.00	6.6
3.50	11	28	16.0	2.50	6.2
4.0	10	25	18.0	2.25	5.5
4.50	9	22	20.0	.2	5

PRESCRIPTION FOR LENSES.

For the purpose of writing prescriptions the following signs and abbreviations are used:

ABBREVIATIONS USED IN REFRACTION.

V. . . . . Vision (seeing power of the eye).
O. D. . . . . Oculus dexter (right eye).
O. S. . . . . Oculus sinister (left eye).
O. U. . . . . . . Oculi utrique (both eyes).
S. or Sph. . . . . Spherical lens.
C. or Cyl. . . . . Cylindrical lens.
D. . . . . Diopter.
+ . . . . Plus or Convex.
— . . . . Minus or Concave.
= . . . . Equal to.
⊂ . . . . Combined with.

The prescription "+ 1 D. S. ⊂ + .25 D. C. Ax. 90°," deciphered by the aid of this table, would read: "Plus one Diopter Spherical combined with plus one-quarter Diopter Cylindrical at axis 90 degrees" (vertical).

NEUTRALIZATION OF LENSES.

To gain an intelligent conception of a lens, three points must be taken into account, viz., its character, its form, and its strength. According to the first, a lens is either convex or concave; its form determines whether or not it is spherical, cylindrical or both; while its strength expresses in diopters its refractive power.

If a convex lens be moved from side to side in front of the eye, an object viewed through it will appear to be in motion, its displacement being in the direction *opposite* the movement of the lens. With a concave lens the reverse is true, the object apparently moving *with* the lens. This truth, known in physics as Parallactic Displacement, affords a ready means of determining the character, kind and strength of a lens.

When the object viewed through the lens moves equally in all meridians, the lens is *spherical*. If a meridian is found at which there is no apparent displacement, the lens is cylindrical, and the meridian producing no displacement indicates the axis of the cylinder. If the object moves in all directions, but more in one direction than in another, the lens examined is a sphero-cylinder, known also as a compound or combination lens. The same simple method, therefore, which served to determine the character of the lens examined will also indicate its kind.

When a convex and a concave lens of equal strength are placed together, they neutralize each other. Moving them from side to side in front of the eye will produce no apparent displacement of an object viewed through them. The strength of a lens, therefore, may be determined by placing over it successively lenses of opposite character and of different degrees of refractive power until a lens is found which nullifies the apparent motion of the viewed object. Knowing the focal distance of each neutralizing lens, the strength of the lens in question is readily determined by this method.

The following are a few hypothetical cases, intended to assist in mastering this method of identifying the kind, character and strength of lenses:

(a) On moving the lens through different meridians before the eye, objects are apparently displaced in an opposite direction and equally in all meridians. It is, therefore, a convex spherical lens.

Beginning with the weakest lens in the trial case, and trying lenses of increasing powers, we find the lens in question is neutralized by placing over it a concave spherical lens of 1.25 diopters strength. The prescription for the lens tested is, therefore, + 1.25 D. S.

(b) Viewed through this lens, we find the object apparently moving with the lens in all meridians except the horizontal. We have, therefore, a concave cylinder.

Neutralizing with convex cylinders of increasing powers and placed horizontally, we find that all apparent displacement ceases with a lens of +1.62 diopters. The examined lens, therefore, is a −1.62 D. C. Ax. 180°.

(c) The next lens causes an apparent movement against the lens, more pronounced in one meridian than in another. It is, therefore, a combination of a convex spherical and a cylindrical lens.

We now have two values to determine, and for the sake of convenience, we begin with the spherical. It is found that after a concave spherical lens of .50 D. strength is placed over the lens in question, there remains a slight movement, in the opposite direction, of the object viewed; a concave lens of .75 D. causes a slight displacement in the same direction. The former is, therefore, too weak, the latter too strong, while a .62 D. is found to neutralize the lens exactly, *in one meridian.* In the meridian at right angles to this the object still continues to move in the opposite direction. Instead of one lens, the .62 D., we now add concave cylinders of different strength, with the axis of each coinciding with the non-refracting meridian of the unknown lens, until one is found which does away with any motion of the viewed object. This result is met with a −1 D. cylinder at axis 75°. The strength of the lens in question, then, is expressed by the prescription: + .62 D. S. ⌢ + 1 D. C. Ax. 75°.

Other Methods.—Another method of recognizing a cylindrical lens is by viewing through it a straight line, *e. g.*, a vertical window sash, steam pipe or the edge of a door. If the lens be rotated in its plane, that portion of the line seen through the lens will be tilted to a greater or less degree, depending upon the strength of the lens and the extent of its rotation. (Fig. 18.) In one position only will the line appear continuous, viz., in the non-refracting meridian of the lens or its axis. This fact is utilized, not only in determining the kind of lens, but also in estimating its strength, for having found the axis, by superimposing known cylinders of opposite character with axes coincident, the lens can be readily neutralized. When so neutralized, it may be revolved with-

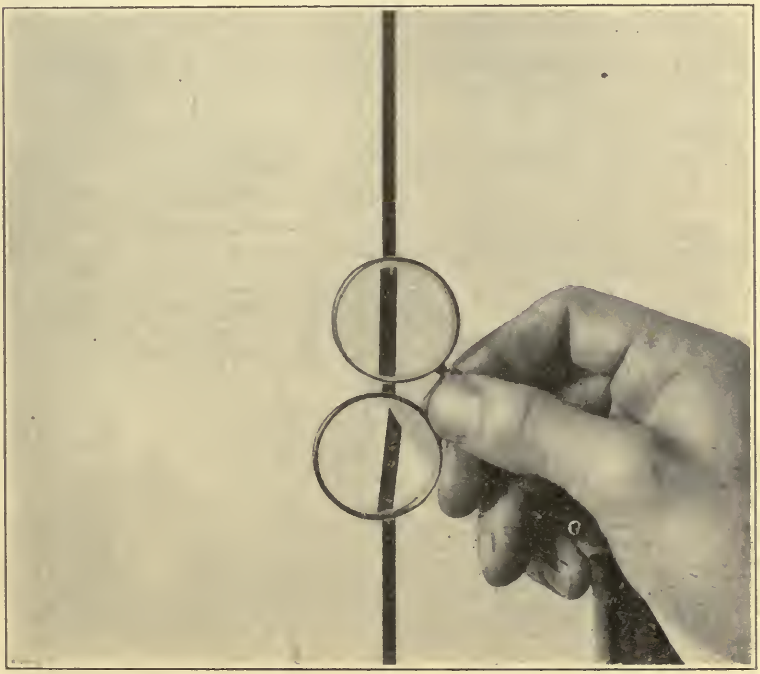

FIG. 18.—Showing Break in Continuity of a Line Caused by Tilting a Cylindrical Lens.

out causing any break in the continuity of the straight edge mentioned.

Measuring the Strength of a Prism.—It is often necessary to determine the strength and position of a simple prism, or of a prism incorporated in a given lens. A prism has no focussing power, forms no images and shows no parallactic displacement. That the given lens is a prism or contains a prism may be determined by first fully neutralizing the refractive features of the lens and then viewing through the lens the edge of an open door, or other surface having a straight border. The portion of the straight edge seen

FIG. 19.—Showing the Effect of a Prismatic Lens.

through the lens will be displaced in the direction of the apex of the prism. (Fig. 19.) By neutralizing with known prisms, their bases overlying the apex of the unknown lens, when the straight edge appears continuous both in and out of the lens, the strength of the prism has been determined.

Mechanical Devices for Measuring Lenses.—A number of

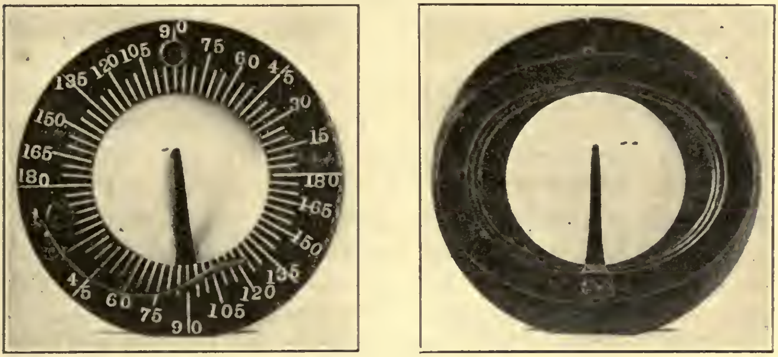

FIG. 20.—Showing Authors' Axis Finder.

devices have been marketed for the purpose of facilitating the neutralization of lenses and determining with accuracy the axis of a cylinder. Such a device is illustrated in Fig. 20,

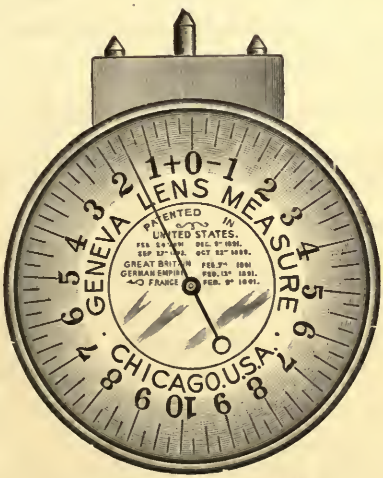

FIG. 21.—Showing a Lens Measure.

and is known as an *Axis Finder.* The rear aspect shows a number of chambers adapted to lenses of standard sizes, while the front view shows two springs for the reception of neutralizing lenses. The radiating lines indicate the meridians in degrees of a circle. When the unknown lens has been properly neutralized the non-refracting meridian of the neutralizing cylinder will be continuous with one of these radiating lines, the degree number indicating the axis of the cylinder tested.

The strength of a lens may also be determined by means of a lens measure. (Fig. 21.) The three pointed rods of the instrument are brought against the surface of the lens to be tested, the middle rod lying against the center of the lens. If either the instrument or the lens be slowly revolved so that the three pointed rods shall successively lie in each and every meridian, the curvature, *i. e.*, the refractivity, of each will be indicated on the dial. The surface of a spherical lens is curved equally in all meridians and gives but one reading. That of a cylindric lens is not curved in the meridian of its axis, while the meridian at right angles to the axis gives the greatest reading and is the measure of the strength of the cylinder.

The average measure, although a convenient contrivance, is not entirely accurate in its results, especially when testing lenses of high refractivity.

THE RELATIONSHIP OF LENSES.

There exists between the different kinds of lenses a well defined relationship which we may here discuss with profit. There is a similarity of refractive effect by which one lens, or a combination of lenses, may sometimes be made to do the work of another entirely different lens or combination. In studying the neutralization of lenses, we found that lens values may be added and subtracted the same as any other values. Not only is this true with regard to lenses of the same character, as, for instance, the addition of a + 1 D. S. to a − .50 D. S. making a + .50 D. S., or a + 1.50 D. S. to a + 2.50 D. S. making a + 4 D. S., but also lenses of different character may be added or subtracted in a similar manner. A − .50 D. Cyl. may be added to a + .50 D. S., leaving a + .50 D. Cly. at the opposite axis. We will consider, first:

The Relationship Between Spheric and Cylindric Lenses.

—A cylindric lens of any given strength has just one-half the total refraction of a spherical lens of the same strength or number. This will at once become clear if we consider every spherical lens as composed of two cylindrical lenses of the same character and number with their axes at right angles to each other. Thus a + 1 D. spherical may be considered as made up of a + 1 D. cylinder at one axis with a + 1 D. cylinder at right angles to the former. Likewise, if we place over a + 1 D. spherical lens a − 1 D. cylindrical, at the horizontal axis, what have we left? A + 1 D. cylinder at the vertical axis; in other words, we have neutralized one of the two cylinders of which the sphere was composed and we have left the other component cylinder. It follows as a self evident fact, that in adding two cylinders of like characters, but of opposite axes and different powers, to form a sphero-cylindrical lens, that the weaker cylinder determines the strength of the sphere, the remainder of the stronger cylinder retaining its identity. Thus: + 1 D. C. Ax. 90° $\bigcirc$ + .75 D. C. Ax. 180° = + .75 D. S. $\bigcirc$ + .25 D. C. Ax. 90°.

To become proficient in lens computations it will be well for the student to work out a number of different examples similar to the following:

Example: + 1.25 D. S. − .50 D. C. Ax. 180° = + (1.25 D. C. Ax. 90°) + (1.25 D. C. Ax. 180°) − .50 D. C. Ax. 180° = + 1.25 D. C. Ax. 90° + .75 D. C. Ax. 180°. ℞ + .75 D. S. $\bigcirc$ + .50 D. C. Ax. 90°.

But the relationship between spheric and cylindric lenses is even closer, for the effect of a spherical lens placed obliquely in the path of luminous rays is actually identical with that of a cylinder. In fact, Young, who was the discoverer of ocular astigmia, believed the cylindric effect (Astigmia) of the refracting media of the eye to be due wholly to the oblique position of the crystalline lens. This cylindric effect increases with the degree of inclination of the lens.

The Relationship of Cylinders.—If a + 2 D. cylinder and a − 2 D. cylinder are so placed that their axes correspond they will neutralize each other. When, however, they are turned about their centres so that their axes are at right angles to each other, they vary constantly in their respective refractive powers, as the two cylinders approach right angles. When they lie in opposite meridians they exercise a combined cylindric effect equal to the sum of the power of the two lenses, viz., 4 D.

The Relationship of Spheres to Prisms.—A spherical lens is theoretically composed of a large number of prisms, base in or out, according as the lens is convex or concave. This was mentioned and illustrated when considering spherical lenses (q. v.).

There exists, however, a practical, as well as a theoretical relationship between spherical and prismatic lenses.

Between the optical centre of a spherical lens and the periphery, the refractive effect is that of a sphere with the addition of a prism. This phenomenon is most apparent in a lens in which the thickest or thinnest point does not lie equi-distant from the periphery. Such a lens is said to be *decentered*. A glance at the accompanying Fig. 22 shows

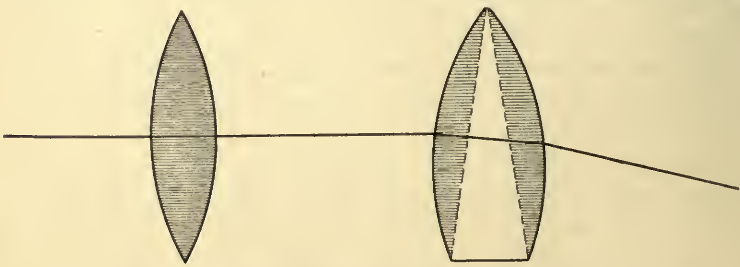

FIG. 22.—Showing Prismatic Effect of Decentering a Lens.

a section of a decentered lens which is seen to be precisely the same as though a normally centered lens had been split flatwise and a prism had been introduced between the halves. The strength of the added prismatic effect depends, of course, upon the strength of the lens and the extent to which it has been decentered. This relationship has been accurately determined and tabulated and may be found in detail in some of the more pretentious works on Refraction.

The Relationship of Cylinders to Prisms.—A cylindrical lens, or the cylindrical element of a sphero-cylindrical lens, when decentered in a direction vertical to its axis, shows the prismatic effect of a spherical lens of the same strength.

CHAPTER III.

THE NORMAL EYE.

INTRODUCTION.

The percentage of eyes approaching more or less closely to a condition which would be counted as normal is relatively small (not more than 2 to 10 per cent.), yet it will be necessary to consider the optical properties of such an eye before entering upon a discussion of abnormal conditions. As health and disease are relative terms there must be a standard upon which to base our comparisons and computations. *Emmetropia* is the ideal state of refraction and the Emmetropic eye is one of perfect morphology and function. In such an eye parallel rays of light fall exactly upon the retina without effort of accommodation. The Emmetropic eye, then, is the end and aim of the refractionist.

REQUISITES OF VISION.

In the emmetropic eye the three requisite conditions to perfect vision are met, viz., 1. The pupillary aperture is free from all obstructions and the media are clear and transparent; 2. The refracting surfaces are such as to focus *parallel* rays *exactly* upon the retina; 3. The retina is sufficiently sensitive to perceive the image created.

DIOPTRIC SYSTEM OF THE EYE.

We shall here consider briefly the individual factors entering into the *Dioptric System*, or optical mechanism of such an eye. Primarily the dioptric system is composed of the Cornea, Aqueous Humor, Crystalline Lens and Vitreous. Since the two surfaces of the cornea are practically parallel and its index of refraction is the same as that of the aqueous, these two media may be considered as one. The anterior surface of the cornea is the most active of all the refracting surfaces of the dioptric system, because the difference between the refracting indices of air and the aqueous humor is greater than that of any two contiguous media in the interior of the eye (see Optical Principles).

The Crystalline Lens is not homogeneous, but consists of a spherical nucleus having a very high refractive index and of a great number of superimposed layers whose curvature and refractive index decrease from within outward. This structure has the effect of: 1st, Diminishing the spherical aberration and, 2d, Giving the lens a greater refractive power than would be possible with a homogeneous body of the same shape (Landolt). The vitreous is a homogeneous medium, the refractive index of which is the same as that of the cornea and aqueous.

STATIC REFRACTION.

Acting together the dioptric surfaces effect the *Static Refraction* of the eye, producing distinct retinal images, with the optical mechanism in a state of repose. The pupil may be slightly contracted, but otherwise muscular activity is suspended and no effort is needed for distinct vision. The visual axes are practically parallel and the eye is focussed for its far point or *Punctum Remotum* (which in the emmetropic eye lies at infinity).

DYNAMIC REFRACTION.

While the eye is focussed for distant vision a near object will appear indistinct. To see this near object clearly, the distance between the observer and the object viewed remaining constant, it is necessary to change the focus. A photographer has to focus his camera in order to obtain a clearly defined image on his plate. To do this he has the choice of four methods of procedure, viz.: 1. To move the object viewed, the lens and plate remaining stationary; 2. To move the lens, the object and plate remaining stationary; 3. To move the plate, the object and lens remaining stationary; 4. To increase or decrease the refractive power of the lens.

In the human eye, inasmuch as the lens and retina are normally immovable, only two of the four means of focussing are possible. By approaching toward, or receding from the object viewed, and more especially by increasing to a greater or less degree the refractivity of the lens, the diverging rays of objects less than twenty feet distant are brought to a focus on the retina. This power of the eye to adjust itself for near vision is known as the *Dynamic Refraction* or *Accommodation.* When exercised to its highest degree the accommodation focusses the eye for its near point, or *Punctum Proximum.* The difference in the refractivity of the eye during maximum and minimum accommodation is called the range or Amplitude (Donders) of Accommodation and is, of course, expressed in terms of diopters.

PHYSIOLOGY OF ACCOMMODATION.

Two factors enter into the accommodation of the eye, viz.: 1. The normal resiliency of the Lens, and 2, the action of the Ciliary Body.

We are indebted to Helmholz for our knowledge of the physiology of accommodation and so complete were his researches as to leave little for modern investigators to add. The Ciliary Body consists essentially of two sets of muscles, one of which constitutes a sphincter (annular muscle of Müller), the other having a radial, longitudinal arrangement and lying parallel with the sclerotic. These fibres extend back into the choroid and have as their fixed point of attachment the corneo-scleral junction. The suspensory ligament of the lens, or Zonule of Zinn, is attached to the Ciliary Body under tension so that when this ligament is cut the lens, left to its own elasticity, becomes more convex.

The same phenomenon occurs by the action of the ciliary muscles as follows: When the lens is released from the tension of the Zonule of Zinn by the contraction of the sphincter fibres principally, the lens bulges. Both surfaces increase their convexity, the anterior more than the posterior. (Fig. 23.)

CONVERGENCE.

To secure binocular vision for near objects, it is not only necessary that the focus be regulated, but that the eyes

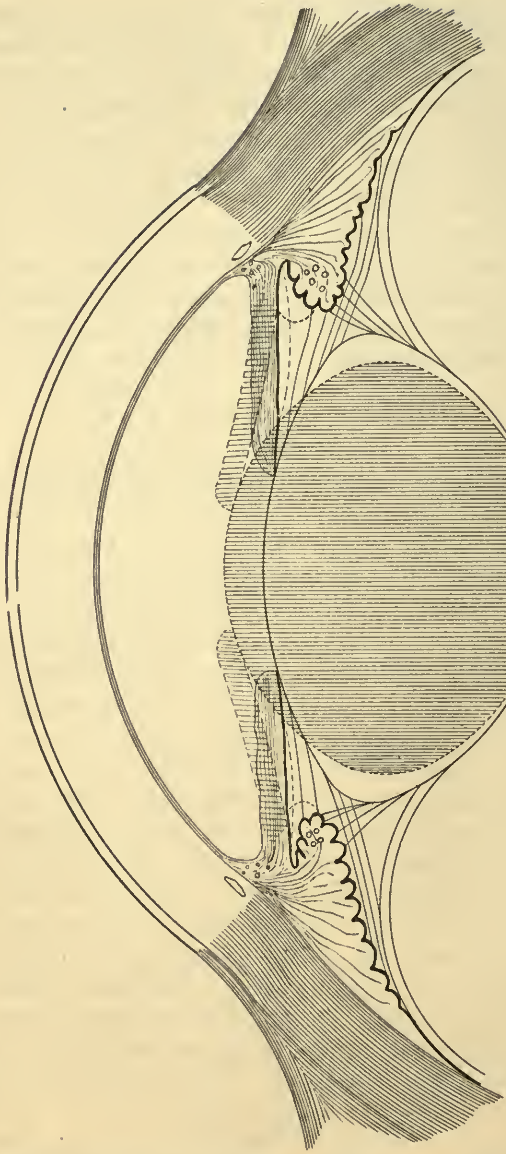

FIG. 23.—Showing Change in the Shape of the Lens During Accommodation.—(After Landolt.)

should rotate inward, the degree of rotation depending upon the nearness of the object. This phenomenon is known as *Convergence.* In the exercise of this function of the eye, the *fovea centralis*, which is the most sensitive portion of the retina, is so directed toward an object that the image is formed upon it. The eye is then said to "fix" the object; the images formed in the two eyes fall upon identical points and fuse so that the brain perceives but one. Should the images fall upon corresponding points above, below, to the right or left of the fovea they should likewise produce but a single impression. If, however, the image should fall upon points bearing a different relation to the fovea, as would be the case if the function of convergence were suspended or improperly performed, both images would be perceived. In other words, we would have a condition known as *Diplopia* or double vision.

For binocular distant vision the axes of the eyes must be parallel. For binocular vision at distances less than twenty feet the *Rectus Internus* muscle draws each eye inward to a degree inversely proportional to the distances of the object looked at. To measure the convergence intelligently we employ as a unit the angle through which the visual axis of the eye moves to fix on a point one meter distant—the meter-angle of convergence (Nagel). If the object viewed be only one-half meter distant the amount of convergence necessary will be two meter-angles, and conversely at two meters distance the convergence would be one-half meter-angle. The same number which expresses the diopters of accommodation necessary for distinct near vision also expresses the amount of convergence in meter-angles. For when the object viewed is one-half meter distant and the convergence is two meter-angles the amount of accommodation brought into play is two diopters, and again, conversely, at two meters distance the amount of convergence is one-half meter-angle and the accommodation required one-half D.

The *amplitude* of convergence is the number of meter-angles of convergence of which the eyes are capable in passing from a condition of complete relaxation—far point of convergence—to one of maximum convergence or the near point.

RELATIONSHIP OF ACCOMMODATION, CONVERGENCE AND PUPILLARY CONTRACTION IN THE EMMETROPIC EYE.

From the above facts it will be seen that accommodation and convergence are very closely associated, inasmuch as both increase and decrease together and to the same degree. This relationship, however, is not absolute, for it is possible for the eye to fix upon a given point and with convergence stationary to increase or decrease its accommodation and, conversely, to focus for a given distance and without altering this focus, to increase or decrease the convergence angle. The former is known as the *relative amplitude of accommodation*, the latter as the *relative amplitude of convergence.*

Throughout the *physiological* range of accommodation and convergence in the emmetropic eye their relationship may be said to be absolute, beyond this limit, relative. For, when the eye is adjusted for its Punctum Remotum, the accommodation may be relaxed still more, and when the accommodation is at its maximum, the amount of convergence associated is not only relatively greater, but is capable of a considerable increase. Advancing age, as will be shown hereafter, diminishes the power of accommodation to a point of total suspension, yet has no effect upon the function of convergence.

The Iris plays an unimportant rôle in connection with the accommodation, in fact, this membrane may be entirely wanting without greatly disturbing the power of accommodation. Normally, however, the pupil contracts during accommodation, and dilates when the latter is relaxed. The nerves supplying the ciliary muscle belong to the Motor Oculi, which contain also the fibres distributed to the sphincter of the pupil. Their origin seems to be in the floor of the fourth ventricle. Irritation of the *anterior* portion of the floor produces *accommodation;* irritation *farther back* causes *contraction of the pupil* and, when that part, where the fourth ventricle passes into the Aquæductus Sylvii, is irritated, contraction of the Rectus Internus results. Generally speaking, pupillary contraction is more closely associated with convergence than with accommodation, for it takes place with convergence in the absence of accommodation. The following table will serve as a summary of these facts:

TABLE II.

SHOWING THE RELATIONSHIP OF ACCOMMODATION, CONVERGENCE AND PUPILLARY CONTRACTION.

The Eyes.	Accommodation.	Convergence.	Pupillary Action.
When adapted to the Punctum Remotum	Relaxed, but has some reserve capacity.	Completely relaxed. Visual axes parallel.	Pupil dilated.
When adapted to Punctum Proximum.	Maximum power exerted.	Exercised to a greater degree than is accommodation and can be increased.	Pupil contracted.
Under Mydriatics.	Relaxed.	Activity decreased.	Pupil dilated.
Under Myotics.	Increased.	Possible action increased.	Pupil contracted.
Advancing Age.	Decreased to a point of total suspension.	Not affected.	Pupil contracted.

OPTICAL DEFECTS OF THE NORMAL EYE.

We have spoken of the Emmetropic eye as one of perfect morphology and function, yet this is a theoretical conception. Such an eye does not exist and, from a practical standpoint, instead of associating the idea of "perfection" with the term Emmetropia, we must be content to accept the Emmetropic eye as the "normal" eye, the standard by which we are to judge anomalies. This normal eye, although the most wonderful of all the organs of the body, the most intricate and complex in its construction, marvelous in its detail and delicate in its adjustment, nevertheless shows many glaring defects. "Many of these," says Bidwell, "are the more striking because they are so obvious. The external surface of the lens formed by the aqueous humour and the cornea is not a surface of revolution, such as would be fashioned by a turning lathe or a lens grinding machine; its curvature is greater in a vertical than in a horizontal direction, and the distinctness of the focussed image is consequently impaired. Again, the crystalline lens is constructed of a number of separate portions which are imperfectly joined together. Striæ occur along the junctions, and the light which traverses them instead of being uniformly refracted is scattered irregularly. Moreover, the system of lenses is not centered upon a common axis; neither is it achromatic, while the means employed for correcting spherical aberration are inadequate."

These defects, being inherent in the design or structure of the eye itself, produce anomalies which we may classify as *physical* in comparison with those of *psychic* origin. The latter result from the erroneous interpretations placed by the mind upon the phenomena presented to it through the medium of the optic nerve and the brain. Under this head may be classified the many strange manifestations known as "Optical Illusions."

In spite of the many defects set forth, however, our eyes do us excellent service because with incessant practice we have acquired a very high degree of skill in their use. Bidwell says, tersely: "If anything is more remarkable than the ease and certainty with which we have learned to interpret ocular indications when they are in some sort of conformity with external objects, it is the pertinacity with which we refuse to be misled when our eyes are doing their best to deceive us."

CHANGES OCCURRING DURING THE LIFE HISTORY OF THE EYE.

In addition to the ocular defects enumerated there must be mentioned certain changes occurring in the eye at different periods of its life history, changes which are prejudicial to good vision. By reason of the regularity and uniformity with which these changes take place, they are looked upon as physiological, and are necessarily incident to the two periods of life, viz., that of growth and development and that of decline (senility). When we consider that the eye continues to develop for many years and that throughout this growth a very accurate and definite relationship must be maintained between its component parts, we can readily appreciate the wide range of possible refractive errors to which the dioptric system is subjected. And when we take cognizance of the many and varied uses and abuses to which the eyes are subjected during the life of the individual, the frequency of refractive errors ceases to be an object of wonder.

Nearly all eyes are far-sighted at birth. This is owing to the fact that the eye-ball has not reached its full size and is, therefore, too short to bring parallel rays to a focus on the retina. In this condition, known as *Axial Hyperopia*, or *far-sightedness*, parallel rays focus too *far* behind the retina. Not only is this condition found to exist in the new-born, but it continues for a longer or shorter period and is still the rule at ten years, although the power of accommodation, which has a wider range of activity in youth than at any other time of life, usually serves to overcome the anomaly in whole or in part.

The pupil, which is very much contracted in new-born infants, soon becomes more dilated, smaller again in adult life and still more contracted in old age. Its activity is greatly lessened in the decline of life, owing to the unyielding character of the tissues of the iris, especially that of the Sphincter Pupillæ.

The accommodation of the eye shows a steady decline throughout life. The lens apparently partakes of the general tendency of the tissues of the body to become more rigid and unyielding as the age of the individual increases and hence the degree of convexity caused by the action of the ciliary muscle is proportionately decreased. While this is undoubtedly the prime factor in causing the functional decline of the accommodative mechanism, the laxity of fibre and muscular atrophy incident to old age must also be considered as playing an important rôle.

This gradual failure of the focussing power of the eye, known as Presbyopia, bears a very definite relationship to the age of the individual. Table 4, page 86.

VISUAL ACUITY.

In order that an object may be distinctly seen by the normal eye, it must be of such size as to subtend an angle of at least one minute, the eye being at the point of the angle. This fact is utilized in the construction of the Snellen test types, the limbs of which subtend an angle of one minute and the whole letter an angle of five minutes. (Fig. 24.) The size of the letter or object included

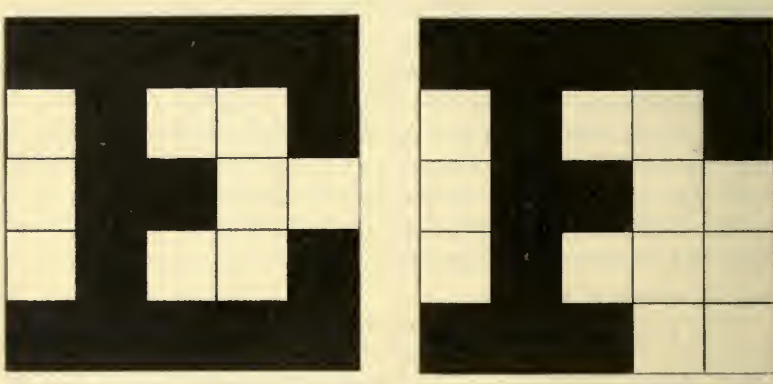

FIG. 24.—Showing Construction of Snellen's Test Letters.

in an angle of five minutes is, of course, constant for a given distance, increasing as it recedes from and decreasing as it approaches nearer the eye. (Fig. 25.) A Snellen test card

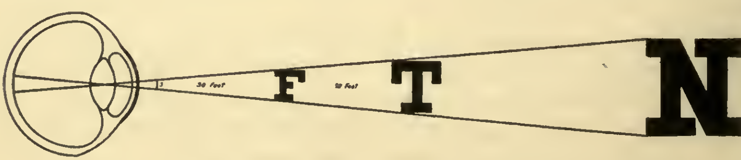

FIG. 25.—Showing Principle Involved in Snellen's Letters.

contains a number of letters of varying sizes arranged in rows, each row bearing a number expressing the distance in feet or meters at which its letters subtend an angle of five minutes, hence the distance at which they should be read by the normal eye. (Fig. 26.)

Seating a patient at a distance of twenty feet from the test card, (Fig. 27) (this distance being chosen because at this range rays of light are practically parallel), and testing one eye at a time, the lowest line the patient is able to read correctly is the measure of his visual acuity. This is recorded in terms of a fraction, the numerator of which expresses the distance of the patient from the test card and the denominator the number above the lowest line read. Hence V $\frac{20}{40}$,

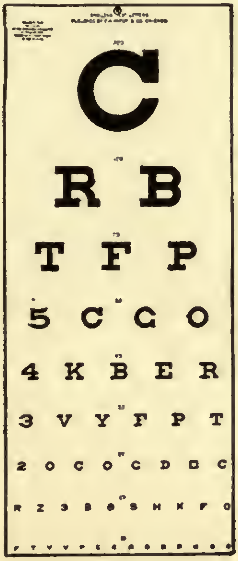

FIG. 26.—Showing Test Card.

would signify that at 20 feet the patient reads the line which he should be able to read at 40 feet. Visual acuity of $\frac{20}{20}$ should be looked upon as the minimum of the normal adult eye, most eyes of young people having an acuity of $\frac{20}{15}$ and even $\frac{20}{10}$. When the acuity falls below $\frac{20}{20}$, except in aged individuals, the eye is no longer to be considered normal.

In testing the acuity of vision the best possible illumination is necessary. When the test is made on cloudy days due allowance must be made for the apparent decrease in vision.

Tests may be conducted in a subdued light by means of porcelain test cards bearing transparent letters which are illuminated from the rear.

FIG. 27.—Showing Changeable Test Card.

CHAPTER IV.

ASTHENOPIA.

Under the term, Asthenopia, may be grouped the many and varied subjective symptoms complained of by patients suffering from some error of refraction. The word signifies "painful vision;" the underlying cause of the condition being exhaustion of:

(a) The Ciliary Muscle, producing what may be called *Accommodative Asthenopia*, or

(b) The Internal Recti Muscles, producing *Muscular* or *Convergence Asthenopia*, or

(c) A combination of both (a) and (b).

In the first form, the Ciliary Muscle is overtaxed by its efforts to overcome some refractive error. In the second, the Internal Recti Muscles are unequal to the task imposed on them. This failure of perfect function may be due to congenital weakness of the muscles; or, too wide separation of the eyes necessitates an excessive amount of convergence in order to bring each eye into perfect alignment. In the third form there is a combination of both these conditions and consequently a doubled cause for painful vision.

SYMPTOMS.

The more common symptoms complained of are headache, pain at the back of the eyes and around the eyes, any of the symptoms usually termed "neuralgia" of the head or face, conjunctival irritation, photophobia, lachrymation, spasm of the lids, blepharitis, apparent movement of objects steadily gazed at, blurring of vision, running together of the type, feeling of dryness of the lids, sensation of sand in the eyes requiring the patient to rub them for temporary relief, dizziness, and even pronounced functional nervous disturbances. While they vary greatly with the patient's general health, all of the symptoms are usually worse after a day's work, or on first waking in the morning. Sometimes a marked error of refraction becomes manifest only as a sequel to some exhausting illness.

The symptoms induced by hyperopia usually follow excessive use of the eyes for close work, such as reading, writing, drawing, sewing, etc., while those of myopia are more commonly induced when the patient uses his eyes excessively for distant vision. The strain caused by astigmia is always present, although it usually becomes more manifest after the excessive convergence and accommodation incident to near work.

ASTHENOPIA AS A CAUSE OF GENERAL DISEASE.

Much has been written on the subject of asthenopia as a cause of general disease. The argument is based on the fact that in eye strain the constant expenditure of nerve energy, due to the patient's efforts to see distinctly, results in nervous exhaustion. It certainly seems reasonable that a pronounced error of refraction when uncorrected, especially in patients who make more than ordinary demands upon their eyes, like any other source of continued irritation, may so far deplete the economy as to render it liable to the invasion of disease which, under normal conditions, would be successfully combated by the protective forces of the body. Every physician will testify to pronounced cases of general disturbance which resisted all forms of treatment until the error of refraction or the muscular imbalance of the eyes had been corrected.

CHAPTER V.

THE TRIAL CASE AND ITS USES.

INTRODUCTION.

The trial or test-case consists of an assortment of convex and concave spherical and cylindrical lenses. (Fig. 28.)

Spherical Lenses.—The spherical lenses are arranged in two double rows, convex on the right side of the case, concave on the left. Between these rows is a double column of

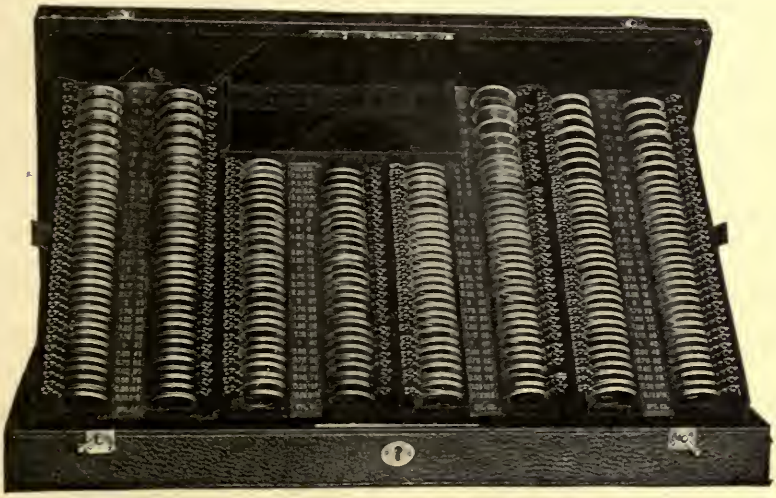

FIG. 28.—Showing Trial Case.

figures, one denoting the strength of the lenses opposite in terms of Diopters, the other specifying the focal distance in inches. In a full case these lenses range from .12 D. to 20 D., the weakest lenses occupying the front of the case. Each lens has stamped upon its handle, or cut into the glass, the figure expressing its strength in diopters.

Cylindrical Lenses.—The cylindrical lenses are similarly arranged in double rows in the center of the case, convex on the right, concave on the left, and are numbered in like manner. They are usually fewer in number than the spherical lenses. In the edge of the lens a little cut into the glass indicates the axis of the cylinder. Each one is so marked, or the lens has a segment at each side rendered opaque by grinding the glass, the edge of the opacity corresponding to the axis of the cylinder. (Fig. 29.)

Prismatic Lenses.—Prismatic lenses usually occupy a separate compartment at the back of the case. They are numbered from 1 to 20 to express in degrees the angle formed by their two sloping surfaces.

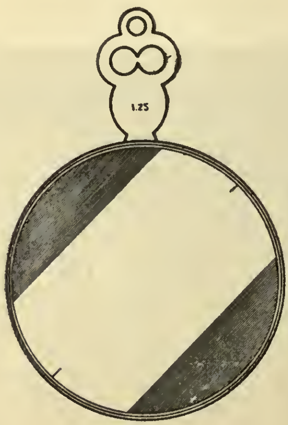

FIG. 29.—Showing Cylindrical Test Lens.

There are in addition a number of accessories, as follows:

(a) An *obturator*, an opaque disc made of metal or hard rubber, used to cover one eye when examining the other.

(b) *Ground glass disc* used for the same purpose.

(c) *Pin-hole disc*, a metal or hard rubber disc having in its center a minute aperture. (Fig. 30.) It has the effect, when placed before the eye, of cutting off the peripheral rays, thereby reducing the size but sharpening the outline of the image produced on the retina. When vision can be improved in this manner it can also be improved by lenses.

(d) *Stenopæic disc.*—This is an opaque disc in the center of which is cut a narrow slit. (Fig. 31.) It is used in testing for astigmia (q. v.).

FIG. 30.—Showing Pin Hole Disc.

FIG. 31.—Showing Stenopæic Disc.

(e) *Maddox rod.*—This is an opaque disc with one or more parallel stenopæic slits, in front of each of which and

FIG. 32.—Showing Maddox Multiple Rod.

FIG. 33.—Showing Double Prism.

parallel to it is a glass rod or cylinder. (Fig. 32.) A flame, when looked at through the maddox rod, appears as a luminous streak passing through the center of the cylinders and at right angles to them. Its use will be explained in discussing the subject of muscular imbalance.

(f) *Double prism.*—This is a disc, at the centre of which are two prisms, base to base. (Fig. 33.) Objects looked at through these prisms will appear double. Its use will be explained in the study of muscular imbalance.

The Trial Frame.—The trial frame is a contrivance, resembling a pair of crude spectacles, Fig. 34, used in conducting a test of vision. It has a lens chamber for each eye, each chamber being capable of receiving two or three lenses. These may be revolved so that the cylindrical lenses may be

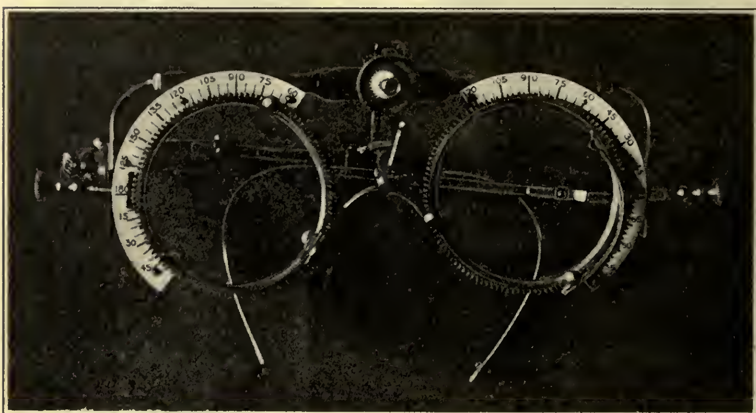

FIG. 34.—Showing Trial Frame.

placed at any axis from 0 to 180 degrees. The angle of the cylindrical axis is indicated in degrees of the circle marked on a celluloid arc above the lens chamber. The trial frame is so arranged that it can be adjusted to suit the patient's nose, pupillary distance, length of head and width of face. (Fig. 35.) In addition to the features common to all, the authors' trial frame, Fig. 36, is fitted with a temple adjustment by which the frame and the included lenses may be tilted to any desired angle. In making the test of vision and in prescribing spectacle frames, especially for near work, this is frequently of great advantage.

FIG. 35.—Showing Trial Frame Properly Adjusted for Conducting a Test.

FIG. 36.—Showing Authors' Trial Frame Adjusted for Reading.

CHAPTER VI.

HYPEROPIA OR FAR SIGHT.

INTRODUCTION.

The Emmetropic eye has been mentioned as one which, when at rest, *i. e.*, with accommodation relaxed, focusses parallel rays in a sharp image upon the retina. This is true, however, only of central rays which unite in, or very near to the fovea centralis or macula lutea, that point on the retina affording most distinct vision. Peripheral parallel

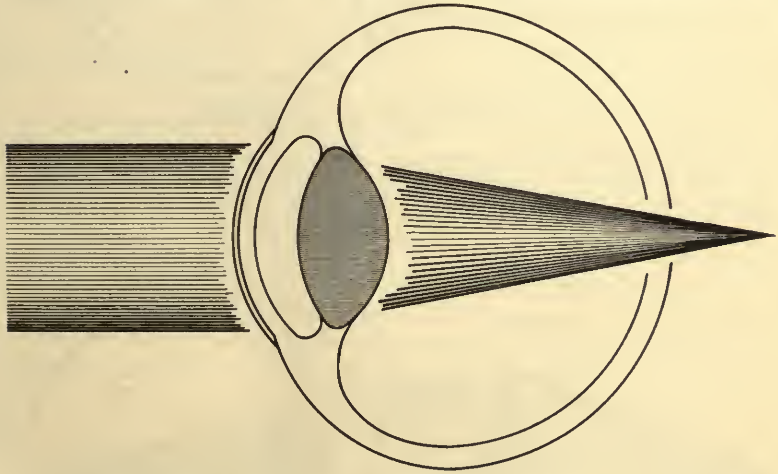

FIG. 37.—Showing the Focus of Parallel Rays Behind the Retina of a Hyperopic Eye.

rays do not converge to a sharp image upon the retina, even in an emmetropic eye. But when, in the absence of accommodation, all parallel rays fail to focus on the retina the condition is known as Ametropia.

The principal forms of Ametropia are: Hyperopia, Myopia and Astigmia.

Hyperopia is also known as Hypermetropia or Farsightedness, expressed by the letter H. In this form of Ametropia the refractive power of the eye is insufficient. Parallel rays focus behind the retina and only by the aid of the accommo-

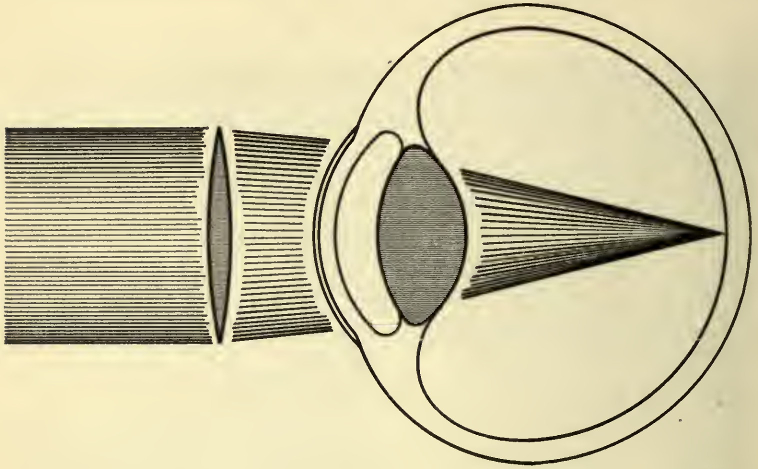

FIG. 38.—Showing a Hyperopic Eye—Corrected for Distant Vision.

dation can they be made to focus on the retina. (Fig. 37.) The divergent rays of close objects focus at a still greater distance back of the retina. In this form of Ametropia a

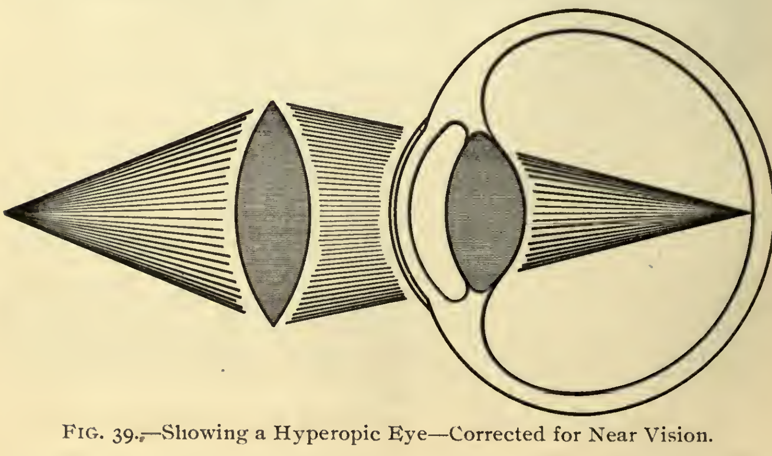

FIG. 39.—Showing a Hyperopic Eye—Corrected for Near Vision.

convex lens is required to bring the focus forward to the retina. (Fig. 38 and Fig. 39.)

Hyperopia may be due to:

(a) Deficient curvature of the refracting media, called *Curvature Hyperopia*, or

(b) Abnormal shortness of the eyeball, called *Axial Hyperopia*, or

(c) A combination of both (a) and (b).

CAUSES.

Hyperopia is usually congenital. By the growth and development of the eyeball, it may be changed to a condition of emmetropia, or more rarely, it may even pass into myopia. While it may remain as a latent error, it becomes manifest in later life.

The extraction of the lens for cataract, leaving the eye in the condition known as *Aphakia*, produces one form of hyperopia.

SYMPTOMS AND SEQUELÆ.

The patient finds it difficult to maintain a distinct image of small objects, and consequently complains of blurring vision. He is forced to stop reading and rub his eyes; after this his sight seems better for a moment, but very soon the haziness of vision recurs. The accommodation finally becomes exhausted and work must be discontinued. Children frequently hold their books near to the face and partially close the eyes to cut off the divergent rays. Too often this leads to an erroneous diagnosis and the prescription of concave glasses. Accommodation and convergence are such closely related acts, nervously, that the excessive accommodation, used in high degrees of hyperopia, and its associated convergence may result in permanent displacement of the eye, a condition known as Strabismus.

SPASM OF ACCOMMODATION.

This annoying complication is due to the persistent contraction of the ciliary muscle by which the patient actually makes himself myopic. Distant vision is rendered indistinct and the patient suffers much pain, discomfort, and the loss of muscular and nervous energy. Spasm is apt to occur in individuals of a neurasthenic type. It is attended by conjunctivitis, blepharitis and congestion of the retina and choroid. Other symptoms are headache, aggravated by using the eyes, functional nervous disturbances and, sometimes, convergent squint. While concave glasses will improve the vision, the error of such a prescription is readily seen.

VARIETIES OF HYPEROPIA.

According to Donders, Hyperopia is *Facultative* when it can be overcome by accommodation without squinting; *Relative* when it can be overcome by accommodation only when the subject squints; and *Absolute* when it cannot be overcome by any efforts of the accommodation.

Manifest hyperopia, indicated by the letters H. M., is that amount of hyperopia, which becomes apparent without paralyzing the accommodation by means of a mydriatic. It is measured by the strongest convex lens through which the eye retains distinct vision.

Latent hyperopia, indicated by the symbols H. L., is that form which is discovered only after the accommodation has been arrested by a cycloplegic. This, when added to the manifest, is the total hyperopia, *Hyperopia Totalis*, indicated by the letters H. T.

DETERMINATION OF HYPEROPIA.

Hyperopia always exists:

1. When distant vision is not reduced by a convex lens.

2. When the patient can read fine print through a convex glass at a greater distance than its focal length.

3. And usually when the near point lies at a greater distance from the eye than is proper for the age of the patient.

CORRECTION OF HYPEROPIA.

With the patient seated six meters (twenty feet) from the Snellen test card and wearing a properly adjusted test frame, place before the uncovered eye convex glasses, passing gradually from weaker to stronger ones until the best vision has been obtained. The *strongest* convex lens giving this result is the measure of the manifest hyperopia (H. M.).

It will be found frequently that a hyperopic person, because his accommodation overcomes the error, has perfect vision with the unaided eye. In such a case, of course, it is impossible to *improve* the vision by means of convex lenses, indeed, concave lenses may appear to afford some improvement. Such an eye does its work satisfactorily as to vision, but at too great a cost in energy; glasses will enable it to perform its function with a much smaller expenditure of muscular effort. In such a case the manifest hyperopia is measured by the strongest convex lens with which the patient can see as well as he does with the unaided eye. The very fact that he sees as well at a distance with a convex glass as without it, proves that the eye is hyperopic; the emmetropic eye and, to a greater degree, the myopic eye sees less distinctly through even a weak convex lens.

In testing the eye for distant vision by means of the Snellen types at a range of six meters, it is essential that the accommodation be relaxed. It is desirable throughout the test to disturb the natural conditions as little as possible. While it is the practice in most public clinics to employ in every case a mydriatic, as a matter of routine and to economize time, such procedure in private practice is necessary only in exceptional cases. The refractionist who is skilled in the use of the test case and the confirmatory tests, and who has tact and patience, may learn to coax out the most obstinate accommodation and accurately measure the degree of eye strain without the routine use of a mydriatic. The more skillful the refractionist, the less will he depend upon the drug.

In order to relax the ciliary muscle, there are some measures which will be found of value. The following may be employed:

1. Place before one eye, its fellow being covered, convex lenses of increasing strength until the image is blurred, then gradually weaken to a point of distinct vision. In other words, overcorrect the error and then return to a lens which gives clear and distinct vision.

2. Place before each eye a strong convex lens, for instance, a plus 4 D. S., allowing the patient to wear them ten or

fifteen minutes, then gradually neutralize by superimposing concave lenses of increasing strength to the point of best vision.

3. Sometimes a two-degree prism, base in, will serve to relax the Internal Rectus muscle and the accommodation.

In every case, the lenses should be increased in strength very gradually, the accommodation relaxing by this method. Great deliberation is of positive value. It is absolutely important to quiet the nervousness of an excitable patient; in every case, to win the confidence of the patient makes the task much easier.

In myopes and in the majority of hyperopic and astigmic patients, the above measures will be sufficient. If, however, the statements of the patient are hesitating, varying and inconsistent, no definite conclusions can be reached by the examiner; in such a case a cycloplegic must be employed.

CYCLOPLEGICS AND MYDRIATICS.

In view of the fact that paralysis of accommodation is usually accompanied by a simultaneous dilatation of the pupil, the terms cycloplegic and mydriatic are ordinarily used synonymously. The majority of cycloplegics are also mydriatics. True mydriatics are those which dilate the pupil without affecting the accommodation, *e.g.*, Euphthalmin, Ephedrin, Mydrin and Cocain. The most commonly used cycloplegics are Atropin Sulphate, Homatropin Hydrobromate, Scopolamin and Duboisin.

In choosing between cycloplegics, the chief factor to be considered is the age of the patient. Atropin (in 1 per cent. solution usually), being the strongest, is best suited to the more active accommodation of children and young adults; Homatropin (in 1 per cent. solution), alone, or in combination with Cocain (2 per cent. solution), being employed to combat the less active accommodation of patients from twenty-five to thirty years of age. After the age of thirty-five, spasm of accommodation is very rare and hence the use of a cycloplegic is rarely required.

Contraindications for the Use of Mydriatics.—In any case of increased tension of the eyeball at any age, the use of a mydriatic is interdicted. This includes suspected cases of glaucoma as well as those in which the disease is actually present.

TABLE III.

SHOWING STRENGTH OF CYCLOPLEGICS AND MYDRIATICS, TIME REQUIRED TO ACT AND DURATION OF DRUG EFFECT.

Drug.	Strength Employed.	Time Required to Reach Maximum Effect.	Duration of Drug Action.
Atropin Sulphate.	1 % solution.	48 hours.	7 to 10 days.
Homatropin Hydrobromate (several instalations at intervals of ten minutes).	1 % solution.	2 hours.	1 to 2 days.
Scopolamin Hydrobromate.	1–10 % solution.	1 hour.	4 days.
Duboisin Sulphate.	½ % solution.	½ hour.	4 days.
Euphthalmin Hydrochlorate.	5–10 % solution.	20 minutes.	5 hours.
Ephedrin Hydrochlorate.	10 % solution.	40 to 60 minutes.	5 to 20 hours.
Cocain Hydrochlorate.	2 % solution.	1 hour.	3 to 4 hours.

Correction of Results Obtained Under a Cycloplegic.—That lens or combination of lenses which gives the patient the best distant vision while under the influence of a cycloplegic expresses the total error of refraction, *i. e.*, the manifest plus the latent error. The latter was brought out by the cycloplegic and represents the tonicity of the ciliary muscle. To prescribe the full correction, *i. e.*, the strength of lens giving most perfect vision under mydriasis, would manifestly be a grave error, because:

1. The ciliary muscle, which in hyperopic eyes is more or less hypertrophied, without drug effect is unable to fully relax; therefore, the accommodation is never fully relaxed in the hyperopic eye.

2. If the ciliary muscle could be fully relaxed, to keep it so by prescribing glasses to perform the functions normally its province, would not only cause the patient great discomfort, but would result sooner or later in muscular atrophy from disuse.

For this reason, it is necessary to deduct from the measurement under atropin or other cycloplegic, from 1 D. to 1.50 D. in the case of children and young adults, and from .75 D. to 1 D. in older individuals. For example, if the total error of refraction, as revealed by the cycloplegic, is + 3 D. S., the prescription for glasses would be from + 1.50 D. S. to + 2 D. S. in a child, and from + 2 D. S. to + 2.25 D. S. for an adult.

MYOTICS.

Myotics are drugs which produce a contraction of the pupil and may induce spasm of accommodation. Those generally employed in medical practice are Eserin (in 1 per cent. solution) and Pilocarpin (in ¼ and ½ per cent. solution). They are used to counteract the effect of mydriatics and to draw the iris away from the iris angle in glaucoma and in peripheral lesions of the cornea.

After using a cycloplegic like homatropin, its annoying effect may be temporarily overcome by the use of a myotic. Frequent installations of eserin, for instance, will counteract the action of the cycloplegic.

CHAPTER VII.

MYOPIA OR NEAR SIGHT.

INTRODUCTION.

As the correction of hyperopia necessitates an increase of the refractive power of the eye by means of convex glasses, so that of Myopia demands a decrease of the refractivity, accomplished by the use of concave lenses. In Myopia the refractivity is too great for the length of the eyeball, so that parallel rays focus in front of the retina. (Fig. 40.) In this

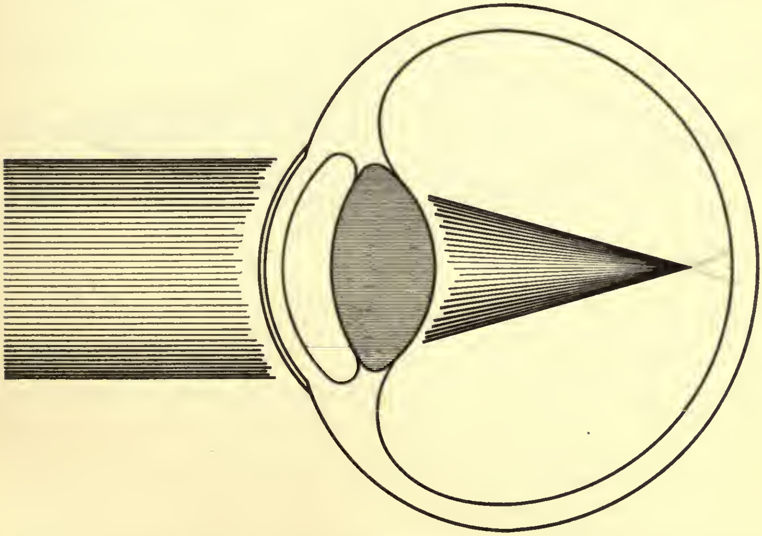

FIG. 40.—Showing the Focus of Parallel Rays in Front of the Retina of a Myopic Eye.

condition the only rays falling on the retina emanate from objects nearer the eye than infinity. The more the rays diverge, *i. e.*, the nearer the object viewed is to the eye, the more distinct will be the vision. Hence, in myopia of mild degree, the patient requires correcting lenses for his distant vision only, no glasses being needed for close work. (Fig. 41.) In myopia of high degree, the glasses prescribed for distant vision are too strong for reading. A second pair of glasses of much weaker power are, therefore, required for close work.

Myopia may be due to:

(a) Increased length of the eyeball, known as *Axial Myopia*, or

(b) Increased curvature of the refracting media, known as *Curvature Myopia*, or

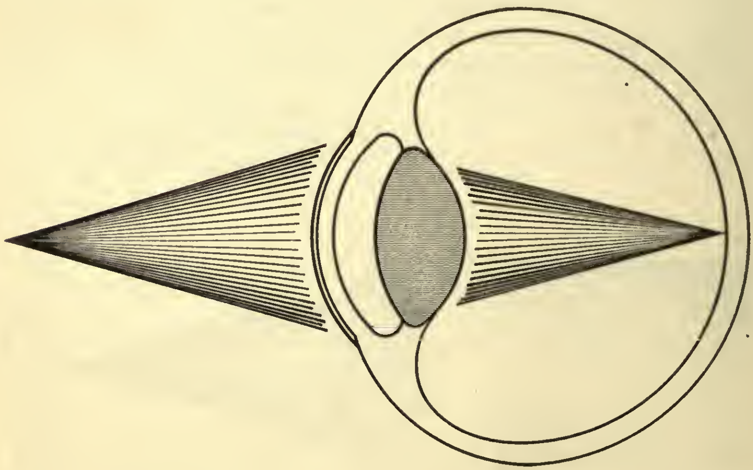

FIG. 41.—Showing Divergent Rays of a Near Object Focussed on the Retina of a Myopic Eye.

(c) A combination of both these conditions.

The great majority of cases of Myopia are probably axial, those cases due to increased curvature of the refracting media being much less frequent. Curvature Myopia may be of two kinds:

(a) That affecting the cornea, and

(b) That affecting the lens.

As an example of the former may be mentioned the condition known as Keratoconus or Bulging Cornea, while the latter is well illustrated by the swelling of the lens which sometimes takes place in incipient cataract. As a result of the increased refractivity caused by this swelling, the patient is able to read without the aid of glasses, a condition known to the laity as "second sight."

CAUSES OF MYOPIA.

Myopia is very largely the result of the unreasonable demands which civilization and higher education make upon the eyes. The excessive and improper use of the eyes for near work during the period of development seems to be the chief predisposing cause. Heredity is also an important causative factor. The exciting cause is usually found in improper hygienic conditions, *e.g.*, poor ventilation and insufficient illumination of school rooms, faulty position of the head and body during study and sedentary habits.

The lengthening of the eyeball found in axial myopia may be brought about in two ways:

(1) Individuals, whose eyes are far apart, are compelled to exercise an excessive amount of convergence when fixing upon near objects. By this excessive convergence the extra-ocular muscles exert undue pressure on the eyeballs, causing a bulging of the less resistent posterior pole, thereby producing the condition known as Posterior Staphyloma.

(2) As a result of chronic inflammatory processes and the destructive changes caused thereby, the coats of the eyeball become softened and less resistent and finally yield to intra-ocular and extra-ocular (muscular) pressure. This form of myopia is usually progressive, often attaining a high degree and sometimes resulting in total blindness.

SYMPTOMS OF MYOPIA.

The patient's distant vision is poor. The eyes are sensitive to light and tire easily, becoming painful after near work. Patients frequently complain of black spots before the eyes and occasionally of flashes of light.

In myopia of high degree the eyeballs are often prominent and staring, giving the face a rather stupid expression. The patient, when reading, moves his whole head instead of his eyes alone, thus following the lines back and forth across the page. The ophthalmoscope shows the optic disc to appear enlarged. There may be divergent squint, the internal recti being unequal to the task of maintaining the excessive amount of convergence necessary.

DETERMINATION OF MYOPIA.

Myopia always exists when, in the absence of spasm of the ciliary muscle:

1st. Distant vision is improved by concave lenses and blurred by convex lenses;

2d. The far point (punctum remotum) lies nearer the eye than infinity.

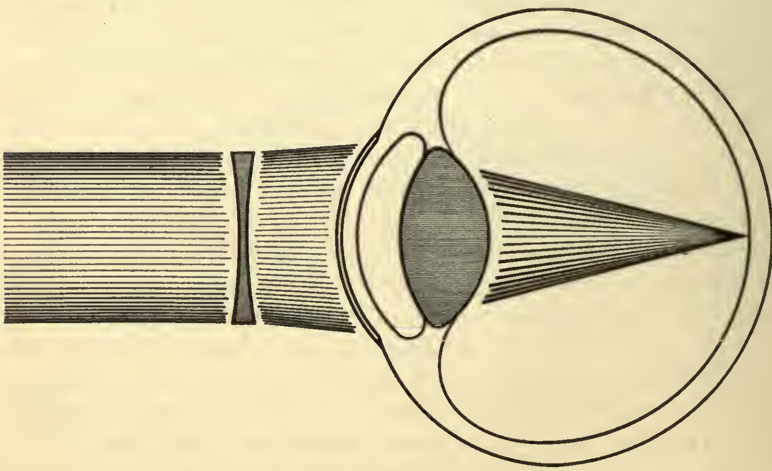

FIG. 42.—Showing a Myopic Eye Corrected for Distant Vision.

CORRECTION OF MYOPIA.

With the patient seated twenty feet from the test card, place before the eye, testing each eye separately, concave lenses of different strength until the most distinct vision is obtained. The weakest lens giving this result is the measure of the myopia and should be prescribed for distant use. (Fig. 42.)

Should the error be one of high degree, *e. g.*, from 5 D. to 8 D., or the accommodation feeble, a weaker lens affording good vision at 14 to 16 inches should be prescribed for reading. This is a point deserving special emphasis, because it is too frequently disregarded.

PROPHYLAXIS.

A myope should be instructed in a proper hygienic regime, *e. g.*, the use only of books having large distinct type, the best possible light, proper ventilation of the study or school room, plenty of out-door exercise and the limitation of close work to the minimum. He should be instructed to wear his glasses only for distant vision, or if two corrections are prescribed, the weaker one for reading should be the invariable practice.

CHAPTER VIII.

ASTIGMIA.

INTRODUCTION.

A beam of light on passing through a convex cylindrical lens becomes wedge-shaped, the sharp edge of the wedge being the focal line (See p. 21). The base of the wedge lies against the lens. (See Fig. 14.) By placing together two convex cylindrical lenses of different refractive strength, with their axes at right angles to each other, there will be formed

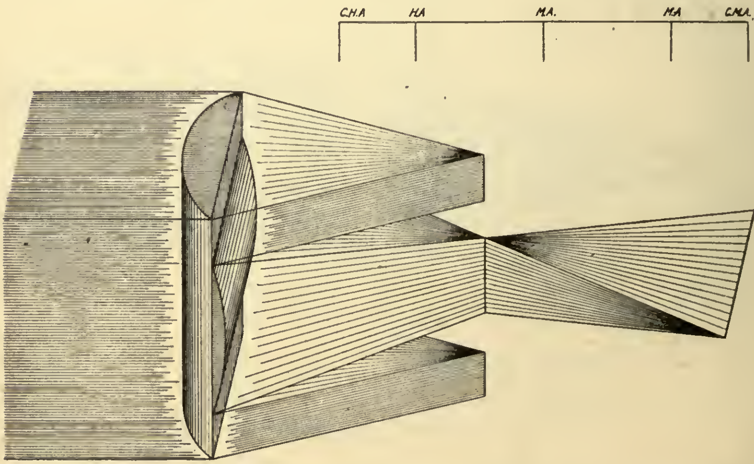

FIG. 43.—Showing the Effect of Crossed Cylinders as Illustrating the Refractive Effect of an Astigmic Surface.

two wedges, a short one by the stronger lens and a longer one by the weaker lens. The edges or focal lines will lie some distance apart and at right angles to each other. (Fig. 43.) The same result is obtained by combining a spherical lens with a cylinder (See Relationship of Lenses).

This represents the refractive condition of some eyes. Either the cornea, or the crystalline lens, or both, so change the transmitted light rays as to have the effect of a sphero-cylindrical lens. The result is that, instead of focussing the rays of light at one point upon the retina, two focal lines are formed some distance apart and at right angles to each other. One of these lines may be upon the retina or both may be behind or in front of that structure. An eye with this peculiar refractive power is said to be astigmic, and the condition is known as Astigmia or Astigmatism. The cause of astigmia usually lies in the cornea, which, instead of being like a section of a sphere, resembles more the bowl of a spoon, *i. e.*, one meridian is more convex than that which is at right angles to it, having, therefore, a shorter focal distance.

In view of the fact that the majority of astigmic eyes show a more pronounced curvature vertically than horizontally, astigmia at this angle is said to be "according to the rule." The opposite condition, viz., that in which the horizontal meridian shows the greater curvature, is spoken of as astigmia "against the rule."

In a general way Astigmia may be divided into two classes, as follows:

Regular Astigmia is that form in which all the meridians of the refracting surfaces of the eye are regular in curvature, *i. e.*, they are the arcs of circles. This is the condition which especially concerns the refractionist because it can be corrected by the use of glasses.

Irregular Astigmia, of interest to the ophthalmologist, but hopeless, optically speaking, is caused by a deformity of the cornea resulting from a burn, injury, ulcer or other diseased condition, followed by the formation of scar tissue. The latter, by its contraction, produces an irregular, refracting surface, the effect of which is to so distort the image formed on the retina that no lens, or combination of lenses, will serve to bring the different parts of the image into one plane. It is rarely improved by the use of glasses.

FORMS OF REGULAR ASTIGMIA.

There are five principal forms of regular astigmia, viz.:

(1) *Simple Hyperopic*, in which one meridian focusses on the retina, the opposite meridian behind it.

(2) *Simple Myopic*, in which one meridian focusses on the retina, the opposite one in front of it.

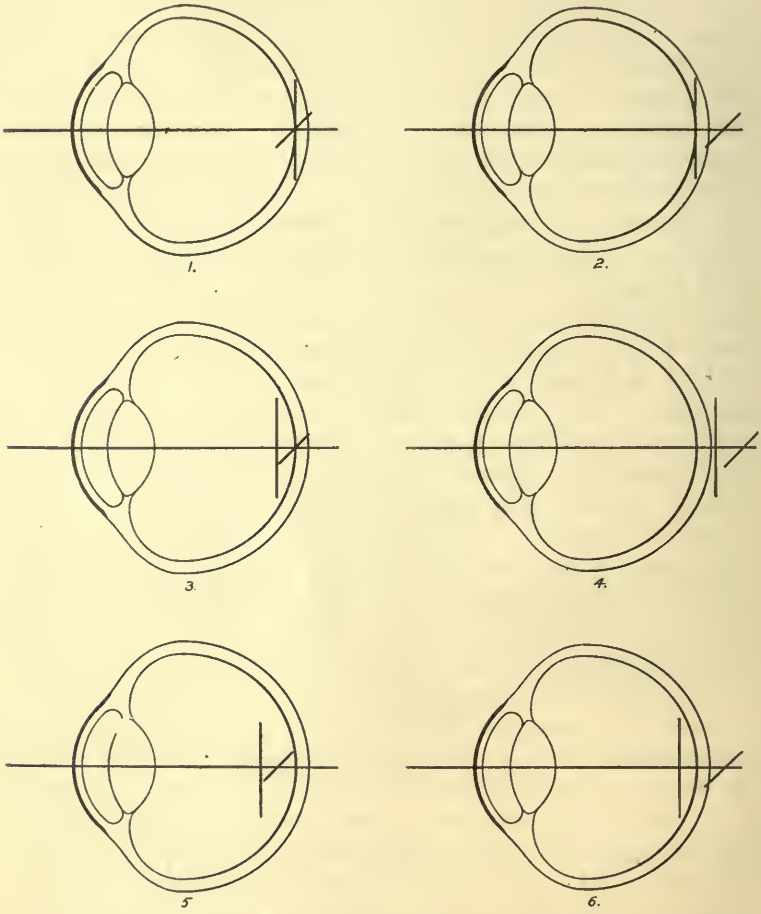

FIG. 44.—Showing Varieties of Astigmia—1. Emmetropia; 2. Simple Hyperopic Astigmia; 3. Simple Myopic Astigmia; 4. Compound Hyperopic Astigmia; 5. Compound Myopic Astigmia; 6. Mixed Astigmia.

(3) *Compound Hyperopic*, in which both meridians focus behind the retina, but at different distances from it.

(4) *Compound Myopic*, in which both meridians focus in front of the retina, but at different distances from it.

(5) *Mixed*, in which one meridian focusses behind and the other in front of the retina.

The different forms are illustrated by Fig. 44. (Also by Fig. 43, the retina being interposed at the points indicated.)

CAUSES OF REGULAR ASTIGMIA.

Astigmia is usually congenital and frequently associated with other defects of vision. Ordinarily it is found to affect both eyes, usually to the same degree and in the same meridian. When acquired, it is usually caused by pressure upon the eyeball of the lids or external eye muscles, or by operation, *e.g.*, cataract extraction or iridectomy. Astigmia may also be caused by an oblique position of the lens of the eye, due to accidental or natural subluxation. (See Relationship of Lenses.)

SYMPTOMS.

These are the usual symptoms of Asthenopia. When the error is comparatively slight, *i. e.*, below 1 D., no indistinctness of vision is noticed. When more than 1 D., however, circular bodies will appear elliptical and straight lines falling in the faulty meridians will appear indistinct. The patient makes frequent mistakes in reading the test types at twenty feet. Astigmia should always be suspected if the patient in attempting to read the letters on the test card, calls some correctly and makes *guesses* as to others. There is more or less blurring of the letters when reading at close range. It is not unusual to find assymetry of the face associated with astigmia, the eye apparently sharing the facial irregularity.

DETERMINATION OF ASTIGMIA.

The examination proceeds exactly as in the determination of Hyperopia or Myopia. The patient is given the best vision possible by the use of spherical lenses. When it is impossible to render vision normal by the use of spherical lenses, it is probably owing to the presence of astigmia.

A simple way of detecting astigmia is by rotating before the eye a weak cylinder, say a plus .50 D. If the vision is made worse in all meridians no appreciable amount of astigmia is present. If the vision is better at any one meridian,

FIG. 45.—Showing Fan of Rays.

astigmia is present and the axis of the cylinder giving most distinct vision is at right angles to the faulty meridian.

A very useful aid in determining astigmia is the fan of rays (Fig. 45) or the astigmic dial (Fig. 46.) This is used at a distance of twenty feet and all the tests are made with one eye at a time. When astigmia is *manifest*, *i. e.*, when it is not concealed by the patient's accommodation, one or two rays of the fan or radiating lines of the dial appear more distinct than the remainder and indicate that the normal meridian lies at right angles to these. (Fig. 47.) When the

FIG. 46.—Showing Astigmic Dial.

astigmia is *latent*, *i. e.*, concealed by the patient's accommodation, it can usually be made manifest by revolving cylinders of varying degrees of strength before the eye. The cylinder at some axis will cause one or two of the rays or lines to appear blacker. This axis coincides with the faulty meridian.

When this method fails a cycloplegic must be employed to put the patient's accommodation entirely at rest.

CORRECTION OF ASTIGMIA.

General Remarks.—In the correction of astigmia, just as in the neutralization of a cylindric lens (see Neutralization of

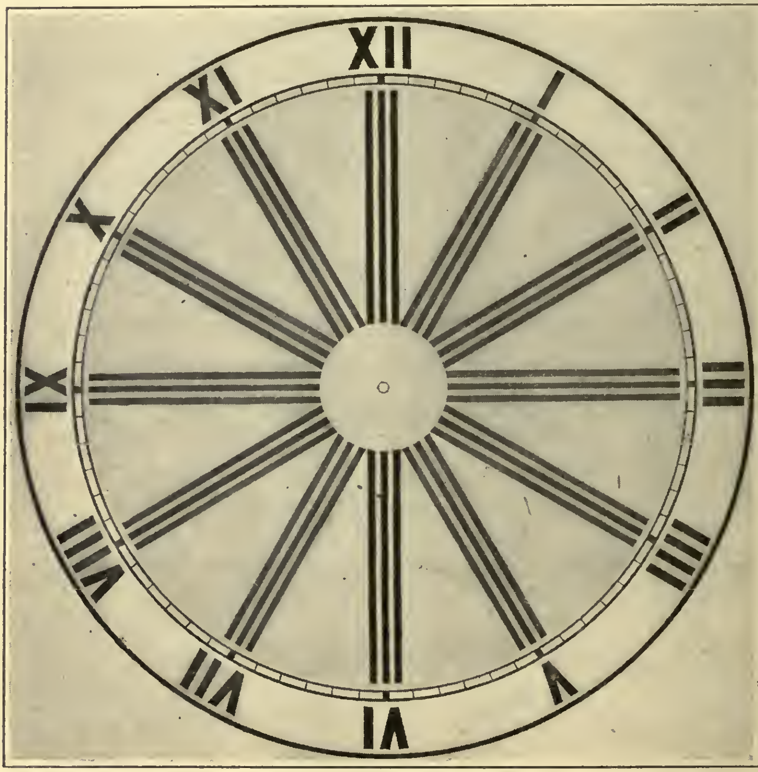

FIG. 47.—Showing Dial as Seen by an Astigmic Eye.

Lenses), three things must be ascertained regarding the correcting lens, viz., the kind, the strength and its position before the eye, *i. e.*, the axis. The latter is indicated in degrees of an arc numbering from right to left. (See Fig. 16.) By placing at the proper axis before the eye convex or concave cylinders of varying degrees of strength, the strongest convex, or the weakest concave, cylinder through which vision is clearest and all of the rays or lines are seen with equal distinctness, is the measure of the astigmia.

Simple Hyperopic Astigmia (H. As.).—By placing before the eye a convex cylinder, of the right strength and at the proper axis, the rays which formed a focal line behind the retina are converged to meet on the retina. (Fig. 48.) The strongest convex cylinder which makes the patient's vision

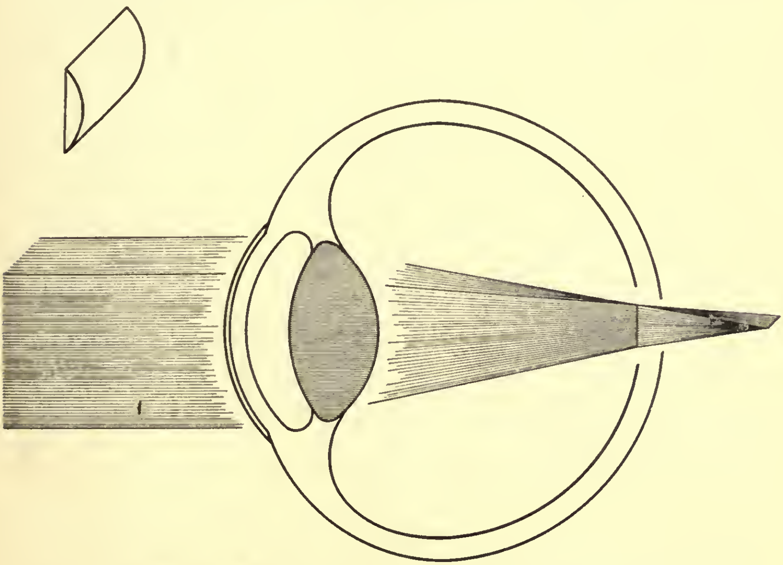

FIG. 48.—Showing Position of Focal Lines in Simple Hyperopic Astigmia and Position of Correcting Cylindric Lens.

clear and all the lines on the dial appear equally distinct is the correction of the condition and should be prescribed for constant wear. When the lens prescribed is weak and the patient's symptoms slight, an exception may be made and the patient be permitted to wear his glasses for near work only.

In some cases in which the error is one of very high degree, the full correction cannot be prescribed, owing to the great discomfort experienced by the patient. It then becomes necessary to reduce the strength of the lens sufficiently to insure comfort, and, at the same time, render vision as good as possible. The final prescription in such a case can be ascertained only by repeated trials.

Simple Myopic Astigmia (M. As.).—By placing before the eye a concave cylinder, of the right strength and at the proper axis, the rays which formed a focal line in front of the retina, Fig. 49, are made less convergent so that they meet

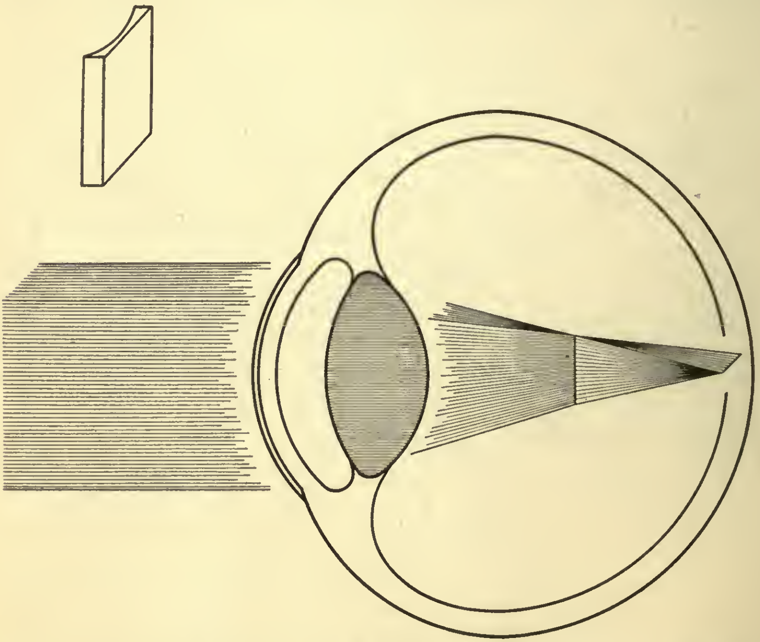

FIG. 49.—Showing Position of Focal Lines in Simple Myopic Astigmia and Position of Correcting Cylindric Lens.

on the retina. The weakest concave cylinder which makes the patient's vision clear and all the lines on the dial appear equally distinct is the correction of the condition.

In cases of low degree, this correcting cylinder may be prescribed for constant wear. When the strength of the lens prescribed exceeds .50 to .75 D. a second pair must be prescribed for near work. Usually it is sufficient to prescribe convex cylinders of the same strength at the opposite axis for near work. In this way the emmetropic meridian is brought forward to the same plane with the faulty meridian, thus changing the condition to one of myopia, which the patient will disregard for reading, if the error be of low degree.

Example. For distant vision: − .75 D. C. Ax. 180°; for reading: + .75 D. C. Ax. 90°.

When the error is one of high degree, *e. g.*, 4 D. to 6 D., it is frequently necessary to prescribe, for reading, a crossed cylindrical lens, *i. e.*, a concave cylinder to carry the faulty meridian toward the retina and a convex cylinder at right

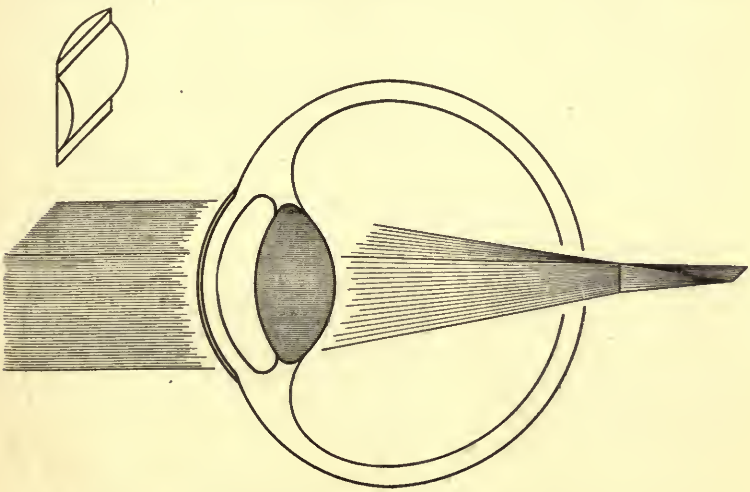

FIG. 50.—Showing Position of Focal Lines in Compound Hyperopic Astigmia and Position of Correcting Cylindric Lenses.

angles to the above to carry the emmetropic meridian forward to the same plane, thus again producing a condition of myopia.

Example. For distant vision: − 6 D. C. Ax. 75°; for reading— 3 D. C. Ax. 75° ⊃ + 3 D. C. Ax. 165°. This prescription may also be written: − 6 D. C. Ax. 75° + 3 D. S. (See Relationship, Page 33.)

Compound Hyperopic Astigmia (C. H. As.).—In this condition both focal lines are behind the retina, but at different distances. (Fig. 50.) By placing a convex spherical lens of the proper strength before the eye, both focal lines are moved forward, one falling on the retina, the other still behind the retina, but nearer than before. Placing a convex cylindric lens of the right strength over the spherical lens at the proper axis, the rays which formed the focal line behind the retina are converged to meet in a point on the retina. The strongest convex spherical and cylindrical lenses, which combined make the patient's vision clear and all the lines on the dial to appear equally distinct, are the correction for the condition.

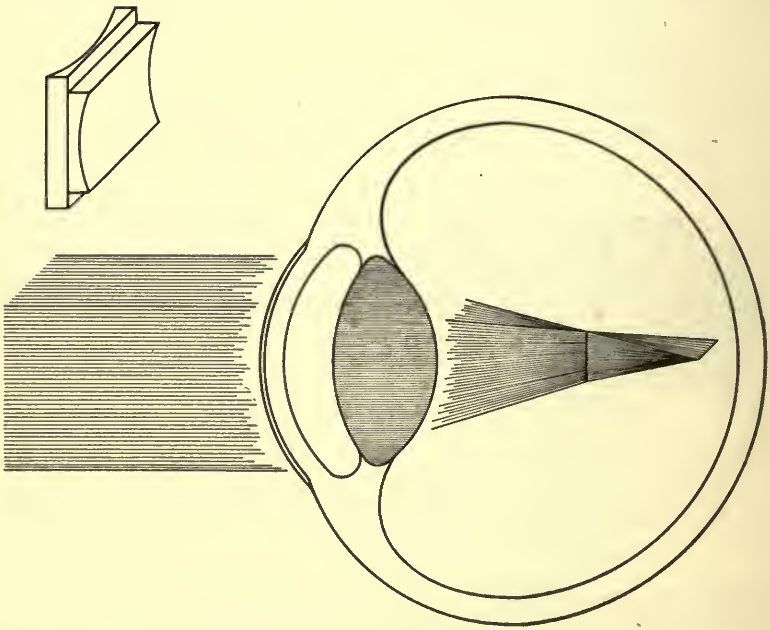

FIG. 51.—Showing Position of Focal Lines in Compound Myopic Astigmia and Position of Correcting Cylindric Lenses.

When the error is of low degree, the glasses prescribed may be worn for close work only. In the majority of cases, however, they should be prescribed for constant wear.

Compound Myopic Astigmia (C. M. As.).—In this condition both focal lines are in front of the retina, but at different distances from it. (Fig. 51.) By placing a concave spherical lens of the proper strength before the eye, both focal lines are moved back, one falling on the retina, the other still in front of it, but nearer than before. Placing over the spherical lens a concave cylindric lens, of the right strength and at the proper axis, the rays which formed the focal line in front of the retina are made less convergent, so that they meet in a point on the retina. The weakest concave spherical and cylindrical lenses, which combined make the patient's vision clear and all the lines in the dial to appear equally distinct, are the correction for the condition.

When the error is of low degree, one prescription may be sufficient, the patient being instructed to wear the glasses constantly. When moderately strong lenses are prescribed for distance, the spherical part may be dropped and convex cylinders be ordered for reading.

Example. For distant vision: − 1 D. S. ⊃ − 1.25 D. C. Ax. 45°; for reading: + 1.25 D. C. Ax. 135°.

When the error is one of high degree:

(a) The same cylinder and axis may be prescribed for reading, or,

(b) The same cylinder and axis, combined with a weaker spherical lens.

Examples. (a) For distant vision: − 3 D. S. ⊃ − 4 D. C. Ax. 15°; for reading: − 4 D. C. Ax. 15°.

(b) For distant vision: − 6 D. S. ⊃ − 3 D. C. Ax. 15°; for reading: − 2 D. S. ⊃ − 3 D. C. Ax. 15°.

Mixed Astigmia (M. A.).—When it is found impossible by means of spherical or cylindrical lenses, or combinations of the same, to secure distinct vision, mixed astigmia is probably present. Cases which at first appear to be high degrees of myopic or hyperopic astigmia, on careful examination, may be found to be mixed.

In this condition, one focal line lies behind the retina, the other in front of the retina. (Fig. 52.) By placing before the eye a convex cylinder, of the right strength and at the proper axis, the rays which formed the focal line behind the retina are made more convergent so that they meet in a line on the retina. Placing before the eye a concave cylinder, of the right strength and at the proper axis (at right angles to the convex cylinder), the rays which formed a focal line in front of the retina are made less convergent so that they meet on the retina.

Glasses prescribed for Mixed Astigmia should be worn constantly. When the myopic cylinder is of high degree, a separate correction should be made for reading, in which case the concave cylinder is decreased and the convex cylinder correspondingly increased.

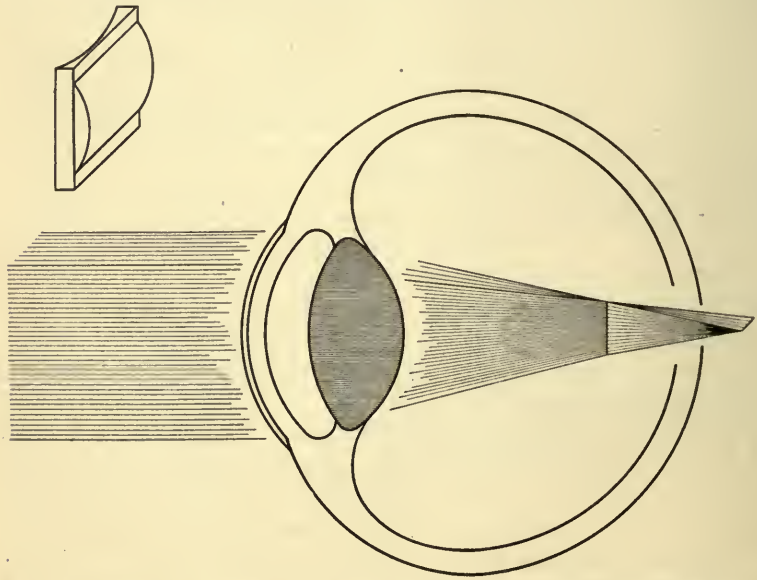

FIG. 52.—Showing Position of the Focal Lines in Mixed Astigmia and Position of Correcting Cylindric Lenses.

Example. − 3.50 D. C. Ax. 180° ⊃ + 1.75 D. C. Ax. 90°.
For reading: − 1.50 D. C. Ax. 180° ⊃ + 3.75 D. C. Ax. 90°.

Stenopæic Disc.—Another method of determining the presence of astigmia is by revolving before the eye the stenopæic disc. (See p. 51.) When in the position affording most distinct vision, place before the slit convex and concave spherical lenses; the strongest convex or the weakest concave lens, giving the greatest improvement, represents the measure of the refraction in this meridian. The slit is then revolved to a position at right angles to its former axis and the refraction of this meridian ascertained in the same manner. The sum of the two results obtained is the total error of refraction.

Example. Vertical meridian: + .25 D. S.
Horizontal meridian: + .75 D. S.
Total error: + 25 D. S. ⊃ + .50 Ax. 90°.

CHAPTER IX.

ANISOMETROPIA, APHAKIA, AMBLYOPIA AND MALINGERING.

ANISOMETROPIA.

By the term, Anisometropia, is meant a difference in the refractive power of the two eyes. One eye may be normal, or both hyperopic, myopic or astigmic, one more so than the other. When the difference is slight, both eyes may be corrected. When the difference is pronounced, the glass required to correct the poorer eye is often too strong to be worn with comfort, causing diplopia or producing other uncomfortable symptoms. Therefore, it is frequently necessary to prescribe a partial correction or even none at all for the poorer eye, and complete correction for the better eye.

APHAKIA.

After the extraction of a cataract, the patient is compelled to wear two pairs of glasses, one pair for distance, the other for near vision. The crystalline lens of the eye having been removed, all accommodation is suspended and the refractive power of the eye is practically limited to that of the cornea alone. Rays of light entering such an eye are not deflected sufficiently to meet on the retina. A strong convex lens (from 5 D. to 12 D.) is, therefore, necessary for distant vision, and a stronger one (from 12 D. to 20 D.) for reading. There is usually present, also, a considerable degree of astigmia, caused by the incision through the cornea and the resulting alteration in its curvature. This must also be corrected in the ordinary way and the proper cylindrical lens added to the spherical lens prescribed.

AMBLYOPIA AND AMAUROSIS.

When, in the absence of any visible changes in the eye, there is a partial loss of vision which cannot be improved by the use of glasses, the condition is known as Amblyopia.

When there is a complete loss of vision without evident changes in the structure of the eye, the condition is known as Amaurosis.

Amblyopia and Amaurosis may be the result of disuse, as in the case of the squinting eye, or it may be caused by injury, loss of blood or cerebral disease. It is also occasionally met in hysterical individuals; in such cases it is temporary and accompanied by other hysterical symptoms.

MALINGERING.

For the purpose of collecting damages or insurance after a trivial injury, or to gain an increase of pension, a patient may pretend to be blind. When complete blindness of both eyes is claimed, it is often difficult to disprove, except by observing the patient without his knowledge. Perhaps the most effective method in such a case is by pretending a blow over the eye. If the patient sees, the eye will be suddenly closed to prevent injury.

When blindness in one eye is claimed, several tests may be made to disclose the true condition. A ten degree prism, base out, may be placed before the eye under suspicion. If the eye sees, it will rotate inward, in an unconscious effort to fuse the two images into one.

If, with a strong convex or concave lens before the good eye and a plane lens before the pretended poor eye, the patient is able to read the Snellen type at twenty feet, blindness is disproved.

It is needless to add, perhaps, that the examination of a patient suspected of simulating blindness must be conducted without arousing suspicion as to the true purpose of the examiner. The examiner should act as if convinced that blindness exists and that he is seeking for its cause.

CHAPTER X.

PRESBYOPIA.

CAUSES AND SYMPTOMS.

The hardening of the lens, previously mentioned in our consideration of the subject of accommodation (p. 43), is a physiological change, which, beginning in early life, shows a steady and almost constant increase as the age of the individual advances. Near vision becomes more difficult, the patient ultimately finding that he is no longer able to see distinctly at close range. Gradually he is compelled to hold his book or newspaper at a greater distance than formerly (Fig. 53) or he finds it necessary when reading fine print to hold it in a bright light, the resulting contraction of the pupil rendering vision more distinct. By these means the wearing of glasses for near work may be deferred, distant vision remaining unimpaired. But the time comes when, even by these means, the threading of a needle or the reading of a newspaper is no longer possible. This is due to the fact that the lens of the eye has so far lost its elasticity that by no effort of the ciliary muscle can the lens be made sufficiently convex to focus on the retina the divergent rays of a nearby object. This failure in the functional activity of the crystalline lens usually becomes manifest between the ages of forty-three and forty-five, although in some cases in which the eyes are used but little for close work and the general health is good, it may not require correction until later.

The phenomenon by which patients of advanced age are able to read fine print without glasses is frequently a source of wonder among the laity and by them considered a sign of unusual constitutional powers. It signifies merely that the individual in his earlier years has been nearsighted, but his myopia was gradually overcome by the increasing presbyopia until the patient finally had normal vision for the first time. The eyeball being too long, the crystalline lens had

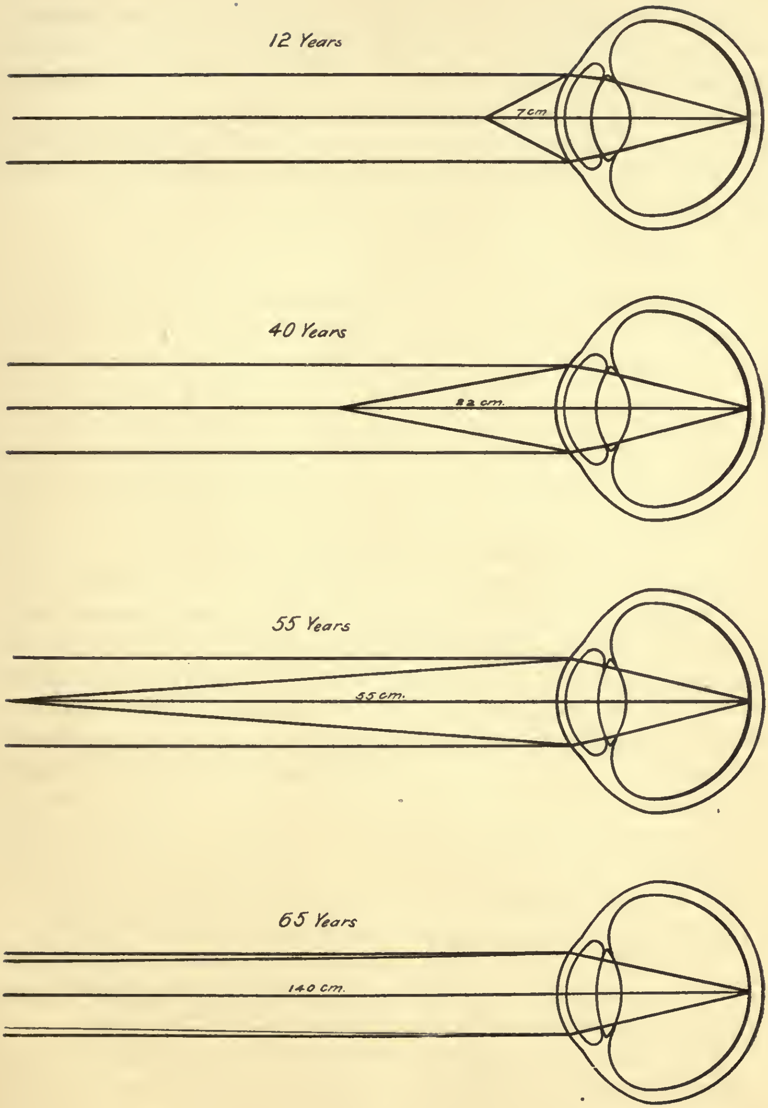

FIG. 53.—Showing Gradual Recession of the Near Point Owing to Hardening and Flattening of the Lens—Presbyopia.

been able to focus clearly on the retina only very divergent rays of close objects. Having lost its elasticity, the lens became more flattened, its refractive power decreased so that rays which formerly focussed in front of the retina now form a clear image upon it.

A very definite relationship exists between the amount of presbyopia, or failure of accommodation, and the age of the patient, as the following table will show:

TABLE IV.

SHOWING THE RELATIONSHIP BETWEEN PRESBYOPIA AND THE AGE OF THE PATIENT.

Age.	Failure of Accommodation.
45	1 D.
50	1.75 to 2.00 D.
55	2.50 to 3.00 D.
60	3.00 to 4.00 D.
65	3.50 to 4.50 D.

CORRECTION OF PRESBYOPIA.

From what has been said, it is evident that patients, who until the age of forty-five years have worn no glasses, after that time should be provided with the proper correction for reading. Provided no astigmia or other more serious error of refraction be present, such patients can readily select a "reading glass" from among an assorted stock without the assistance of a refractionist. From the very nature of presbyopia, it will be seen that the patient's glasses must be changed every three to five years, their strength being steadily increased to make up for the gradual decrease incident to the flattening of the crystalline lens. In selecting glasses for presbyopia, the following rules will be helpful:

(a) When no other error of refraction exists the strength of the reading glasses will be determined by the age of the patient and will conform approximately to the table.

(b) When the patient has previously worn glasses for distant vision on account of astigmia or myopia of low degree, the reading correction prescribed will be the distance prescription increased by the correction for presbyopia at the patient's age.

(c) When the patient has previously worn glasses for both distant and near vision on account of myopia of high degree, or of myopic or mixed astigmia, of high degree, the reading correction prescribed will be the previous reading lens added to the presbyopic correction for the given age.

Examples. (b) A patient who had been wearing − 4 D. S. ⊃ − 2.75 D. C. Ax. 15° for distance and − 1.50 D. S. ⊃ − 2.75 D. C. Ax. 15° for reading would, at age forty-five years, require for reading the addition of + 1 D. Sph., making his prescription read − .50 D. S. ⊃ − 2.75 D. C. Ax. 15°.

(c) A patient who had been wearing + 2.75 D. C. Ax. 45° ⊃ − 1.50 D. C. Ax. 135° for distance and + 4.25 D. C. Ax. 45° for reading would, at age fifty years, require for reading + 2 D. S. ⊃ + 4.25 D. C. Ax. 45°.

In deciding upon the strength of glasses for reading, it is not always practicable merely to add to the patient's distance glass the strength of lens necessary at the age of the patient. Too strong a lens for near work would be uncomfortable. Here, as elsewhere in the practice of refraction, no hard and fast rules can be followed out, the patient's comfort being the first consideration. A good rule to follow is to take the refraction of each eye separately for near work, selecting such lens or combination as will give the most acute vision. Then try the two eyes together, reducing the total correction to one which gives good vision, without causing the patient any uncomfortable symptoms.

CHAPTER XI.

CONFIRMATORY TESTS (OBJECTIVE).

INTRODUCTION.

The tests heretofore described have been entirely *subjective*, *i. e.*, dependent in every case upon the replies of the patient to the questions of the examiner. In children and illiterates, these tests are not always practicable, and *objective* tests must be substituted. In fact, as a matter of

FIG. 54.—Showing Argand Burner with Thorington Retinoscopy Chimney.

routine, it is advisable to employ one or more confirmatory tests in all cases of refraction. This reduces the possibility of error to the minimum.

Objective tests are those which depend solely upon the examiner. They consist essentially of a series of maneuvers carried out in a dark room by means of a suitable lamp (an Argand burner is well suited to this purpose, Fig. 54,) retinoscopic mirror (Fig. 55) and objective lens. In place of a retinoscope, the mirror of an ophthalmoscope may be employed, while an ordinary case lens of + 16 D. or + 18 D. will serve the purpose of an objective lens.

MIRROR TEST (CONCAVE MIRROR).

Direct Method.—The examiner, if not emmetropic, must first correct his own error of refraction by means of glasses or the proper lens placed behind the sight-hole of the oph-

FIG. 55.—Showing Retinoscope.

thalmoscope. He should then seat himself opposite his patient, in a darkened room and at a distance of fifteen inches, directing the patient to look toward the right side of the observer's head when the right eye is being examined, and to the left side if the other eye. The fundus is now illuminated, and the reflex observed; if no details of the fundus are visible, the patient is emmetropic. If any part of the disc or retinal vessels can be seen, the patient is ametropic. The observer now moves his head in various directions, and notes the resulting movement of the retinal vessels; according as these move in the same direction *with* the head of the observer, or in a direction *opposite* to the latter, the error of refraction is determined.

Direction of Movement of Retinal Vessels.	Refractive Error.
(a) Movement with in all directions.	Hyperopia.
(b) Movement with in one meridian.	Simple Hyperopic Astigmia.
(c) Movement against in all meridians.	Myopia.
(d) Movement against in one meridian only.	Simple Myopic Astigmia.
(e) Movement *with* in one meridian and *against* in the other.	Mixed Astigmia.

If the image is blurred, the strongest convex or the weakest concave lens, which will render it distinct, is the measure of the error.

Indirect Method.—This test should be conducted under a mydriatic. The conditions are the same as in the previous test, with the addition of an object lens which is held as near the patient's eye as possible. Reflecting the light into the eye to be examined and keeping the optic disc in view the lens is gradually withdrawn to a distance of several inches, and the resulting change in the size of the disc noted. The following table will serve to show the diagnostic significance of the change in the size and shape of the optic disc on withdrawing the object lens:

Conduct of the Optic Disc.	Refractive Error.
(a) If the disc remain the same size throughout.	Emmetropia.
(b) If the disc diminish in size.	Hyperopia.
(c) If the disc diminish in size in one meridian only.	Hyperopic Astigmia.

Conduct of the Optic Disc.	Refractive Error.
(d) If the disc diminish in all meridians, but more so in one than in the others.	Compound Hyperopic Astigmia.
(e) If the disc increase in size.	Myopia.
(f) If the disc increase in one meridian only.	Myopic Astigmia.
(g) If the disc increase in all meridians, but more so in one than in the others.	Compound Myopic Astigmia.
(h) If the disc increase in one meridian and decrease in the opposite.	Mixed Astigmia.

RETINOSCOPY OR SKIASCOPY (KERATOSCOPY).

This test is known also as the shadow test. To obtain accurate results by its use, a mydriatic should be employed. The observer is seated opposite the patient, at a distance of one meter in a dark room. The lamp should be placed above and a little to the rear of the patient, leaving his face in the shadow. The test frame should be adjusted to the patient's face and the eye not under examination should be covered by means of the obturator. The patient directs his gaze at the observer's forehead, the light is reflected into the eye as in the previous tests and is made to pass across the retina by slightly rolling the handle of the mirror between the thumb and forefinger, thereby causing the mirror to revolve in the axis of the handle or vertical meridian. Repeat the test, holding the handle horizontally and diagonally, noting in each case:

(a) The shape and size of the shadow surrounding the light reflex.

(b) The brightness of the image.

(c) The relative direction of the movement of the shadow as compared with the direction of rotation of the mirror.

(d) The rate of motion of the reflex.

Generally speaking, if the reflex is bright, the surrounding shadow narrow or crescentic, and the rate of motion slow, the refractive error is one of low degree and *vice versa*.

The mirror used may be either plane or concave. When a plane mirror is used the results are the reverse of these, but the following are the results obtained with a concave mirror:

Emmetropia.—The shadow may show no apparent movement, or a slight movement against the mirror in all meridians. The luminosity is pronounced, and the edge of the shadow is more or less crescentic.

Hyperopia.—The shadow moves against the mirror in all meridians. Place before the eye convex lenses of different strength until the movement is reversed. From the weakest convex lens which reverses the movement deduct + 1 D. and the result represents the measure of the Hyperopia.

Myopia (Low degree).—The shadow moves against the mirror when the error is less than 1 D. Place before the eye convex lenses of different strength until the movement is reversed. From the weakest convex lens which reverses the movement deduct + 1 D. and the result represents the measure of the Myopia.

Myopia (High degree).—The shadow moves with the mirror in all meridians. Place before the eye concave lenses of different strength until the strongest lens is found with which the shadow continues to move with the mirror. From this likewise deduct + 1 D. (add − 1 D.) and the result is the measure of the myopia.

Astigmia (Hyperopic).—The shadow moves against the mirror in all meridians. The weakest convex lens which reverses the movement in one meridian will not be strong enough to reverse the movement in the opposite meridian. Note the strength of the former, then try stronger lenses until one is found which will reverse the movement in the opposite meridian. By deducting + 1 D. from the two lenses which reversed the movement in the two principal meridians, the refraction is obtained.

Astigmia (Myopic).—When of low degree, the image moves against the mirror in all meridians. The test is the same as the preceding.

When the error is of high degree and the case is one of simple myopic astigmia, the image moves rapidly with the mirror in one meridian and slightly against in the other.

When the error is of high degree and the case is one of compound myopic astigmia, the image moves with the mirror in both meridians, more rapidly in one than in the other. The strongest concave lens with which the shadow continues to move with the mirror in all meridians is the measure of one of the principal meridians (after deducting + 1 D., *i. e.*, adding −1 D.). Now increasing the strength of the neutralizing lens, the shadow will be reversed in all but one meridian, viz., the other principal meridian. The strongest concave lens with which the shadow continues to move with the mirror is the measure of the refraction in this meridian (after deducting + 1 D., *i. e.*, adding − 1 D.).

Astigmia (Mixed).—When the error in each of the principal meridians is less than 1 D. the image moves against the mirror in all meridians. When the error is greater than 1 D. the movement in one meridian will be with the mirror, in the opposite meridian against it. The test is made like the preceding ones.

When astigmia is of high degree the retinal reflex has the appearance of a band of light, so that the edge of the shadow is straight and sharply defined. This band of light coincides with one of the principal meridians and with the axis of the correcting cylinder.

CHAPTER XII.

MUSCULAR IMBALANCE.

OCULAR MOVEMENTS.

When the eyes are directed toward an object they are said to "*fix*" this object. When in this position the image falls upon the retina of each eye at the Macula Lutea, or point of most acute vision. This is necessary for two purposes, viz.: First, in order that the brain perceive but one image of the object looked at; and, second, in order that the image be as clear as possible.

The act of fixing is accomplished by the *extrinsic muscles* of the eye, consisting of four straight and two oblique muscles, viz., the Superior Rectus, Inferior Rectus, Internal Rectus, External Rectus, Superior Oblique and Inferior Oblique. The Recti move the eyes upward, downward, inward or outward, while the oblique muscles cause the eye to rotate in the plane of the equator of the eyeball. More than one muscle takes part in each of these movements, as is shown by the following table:

TABLE V.

SHOWING OCULAR MUSCLES CONCERNED IN THE SEVERAL EXCURSIONS OF THE EYEBALL.

Movement.	Direction.	Muscles.
Elevation.	Upward.	Superior Rectus. Inferior Oblique.
Depression.	Downward.	Inferior Rectus. Superior Oblique.
Adduction.	Inward.	Internal Rectus. Superior Rectus. Inferior Rectus.
Abduction.	Outward.	External Rectus. Superior Oblique. Inferior Oblique.
Sursumduction.	Rotation of the upper part of the eye inward.	Superior Oblique. Superior Rectus.
Sursumduction.	Rotation of the upper part of the eye outward.	Inferior Oblique. Inferior Rectus.

MUSCULAR BALANCE OR ORTHOPHORIA.

Under normal conditions both eyes move simultaneously and to the same extent. Whether focussed for near or distant objects, the eyes may be moved up, down, in or out, and in so doing, both eyes move at the same time, without altering their positions as regards each other. This is known as "*associated*" movement of the eyes. When the muscles of the two eyes are in perfect equilibrium or balance, the condition is known as *Orthophoria*.

The amount of movement of which the normal eye is capable is about 45° upward, inward and outward, and about 55° downward. This latitude of motion constitutes what is known as the *Field of Fixation*.

HETEROTROPIA OR STRABISMUS.

When the two eyes are directed toward the same object the image falls upon corresponding points of the two retinæ, so that the brain perceives but one, a condition known as *Binocular Single Vision*. This is, of course, the normal state. When the two eyes are not directed toward the same object the condition is known as *Heterotropia*, *Strabismus*, *Squint* or *Cross-eye*. The image in such a condition does not fall upon corresponding points of the two retinæ, so that the brain perceives the image from each retina, and the patient has double vision or *Diplopia*.

That image produced on the retina of the eye which fixes, falls upon the macula and is, therefore, called the *true* image, while that produced on the retina of the deviating eye does not fall on the macula and is, therefore, known as the *false* image. After the condition of Heterotropia has existed for some time, the patient learns to disregard or suppress the false image and depends entirely upon the vision of the normal eye. The functional disuse to which the retina of the squinting eye is subjected, results ultimately in a loss of sensitiveness to light stimulation, a condition known as *Amblyopia* and one which cannot be improved by the use of glasses.

HETEROPHORIA.

In the absence of an actual deviation of either eye, there may yet be present a muscle imbalance or Heterophoria, owing to the fact that one muscle or set of muscles is weaker than another. An almost constant effort is, therefore, necessary to compel the weaker muscle to do as much work as its stronger opponent. This continued strain leads often to pronounced symptoms of asthenopia.

Heterophoria bears much the same relation to heterotropia or squint as a latent error of refraction does to one which is manifest, *i. e.*, it is concealed and overcome by the exertion of sufficient muscular and nervous energy, whereas a squint is manifest and cannot be overcome by any muscular effort. Heterophoria is a *tendency* toward deviation, while heterotropia is an *actual* deviation.

FORMS OF HETEROPHORIA.

The varieties of Heterophoria are:

Esophoria, a tendency of the eye to turn inward.

Exophoria, a tendency of the eye to turn outward.

Hyperphoria, a tendency of the eye to turn upward.

Hypophoria, a tendency of the eye to turn downward.

Hyperesophoria, a tendency of the eye to turn upward and inward.

Hyperexophoria, a tendency of the eye to turn upward and outward.

Cyclophoria, a tendency of the eye to turn in the plane of the equator of the eye.

DETERMINATION OF HETEROPHORIA.

The presence of latent errors of refraction was determined by making such errors manifest. This was done by overcoming the activity of the muscles of accommodation, which concealed the underlying conditions. In a similar way the presence of heterophoria is made manifest. Numerous methods have been devised and many instruments have been constructed for the determination of heterophoria, but all are based on the following fundamental principles:

(a) By producing artificial diplopia and determining whether the two images fall upon corresponding points of the two retinæ.

(b) By creating two different images, one falling upon the retina of one eye, the second upon the retina of the other, and determining whether the two images fall upon corresponding points of the two retinæ.

For the purpose of creating an artificial diplopia strong prisms are employed. An object looked at through a prism appears displaced toward the apex, the extent of the displacement depending upon the strength of the prism. (See Fig. 19, p. 30.) This apparent displacement is due to the fact that light rays in passing through a prism are deflected toward

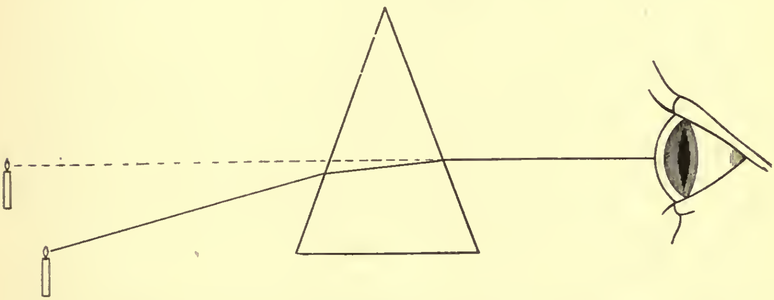

FIG. 56.—Showing Apparent Displacement of an Object Toward the Apex of a Prism.

the base. The eye, perceiving the rays as they emerge along their altered course from the prism, sees the image in the direction of this altered course (Fig. 56.) Hence, if a strong prism be placed before one eye while the other eye remains uncovered, two images will be seen; one image will be deflected toward the apex of the prism, while the position of the other remains unchanged.

A double prism, two prisms placed base to base, may be employed. When placed before one eye, two deflected images are produced, one toward the apex of each prism, while the image of the uncovered eye will lie between these two deflected images.

The tests for Heterophoria most frequently used are: (1) Prism test; (2) Maddox rod test; (3) Cobalt test.

PRISM TEST.

The right eye being uncovered, by placing before the left eye an eight degree prism with its base up or down, two images will be seen, one above the other. If both images lie in the same vertical plane, one exactly above the other, those muscles which move the eyes to the right and left (horizontally) are properly balanced. If they do not lie one exactly above the other, the horizontal muscles are not balanced, and that prism, base in or out, which causes them to lie in the same plane, one exactly above the other, is the measure of the heterophoria. When the base of the prism which corrects the error is directed inward, the condition is one of Exophoria.* If the base is directed outward the condition is Esophoria.

Example: If a four degree prism, base out, is found to place the two images one exactly above the other, the condition is one of Esophoria and its measure is four degrees.

To test the equilibrium of the vertical muscles place before the left eye a ten degree prism, base in. If the two images are on the same level, perfect equilibrium exists. If one is higher than the other, heterophoria is present, and that prism, base up or down, which causes the two images to lie on the same level, is the measure of the error.

MADDOX TEST.

This test is best executed in a darkened room. Place the simple or multiple Maddox rod, Fig. 32, before the left eye, the right eye remaining uncovered. Direct the patient to look at a flame twenty feet distant. The uncovered eye will perceive the image of the flame, while the other will see a streak of light. When the Maddox rod is horizontal this streak will be vertical and *vice versa*.

If the streak does not pass directly through the flame, heterophoria is present and the relative position of the streak to the flame will serve to diagnose its kind. That

*The apex of the correcting prism, like the sharp edge of an axe, is always directed toward the muscle which would be cut were the case one of actual deviation or strabismus.

prism which causes the streak to run directly through the flame is the measure of the error.

The following table will serve to indicate the diagnostic value of the several positions assumed by streak and flame:

TABLE VI.

SHOWING RELATIVE POSITION OF STREAK TO FLAME IN THE DIAGNOSIS OF HETEROPHORIA.

(Maddox Rod over Left Eye.)

Position of Maddox Rod.	Direction of Light Streak.	Position of Streak with Regard to Flame.	Heterophoria.
Horizontal.	Vertical.	To the left of flame.	Esophoria.
"	"	To the right of flame.	Exophoria.
Vertical.	Horizontal.	Above the flame.	Hypophoria (left eye turns down).
"	"	Below the flame.	Hyperphoria (left eye turns up).

COBALT TEST.

This is similar to the Maddox Rod test, a blue image of the flame being substituted for the light streak. By placing the Cobalt blue glass found in the test case before the left eye, the right eye being uncovered, and directing the patient to look at a flame twenty feet away, two images will be perceived, one yellow and one blue. The relative positions of the two images will serve to diagnose the condition. If the colored image is at the left of the true image, the condition is that of Esophoria. If the colored image is at the right, the condition is that of Exophoria. If above, the left eye turns down; if below, the left eye turns up—Hyperphoria. This is a simple procedure which will serve to demonstrate the presence of heterophoria.

COVER TEST.

While one eye is covered, the patient should be directed to look at some object about twelve inches distant. If, on removal of the obturator, the eye is seen to move, muscle imbalance exists. *The direction of this movement indicates the weak muscle,* for it was the weak muscle which was relaxed while the eye was at rest. When the eye was uncovered this weak muscle, in response to excessive stimulation, drew the eye to its proper position to re-establish muscular balance. Hence, if the eye moves inward on uncovering, outward deviation had taken place while the eye was at rest and the condition is, therefore, one of Exophoria.

DETERMINATION OF CYCLOPHORIA.

Insufficiency of the oblique muscles of the eye is seldom found to exist alone, but usually in conjunction with an insufficiency of one of the recti muscles. It is best determined by means of the double prism found in the test case. This is placed before one eye, the other eye being uncovered. A card on which a horizontal line is drawn is held at a distance of eighteen inches. By the action of the double prism two lines are seen parallel to each other. Between them is a third line, the image on the retina of the uncovered eye. If the line is parallel with the other two, perfect balance is present. But if this third line is oblique to the other two, cyclophoria is indicated. That prism, by the aid of which the three lines are made parallel, is the measure of the error. The position of the correcting prism before the eye will be oblique, with the base in or out.

CORRECTION OF HETEROPHORIA.

According to the degree of the insufficiency, four methods are available for the relief of muscular imbalance, viz.:

(a) Correction of the error of refraction.

(b) Prism exercise.

(c) Wearing of correcting prisms.

(d) Operation.

Correction of the Error of Refraction.—In mild cases correction of the error of refraction will be sufficient for the relief of the condition. The muscles which turn the eyes inward are supplied by the third nerve, which also supplies the ciliary muscle. This will explain the very close relationship existing between accommodation and convergence. Any increase or decrease in the stimulation of the muscles of accommodation likewise affects the muscles of convergence.

Esophoria is usually the result of uncorrected Hyperopia. The constant contraction of the ciliary muscle in its effort to overcome the hyperopia is accompanied by increased nerve stimulation of the internal recti, resulting in too great convergence.

Exophoria is usually associated with myopia. The relaxation of the ciliary muscle being necessary to clear vision, the muscles of convergence do not receive the requisite amount of stimulation and, in consequence, relax.

Hyperphoria is frequently found associated with marked assymetry of the face and with some forms of anisometropia.

Prism Exercise.—By means of persistent, regular and systematic exercise of the weaker muscle, the same can frequently be strengthened sufficiently to do its work properly, especially after any existing refractive error has been corrected. In conducting prism exercises, the prism should always be inserted in the position which actually increases the error, *i. e., base over the stronger muscle.* Prism exercise is most promising of success in the treatment of exophoria, less so in correcting esophoria or hyperphoria.

These exercises are conducted as follows: Weak prisms are placed before the eyes, base over the stronger muscle, and the patient is directed to look at a flame twenty feet away. As soon as the double images come together, the result of considerable effort on the part of the patient, the prisms are removed. After a moment's rest, they are again replaced. These exercises should be conducted five or ten minutes daily, the strength of the prism being gradually increased.

Wearing of Prisms.—When the kind and amount of heterophoria has been determined, it is frequently necessary to assist the weaker muscle by prescribing a prism for constant wear. No hard and fast rule can be followed in determining the strength of the prism to be prescribed. The following suggestions will be useful:

Exophoria.—From one-half to three-quarters of the strength of the correcting prism may be prescribed.

Esophoria.—When of low degree no prism need be worn. When of high degree, about one-quarter of the strength of the correcting prism may be prescribed.

Hyperphoria.—The full correcting prism should be prescribed.

For the sake of comfort and cosmetic effect, it is customary in prescribing prisms to divide the prism correction between the two lenses. Instead of placing a four-degree prism before one eye with an ordinary lens before the other, two two-degree prisms are ordered. If the base of the prescribed prism is directed inward, both prisms must be directed inward; if outward, both prisms are prescribed base out. The effect of a two-degree prism base out before each eye is the same as that of a four-degree prism base out before one eye, because in each case the images falling on the two retinæ are deflected inward an equal amount.

Only weak prisms can be worn; strong prisms have the effect of breaking up the light which passes through them, producing what is known as Chromatic Aberration. The weight of such prisms is a further objection to them.

When a patient presents a refractive error in addition to his heterophoria, instead of prescribing prisms the lens may be ordered decentered. (Fig. 22.) (See "Relationship of Lenses," p. 34.) Decentering a *convex lens inward* or a *concave lens outward* produces the effect of a *prism, base in*, and, of course, a convex lens decentered outward, or a concave lens inward, produces the effect of a prism *base out*. The strength of the prismatic effect obtained depends upon (a) the curvature of the surface, *i. e.*, upon the strength of the lens, and (b) upon the extent of the decentration.

Operation.—Only in extreme cases, in which the suggested methods have been tried without relief to the patient, should recourse be had to operative procedure. A partial tenotomy of one or both of the stronger muscles may be made. This phase of the subject, however, falls beyond the scope of this treatise.

CHAPTER XIII.

SPECTACLES AND EYE GLASSES.

INTRODUCTION.

The most satisfactory method of wearing glasses is in spectacle frames. The advantages of spectacles over eye glasses are: (a) They can be worn when eye glasses cannot be kept in place; (b) They maintain cylindrical lenses at their proper axes; (c) They cannot fall off, no matter what may be the position of the patient's head.

On the other hand, the fact that eye glasses, especially the rimless variety, are much less conspicuous and more becoming to most people, gives them the advantage whenever the cosmetic effect is an important consideration. Glasses will be more cheerfully endured if they are becoming than if they are not so. The lighter weight of eye glasses is an added advantage. Eye glasses are of doubtful value and ordinarily should not be prescribed when the patient's correction calls for strong cylinders, because a slight drooping of the lenses, by changing the axes of the cylinders, alters their refractive effect.

SPECTACLES.

There are two principal varieties of spectacle mountings, viz., those having metal rims encircling the lenses, called "full frames," and those without such rims, known as "rimless" or "skeleton" mountings.

Full frame spectacles are more durable than the rimless, owing to the protection afforded the lenses by the metal rims. (Fig. 57.) The chief objection to this form of spectacle is the fact that the rims interfere with vision, thus proving a source of annoyance to the patient. A further objection is the fact that the rims render the frames more conspicuous and also add to their weight.

The rimless or skeleton mountings are neater in appearance, less conspicuous, of lighter weight, and do not interfere with vision. (Fig. 58.)

Spectacle mountings consist of a bridge or nose piece, two lenses, with or without rims, and two temples or side pieces which pass backward over the ears and serve to hold

FIG. 57.—Showing Full Frame Spectacle Mounting.

the frame in place. The frames may be constructed of gold, silver, nickel or steel; various alloys are also used, the chief constituent of which is tin. Gold, by virtue of its superior wearing qualities, has proved most satisfactory. Silver

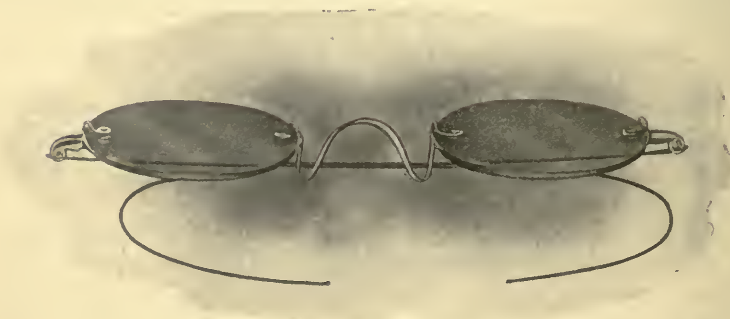

FIG. 58.—Showing Rimless or Skeleton Spectacle Mounting.

frames are soft, easily bent out of their proper shape, and too readily tarnish, while steel and nickel plated frames are liable to rust.

REQUISITES OF PROPERLY FITTING GLASSES.

For glasses to occupy their proper position, and to be worn with comfort, the following conditions must be met:

1. The optical center of each lens must be directly in front of the pupil of each eye.

2. The lenses must be so far removed from the eyes that the patient's lashes do not come in contact with them.

3. Both lenses must lie in the same plane and this plane must be at right angles to the direction of vision.

4. The long diameter of the lenses must be horizontal.

5. The lenses must be large enough to afford an ample field of vision.

6. The bridge or nose-piece of spectacles must be of the proper height and width to lie flush with the nose, and the temples must be long enough to pass loosely over the ears, and far enough apart to avoid any pressure on the sides of the face.

7. The guards of eye glasses must lie flush with the sides of the nose and must neither irritate nor exert undue pressure upon the tissues.

MEASUREMENTS AND DATA FOR ORDERING SPECTACLES.

In ordering spectacle frames it is necessary that the manufacturer be furnished with certain data and measurements. These are:

(a) The prescription for each lens.

(b) The kind of frame, whether full or rimless.

(c) The material of construction, whether gold, silver, nickel, steel or alloy.

(d) The interpupillary distance.

(e) The size of the lenses desired and their angle, *i. e.*, whether vertical or with their upper edges tilted forward.

(f) The dimensions, the height and breadth, of the bridge or nose piece.

(g) The form of the temples, whether straight or riding bows. When the latter are ordered the kind must be specified, whether plain or cable.

(h) The length of the temples.

Interpupillary Distance.—This is the distance between the two pupils. It is best measured by holding a small ivory rule before the patient's eyes, Fig. 59, and noting the

FIG. 59.—Showing Method of Measuring Interpupillary Distance.

distance between the outer edge of one pupil and the inner edge of the other, or from the center of one to the center of the other. When the iris is very dark, or the illumination poor, it is sometimes easier to measure the distance from the outer corneo-scleral junction of one eye to the inner corneo-scleral junction of the other. In the manufacture of the frames the distance between the optical centers of the lenses must correspond with this measurement.

Size of Lenses. The majority of manufacturers now conform to one standard system of designating the size of lenses. The latter are numbered, beginning with the smallest: 4, 3, 2, 1, 0, 00, 000, 0000 and Jumbo. (See Fig. 60.) The sizes most commonly used are: For male adults, 00 and 000; for female adults, 1, 0 and 00 and for children 2, 1 and 0.

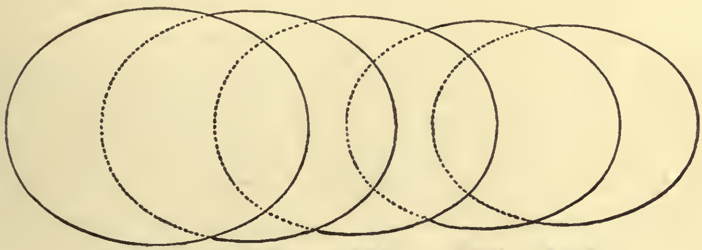

FIG. 60.—Showing Standard Lens Sizes.

Angle of Lenses.—When the glasses are to be worn for distant vision only, the lenses should lie in a vertical plane, *i. e.*, at right angles to the direction of vision.

When the glasses are prescribed for reading, the frames should be tilted to lie in a plane more nearly parallel with the patient's book, see Fig. 36. The lenses should also be from a sixteenth to an eighth of an inch lower than for distance, because the eyes are directed downward. This lowering of the lenses is effected by increasing the height of the bridge.

Bridge or Nose Piece.—This is best measured by trying on a sample frame and making the needed corrections. The width of the bridge is the distance between its lower extremities, while the height is the vertical distance between the crest of the bridge and the pupillary line (an imaginary line passing horizontally through the center of each pupil).

The distance of the lenses from the eyes is regulated by the crest of the bridge. To place the lenses farther from the eyes, the crest of the bridge is ordered "inset," *i. e.*, it is made to lie behind the plane of the lenses. To place the lenses nearer the eyes the crest of the bridge is ordered "outset," *i. e.*, it is made to lie in front of the plane of the lenses. Prominent eyes and small, flat noses require an inset, while deep-set eyes and prominent noses require an outset.

Temples.—These are the side pieces which hold the frame in place. For reading, straight temples may be ordered. In the majority of cases, however, riding bows will be preferable. These pass backward over and around the ear. Plain riding temples are made of stiff, tempered wire, while cable

FIG. 61.—Showing Rimless or Skeleton Eye Glass Mounting.

temples are spirally wound with a narrow, thin, metal strip, making them more flexible and less liable to exert pressure on the ear.

Temples are usually made in three lengths, viz., short, medium and long, these being respectively five and one-half, six, six and one-half inches in length. Short temples are required for children and medium temples for the average adult. Only when the head is unusually large need long temples be supplied.

EYE GLASSES.

There are two principal varieties of eye glasses, viz., the full and the rimless frames, corresponding to the two varieties of spectacle frames already described. The rimless mounting, on account of its lightness, simplicity and beauty, is usually preferred. (Fig. 61.)

Eye glasses consist of two lenses, a spring, two studs and two nose guards. The frames are constructed of the same material as that used in the manufacture of spectacles.

MEASUREMENTS AND DATA FOR ORDERING EYE GLASSES.

In ordering eye glasses the following data and measurements must be furnished the manufacturer:

(a) The prescription for each lens.
(b) The kind of frame, full or rimless.
(c) The material of construction.
(d) The interpupillary distance.
(e) The size of the lens desired.

FIG. 62.—Showing Full Frame Eye Glass Mounting.

(f) The kind of guards, and their angle with the plane of the lenses.
(g) The distance between the upper ends of the guards.
(h) The distance between the lower ends of the guards.
(i) The shape and length of the spring.
(j) Whether or not a handle or hole for cord or chain is desired.

Springs.—The spring connects the two halves of the frame. (Fig. 62.) It may be either vertical or horizontal. Vertical springs are made in two shapes, the one circular, called a "hoop," the other elliptical, called the "oblong" spring, the choice between them lying with the patient.

Vertical or regular springs are either short, medium or long. Medium springs are suited to the majority of cases. Only in exceptional cases are short or long springs required.

Studs.—These are the small metal pieces which serve to hold the spring and guards together and to join them to the lenses. They are made of different lengths for the purpose of regulating the distance between the lenses to make this coincide with the interpupillary distance. Offset studs are designed to place the lenses in a plane in front of the spring. This is necessary in patients having prominent eyes and long lashes in which the guards do not remove the lenses far enough from the eyes.

Guards.—These are the two pieces which rest against the sides of the nose. They are measured by placing a sample frame on the patient's nose and ascertaining the distance between the two upper ends and that between the two lower ends.

There are three principal varieties of guards, viz.:

(a) Shell-faced guards, in which the bearing surface, or that which lies against the nose, is covered with tortoise shell or celluloid.

(b) Cork-faced guards, in which this surface is covered with cork.

(c) All-metal guards. The latter are most modern, and in the majority of cases the most satisfactory, because: 1. They do not become foul with the accumulation of perspiration and dirt, as do the others; 2. They are made with a wide bearing surface to lessen the irritation on the nose, and 3. They are much neater in design.

The position of the lenses is largely regulated by the guards. To set the lenses out sufficiently to prevent the lashes from coming in contact with them, "off-set" guards are used, the arms of which place the nose-pieces or shanks back of the plane of the lenses. The amount of off-setting depends upon the length of the arms.

To hold the lenses in a perpendicular position for distant vision, or to tilt them for reading, the arms are attached to the shanks at varying angles. Sample glasses fitted with guards at different angles should be tried until one is found which meets the requirements of the case.

When it is desired to lower the lenses, guards of the proper angle and off-set, with arms attached to the lower end of the shank, should be ordered. The lenses of eye glasses may be still further lowered by "dropping" them. that is, by attaching them to the frame above the pupillary line; or in the case of rimless eye glasses, by boring the holes for studs above the horizontal axis.

OTHER FORMS OF GLASSES.

In addition to the above described regular forms of spectacles and eye glasses, there are a number of modifications designed to meet the special requirements of certain patients. The most important among these are the Half Oval Eye Frames, Reversible Spectacles, Hook or Grab Fronts and Clerical Glasses.

Half Oval Eye Frames.—This form, Fig. 63, is convenient

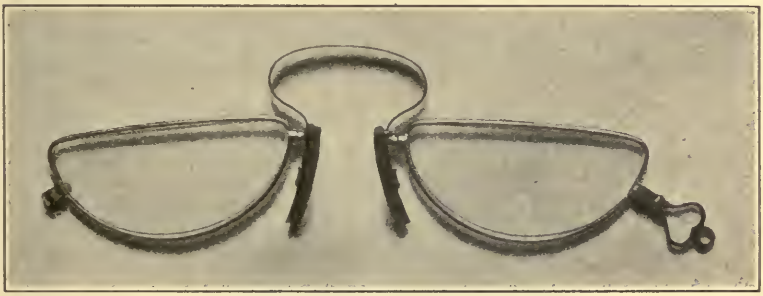

FIG. 63.—Showing Half-Oval Eye Glass Frame.

when no distant correction is used and when the patient's occupation requires correction for near work alternately with distant vision. These frames are used by teachers, preachers and those engaged in certain kinds of office work.

Reversible Spectacles.—When a patient has sight in only one eye and this eye requires correction for both distant and near vision these frames are useful. It is fitted with a double bridge. The lens for distant vision is placed on one side, that for reading on the other. To change from the distant lens to that for near work the patient has merely to reverse the frame, *i. e.*, to put them on upside down. This form of spectacle is especially useful to old people having one aphakic eye, the other being cataractous.

Hook or Grab Fronts. — These frames, as the name indicates, may be hooked over a spectacle frame for reading. They are fitted with lenses of such strength that, when added to the distance lenses, the combined effect is the patient's reading correction.

Clerical or Adjustable Eye Glasses.—These are useful for lecturers, ministers and others who are compelled to remove their glasses frequently. The guards lie in the plane of the lenses and readily adjust themselves to the nose.

CHAPTER XIV.

SPECIAL FORMS OF LENSES.

BIFOCAL LENSES.

When the patient requires correction of both distant and near vision, the necessity of two pairs of glasses may be obviated by prescribing bifocal lenses. The original bifocal, invented by Benjamin Franklin, consisted of two half-oval lenses, the upper half being the patient's correction for distant vision, the lower half the correction for reading. This form is now known as the "split" bifocal. (No. 3 of Fig. 65.)

A great many other forms have been developed, all based on the original idea of affording, in one frame, both distant

FIG. 64.—Showing Grooved Bifocal Lens.

and reading correction. In some of these the reading correction is ground on the lower part of the distance lens, in others a small reading lens fits into a notch cut out of the distance lens (Fig. 64), while in a third form a small "wafer" lens is cemented on the back or front of the distance lens (No. 1 and 2 of Fig. 65). This wafer is of such a strength that, when added to the distance glass, the total refractivity is the correction for reading. This form, known as the cement bifocal, is the most satisfactory and is now almost universally prescribed. The size and shape of the wafer must be suited to the taste and requirements of the patient.

Although bifocal lenses are a great convenience, they present several objectionable features. The most serious of these lies in the fact that the patient, when looking at the floor, when ascending and descending stairs, and getting in and out of vehicles, is confused by the blurring effect of the reading wafer. At such times he is, therefore, compelled to look under his glasses, or over the upper edge of the wafer.

The edge of the wafer, in a properly adjusted spectacle frame, is below the pupil, in order that the patient's distant vision be unimpaired. The wafer may be decentered somewhat to increase the field of distant vision. But even with the most perfect adjustment, the bifocal lens is frequently a great

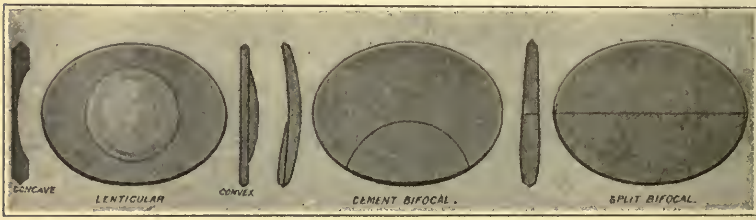

FIG. 65.—Showing Different Forms of Bifocal Lenses.

annoyance to the patient. The annoyance of the wafer is partially overcome by constructing the distance lens of two thin lenses, each having a groove in its lower part and then cementing these two lenses together, their plane surfaces in apposition. The reading wafer is then inserted into the groove between the two lenses. This form is known as the "invisible" bifocal. In the heavy glasses required in cases of aphakia this is the only practicable arrangement. Its chief objection lies in the expense of manufacture.

PERISCOPIC LENS.

A periscopic lens is one which is convex on one side and concave on the other. The concave surface has a spherical curvature of 1.25 D. This curvature, conforming closely to the arc of rotation of the eye, brings the border of the lens nearer the eye and does away with the large gap between the edge of the lens and the face. In this way the field of vision is enlarged, and the refracting surfaces of the lens are maintained at right angles to the line of vision, irrespective of the movements of the eye. For these reasons, a periscopic lens is to be preferred to the ordinary flat lens, only the central part of which is optically correct. Objects seen through the outer portions of the common lens appear more or less distorted, a phenomenon known as Spherical Aberration; this is more apparent in the stronger convex lenses. There is in a flat lens also a prismatic effect which increases the more the eye is turned from the centre of the lens. This is due to the fact that the line of vision is not at right angles to the refracting surface. These objections are removed by the use of the periscopic lens.

Meniscus Lens.—When a periscopic lens has a deeper concave surface than 1.25 D. and a spherical refractive effect, it is called a Meniscus. A converging meniscus is one in which the convex surface has a greater curvature than the concave, (No. 6 of Fig. 17) having, therefore, the refractive effect of a convex lens. A diverging meniscus is one in which the concave surface has a greater curvature than the convex, (No. 7 of Fig. 17) having therefore, the refractive effect of a concave lens.

TORIC LENS.

A toric surface is one which is shaped like the bowl of a spoon, *i. e.*, with one of the principal meridians more convex than the other. In the case of a spoon, the meridian lying crosswise of the bowl is more convex than the meridian lying lengthwise of the bowl. The convex side of the bowl represents, crudely, a convex toric surface; the concave side, a concave toric surface.

The term "Toric" is derived from the latin "tor," signifying the base of an architectural column. Such a base has two curvatures, the horizontal one being the arc of a larger circle and hence less convex than the vertical one. Making a vertical section of such a tor, *i. e.*, cutting off a segment, we have, roughly speaking, a plano-convex toric lens. (Fig.

66.) By grinding into a flat block a surface conforming to the tor, we have a plano-concave toric lens. (Fig. 66.)

A toric lens (Fig. 67) is usually ground with the toric sur-

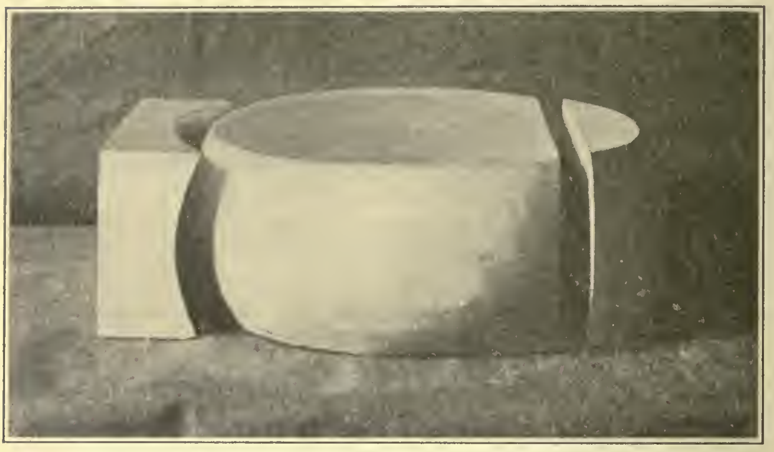

FIG. 66.—Showing a Tor with Sections to Represent Plano-Convex and Plano-Concave Toric Lenses.

face on the anterior side, the posterior surface being a concave sphere of either 3 D., 4.50 D., 6 D. or 9 D. strength. It is used exclusively for the correction of simple, compound, or mixed astigmia.

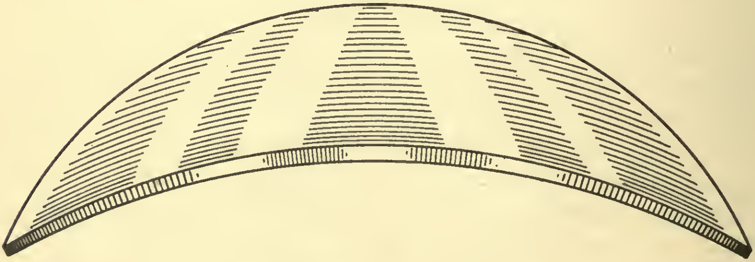

FIG. 67.—Showing a Toric Lens.

As has been stated, one of the principal meridians of a toric surface has a stronger refractive power than has the other. The weaker is called the "base curve" and is always in the same meridian as the axis of the cylinder prescribed.

When the base curve has the same refractive power as that of the concave spherical surface, there will be no refraction in this meridian. The lens will, therefore, have the effect of an ordinary cylinder, the axis of which coincides with the meridian of the base curve.

Example. + 1 D. C. Ax. 90° in toric form may be ground as follows:

Anterior surface — Base curve: plus 6 D. in the meridian of 90°; + 7 D. in the meridian of 180°.

Posterior surface — 6 D. Sph.

When the base curve has a different refractive power than that of the concave spherical surface, the lens is a sphero-cylinder, and the difference in refractivity between the base curve and the concave surface determines the strength of the spherical part of the lens.

Example. + 1 D. S. ⊂ + .50 D. C. Ax. 90° in toric form may be ground as follows:

Anterior surface — Base curve: + 7 D. in the meridian of 90°; + 7.50 D. in the meridian of 180°.

Posterior surface — 6 D. Sph.

One great advantage of toric as well as periscopic lenses, over the ordinary flat lens, is their lessened weight. This feature is especially valuable in the prescribing of cataract lenses or those having a strong spherical element, with or without a cylinder. This is owing to the fact that the curves are equally divided between the two sides of the lens. The spherical aberration of such a lens is less than in one having the entire curve on one surface.

In the prescribing of toric lenses, it is well to use an inset stud, thus taking advantage of the hollow of the lens to bring the latter as near the eye as possible.

APPENDIX.

MECHANICAL AIDS TO REFRACTION.

A number of instruments mentioned in the text, and others considered of value in confirming the results of the test case, are here described.

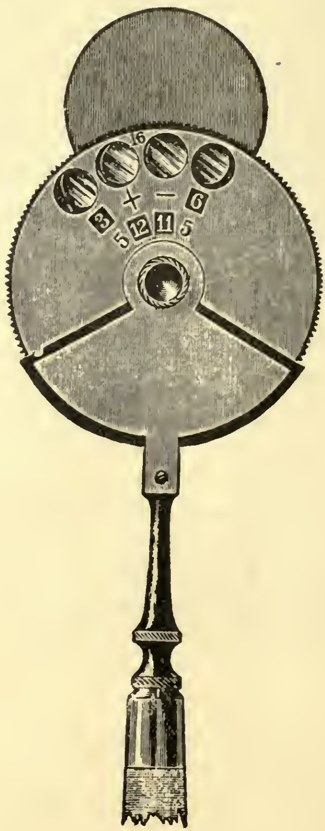

Fig. 68.—Showing Rear View of Ophthalmoscope.

OPHTHALMOSCOPE.

Since the invention of the ophthalmoscope by von Helmholz some fifty years ago, the instrument has been greatly improved and is made in many different forms. The Loring pattern (Fig. 68) typifies the modern instrument. It contains two independent rotatable discs, the lower disc carrying fifteen lenses, and the superposed disc four supplementary lenses. By combining the lens powers in both discs, all of the positive and negative equivalents from .50 D. to 24 D. are quickly obtained and automatically recorded, the positive and negative quantities being expressed in white and red figures respectively. The lenses in the ophthalmoscope are used principally for the neutralization of errors in the refraction of the observed eye, and hence the acquirement of a clear view of the intra-ocular tissues. The use of the ophthalmoscope for determining errors of refraction has been fully outlined. (See Objective Tests.)

LUMINOUS OPHTHALMOSCOPE.

In this instrument (Fig. 69) the light, instead of being reflected into the eye from a wall lamp, as with the ordinary ophthalmoscope, is supplied by a small electric lamp encased within the handle. It passes through a strong condensing lens and is then reflected into the observed eye. The examiner looks above the edge of the mirror, thus avoiding the usual corneal reflex which frequently embarrasses a clear view of the fundus.

This form of instrument has several advantages over the ordinary form, viz.:

1. It can be used in either daylight or darkness.
2. It affords a larger field of view.
3. It can be brought very close to the eye.
4. It can be used at the bedside.

The chief objection to this form of instrument as compared with the ordinary type is the time and trouble required to keep it in perfect working order.

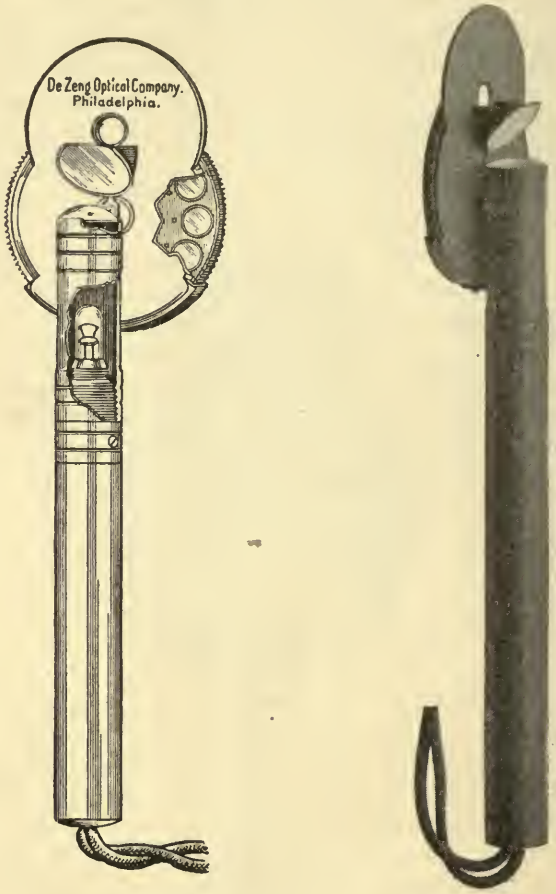

FIG. 69.—Showing Luminous Ophthalmoscope.

LUMINOUS RETINOSCOPE.

In the Luminous Retinoscope, as in the case of the Luminous Ophthalmoscope, the source of light is combined with the instrument (Fig. 70). An electric lamp is encased in a tube facing a diagonally placed mirror by means of which the light is reflected into the eye. The use of the retinoscope for diagnosing refractive errors is described under Retinoscopy. (P. 91.)

FIG. 70.—Showing Luminous Retinoscope.

The advantages claimed for this instrument over the ordinary form are:

1. It can be used in daylight.
2. It has stronger illumination.
3. It is portable.

THE OPHTHALMOMETROSCOPE.

This instrument (Fig. 71) consists of a Luminous Ophthalmoscope with the addition of an illuminated test object of multiple radiating lines, so arranged as to be projected

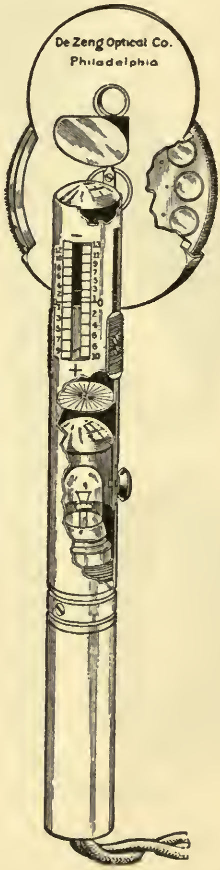

FIG. 71.—Showing Ophthalmometroscope.

and focussed upon the retina. The rays from a small electric lamp are gathered by a strong, adjustable condensing lens directly over it, and projected upon the translucent test object. The light from the illuminated test object is directed by the obliquely fixed reflector into the eye, where, by looking through the peep aperture above the mirror, a perfect reproduction of the test object may be seen upon the retina.

In applying the instrument for the measurement of errors of refraction the operator moves the test object up or down in the tube, as required to focus it sharply on the retina, employing at the same time such lens power at the peep aperture as may be found necessary to give a clear view of the fundus.

In Emmetropic eyes all the radiating lines of the test object will appear uniform and most distinct with the index at zero.

In Simple Hyperopia all the radiating lines will appear uniform and most distinct with the index upon the scale of white figures, which is below zero.

In Simple Myopia all of the radiating lines will appear uniform and most distinct when the index is upon the scale of red figures, which is above zero.

In Simple Astigmia the radiating lines in one meridian will be in focus at zero, while those in the opposite meridian will appear blurred, and if, to focus the blurred lines, the test object is moved down, the error is Simple Hyperopic Astigmia, while if moved up, Simple Myopic Astigmia.

In Compound Hyperopic Astigmia the Hyperopia is equal to the smallest number among the white figures, indicating the focus of the lines in one meridian, and the astigmia to the difference between this number and that greater one on the same scale, at which the lines in the opposite meridian are focussed.

In Compound Myopic Astigmia the same conditions prevail, excepting that the foci of both meridians are recorded upon the scale of red figures.

In Mixed Astigmia the focus of one meridian is recorded by the white figures, and that of the opposite meridian upon the red ones.

To obtain the best results with this instrument the pupil should be dilated.

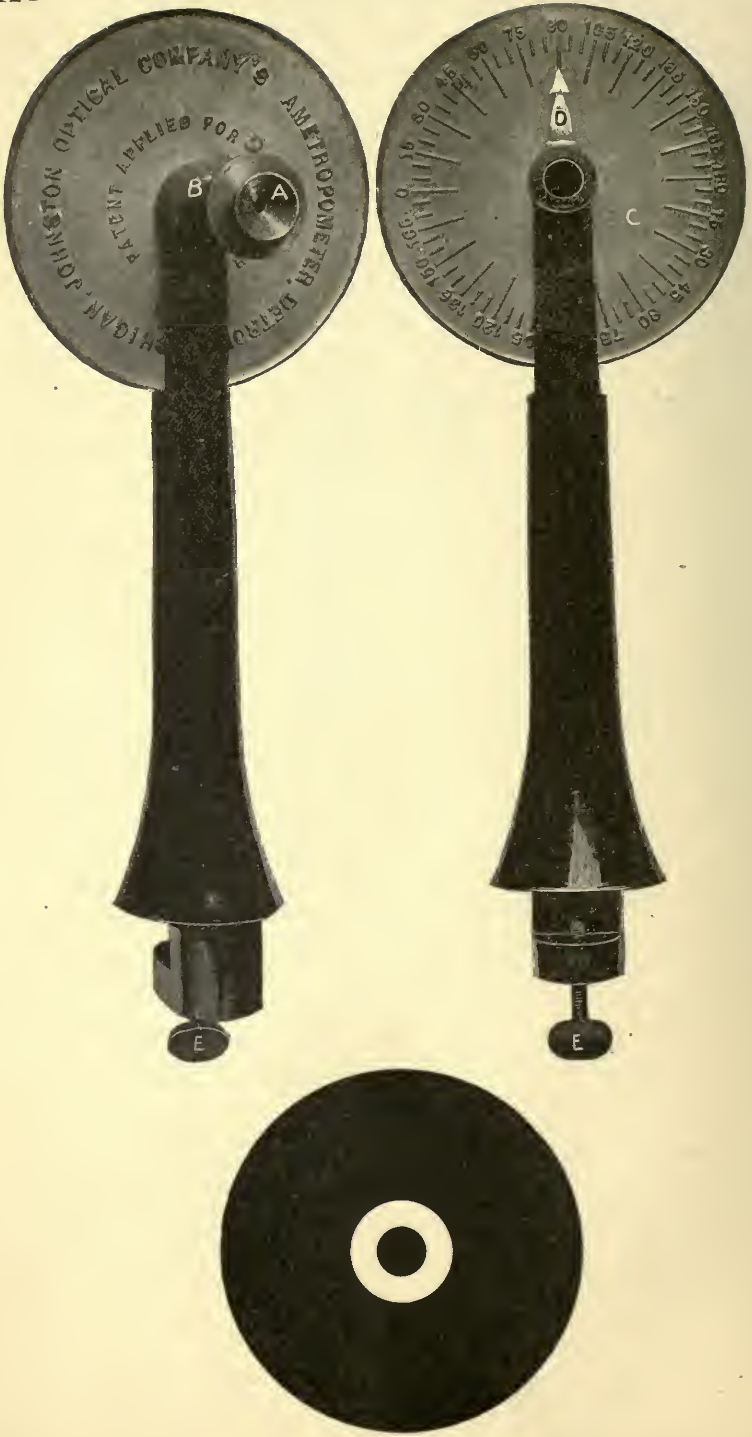

FIG. 72.—Showing Ametropometer.

AMETROPOMETER.

This instrument (Fig. 72) consists essentially of a metal tube and a disc fitted with a double prism which can be revolved to any desired axis. A metal target, bearing a white ring on a black background, is hung at a prescribed distance. The patient is instructed to place his eye close to the eye-piece, his head being steadied by means of a chin rest. Directing his gaze toward the target he will see two white rings, their relative positions in the different meridians being determined by revolving the metal disc. The position of the two rings in the several meridians serves to diagnose the refractive condition of the eye examined.

REFRACTOMETER (DE ZENG'S).

This instrument (Fig. 73) is designed for the purpose of measuring refractive errors and is adapted especially to

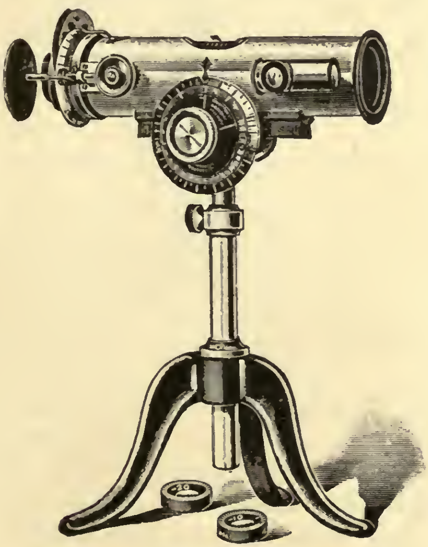

FIG. 73.—Showing Refractometer.

cases in which a cycloplegic is contraindicated. It consists of two metal tubes, one sliding within the other, and regulated by a rack and pinion adjustment. The outer tube contains a concave lens of 20 D. strength, the inner one a convex, achromatic lens. These lenses, at different distances from each other, have a combined refractive effect varying from + .12 D. to + 18 D. and from − .12 D. to − 9 D. The convex spherical effects are recorded on a revolving dial at the side, the concave effects on the top of the inner tube. At the front of the tube is a revolving head, composed of two revolving discs, containing a stenopæic slit and a number of concave cylinders.

The best method employed in conducting a test is that known as "fogging," *i. e.*, overcorrecting a hyperopic or undercorrecting a myopic eye. This causes the type to blur and the accommodation to relax, so that the latent errors are made manifest. By adjusting the instrument until the vision is clear the amount of refractive error is readily noted. By fogging and again clearing the vision while the patient's gaze is directed toward the astigmic dial, the presence of latent as well as manifest astigmia can be determined. When astigmia is present it can be measured and the axis verified by the use of the cylindric lenses contained in the revolving discs.

PLACIDO'S DISC OR KERATOMETER.

Placido's disc consists of a target attached to a handle and pierced through the centre by a small sight-hole (Fig. 74). On the reverse side is an attachment for receiving lenses. To use the disc the patient is placed with his back to a strong light. The examiner holds the disc with the sight-hole directly in front of his eye, and, with the target brightly illuminated, approaches the eye to be examined until the outer edge of the image on the cornea coincides with the corneo-scleral junction of the examined eye. By placing a convex spherical lens of 3 D. or 4 D. behind the sight-hole, the image will be magnified, when, if astigmia be present, the black and white circles will appear oval. This test is of use in determining corneal astigmia only. It has, of late years, been largely supplanted by more accurate procedures.

FIG. 74.—Showing Placido's Disc.

OPHTHALMOMETER.

The Ophthalmometer (Fig. 75) is a device used for the determination of corneal astigmia. It consists of a horizontal tube or telescope mounted upon a movable tripod. Within this tube is a combination of lenses and prisms and two reflectors, technically called "mires," known as the "steps" and "parallelogram." The mires are illuminated by means of electric lamps.

The patient is placed so that the eye to be examined is in proper position at one end of the tube, the observer focussing from the other end. When the instrument is properly focussed, the observer will see, reflected from the cornea of the patient's eye, a double image of the two mires. The central image, in which the mires are close together, is the one to be observed.

In the "primary" or first position, adjustment is made so that the edges of the mires touch and the black lines in each are continuous. When these conditions are met, the tube is rotated ninety degrees to the right or left. In this way any difference in curvature in the meridians of the cornea will be indicated, either by the overlapping or separation of the mires.

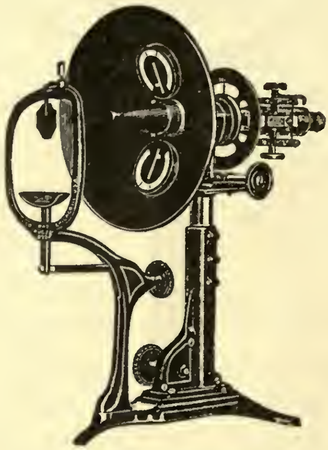

FIG. 75.—Showing Type of Improved Ophthalmometer.

The mire known as the "steps" is made up of eight equal divisions. The amount of astigmia is measured by the number of the steps overlapped or separated, one step corresponding to 1 D. of astigmia. The amount and kind of astigmia, as well as the axis of the correcting cylinder, are indicated on a graduated arc attached to the tube. If the image remains the same in all meridians no corneal astigmia is present.

In view of the fact that lenticular astigmia is not measured by the ophthalmometer the results obtained do not, as a rule, indicate the total error of refraction. The instrument is essentially a "keratometer" and its use constitutes merely a confirmatory test.

RISLEY'S ROTATING PRISM.

This instrument (Fig. 76) used in testing insufficiencies of the external ocular muscles, is intended to do away with the necessity of a large number of prisms. It consists of two 15° prisms which are revolved in opposite directions by a milled head screw, thus furnishing a prism the strength of which can be increased from 0° to 30°. It is made of the diameter of trial lenses and can be placed before the eye in the trial frame.

FIG. 76.—Showing Risley's Rotating Prism.

PHOROMETER (STEVENS').

The Phorometer is an instrument designed for the testing of muscular insufficiencies. It contains two cells in each of which rotates a 5° prism. Each cell has a border of teeth, a small wheel gearing the two cells together and causing them to rotate in opposite directions, thus furnishing a prism the strength of which can be increased from 0° to 10°. A spirit level is placed beneath the prisms to maintain them in a horizontal position.

The improved instrument (Fig. 77) has added to the above, Risley's Rotary Prism and Maddox Multiple Rod in such manner that the Phorometer can be used independently of the other two or in conjunction with them. It is equipped with a wall bracket swinging freely by means of a hinge connection and can be readily raised or lowered by means of a geared adjustment.

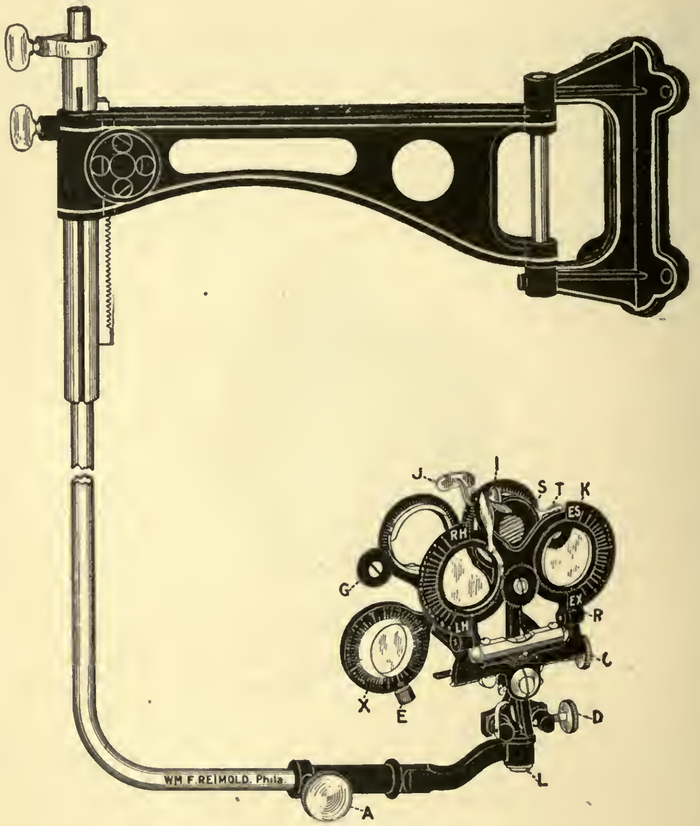

FIG. 77.—Showing Improved Phorometer.

PERIMETER.

Of no value in obtaining the refraction, this instrument (Fig. 78) is used to measure and outline the visual field of the eye. It consists essentially of a wide metal arc fastened to a disc, the two being supported by an upright. A small black metal plate bearing a white spot is clutched to the arc in such a manner that it can be moved freely along the arc from end to end. The arc can be readily rotated to lie in any meridian. The disc, being fastened to the arc, moves with it, its purpose being to hold a small chart on which the patient's visual field is traced. A chin rest is supplied for the purpose of steadying the patient's head.

The patient, having been placed in position, is instructed to direct his gaze toward the centre of the arc which is first placed in the vertical meridian. The small metal plate bear-

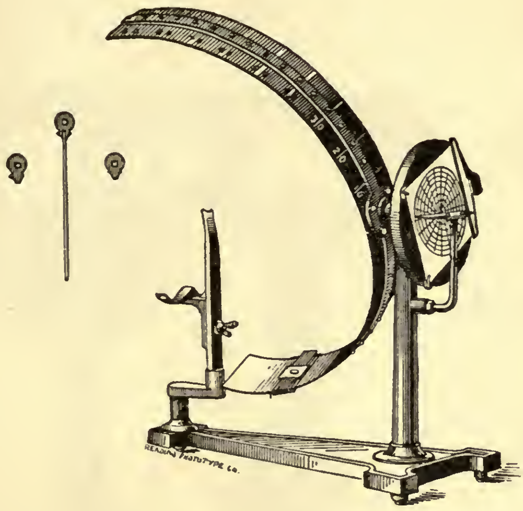

FIG. 78.—Showing Perimeter.

ing the white spot is then moved up and down along the arc until it disappears from the patient's sight. The two points on the arc where this occurs will correspond with two of the degree numbers on the back of the arc and are indicated on the chart by means of dots or pin pricks. The arc is then rotated to another meridian and the same procedure repeated. When all meridians have been tested the dots on the chart are joined together by means of a line, when the field will have been outlined. For the purpose of comparison, the chart bears the outline of a normal visual field. The improved instrument is fitted with an attachment by which the results are automatically recorded on the chart. The color of the slide may be changed for the purpose of testing the color field.

STIGMATOMETER.

The Stigmatometer (Fig. 79) is an instrument for testing the refraction of the eye by the objective method. It casts an image on the patient's retina which is plainly visible to

FIG. 79.—Showing Stimatometer.

the observer. This image is focussed by adjusting the instrument to conform to the refraction of the eye under observation, the adjustment being read off on the scale and the refractive error indicated. This instrument is also a complete ophthalmoscope for the direct examination. It consists of a mirror, a lens, a screen, light and an operator's lens plate.

Use as an Objective Test.—The patient is placed with his chin on the rest and the mirror adjusted before the eye to be examined, the light being reflected into the pupil so that the patient sees the image of the object. With the holder containing the astigmic dial at a given point, the object is rapidly moved from right to left until the lines (or part of them) are visible to the operator. This image is focussed by moving the screen, the figures on the bar indicating in diopters the amount of refractive error. If in this position but one line is clearly seen, astigmia is present and the object is now moved back until the line at right angles is distinct, when the difference in the two readings indicates the cylinder to be prescribed in addition to the sphere indicated.

As a Subjective Test.—In using the stigmatometer as a subjective test, the same principles apply as in its use by the objective method, the difference being that the patient is questioned as to his vision.

By withdrawing the screen, which is readily removable, the instrument becomes an ophthalmoscope.

GENERAL INDEX.

B

C

D

E

F

G

H