REFRACTION

AND

HOW TO REFRACT

THORINGTON

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INCLUDING SECTIONS ON OPTICS, RETINOSCOPY, THE FITTING OF SPECTACLES AND EYE-GLASSES, ETC.

BY

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Fourth Edition

TWO HUNDRED AND TWENTY ILLUSTRATIONS

THIRTEEN OF WHICH ARE COLORED

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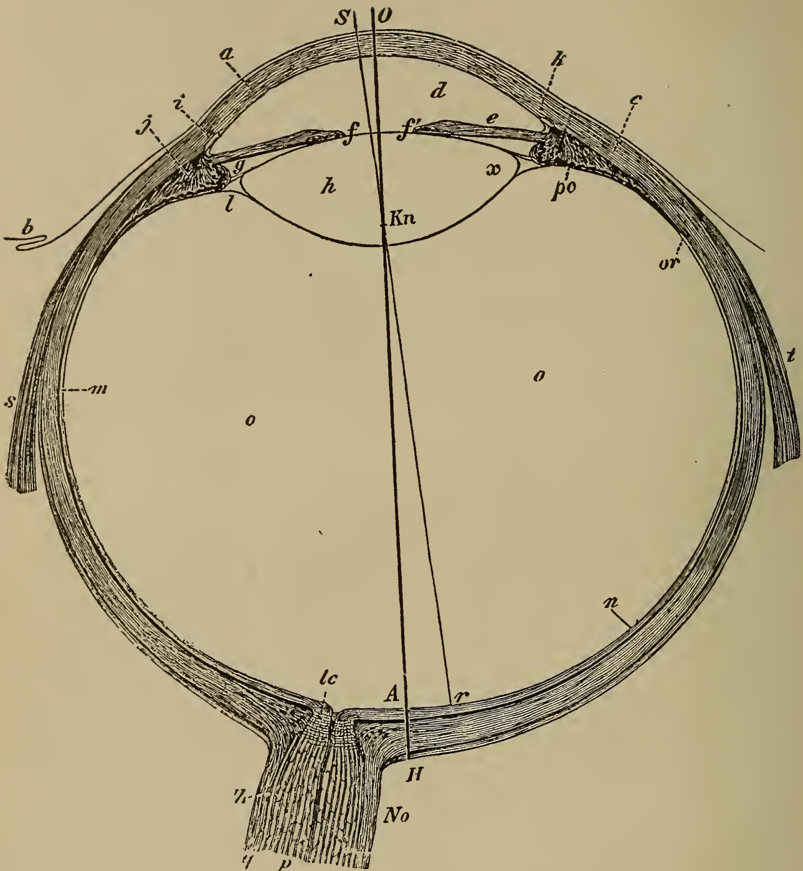
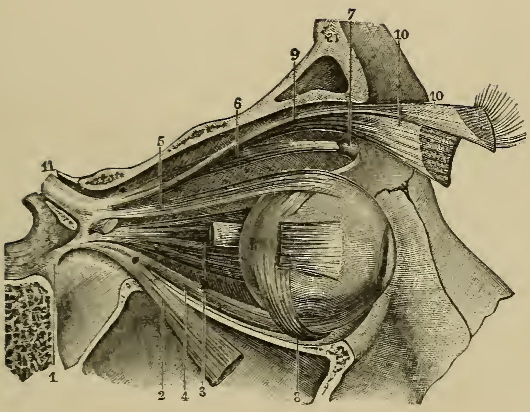


Horizontal Section of the Right Eye.—(*Landois.*)

a. Cornea. *b.* Conjunctiva. *c.* Sclerotic. *d.* Anterior chamber containing the aqueous humor. *e.* Iris. *ff'.* Pupil. *g.* Posterior chamber. *l.* Petit's canal. *j.* Ciliary muscle. *k.* Corneoscleral limit. *i.* Canal of Schlemm. *m.* Choroid. *n.* Retina. *o.* Vitreous humor. *No.* Optic nerve. *q.* Nerve-sheaths. *p.* Nerve-fibers. *lc.* Lamina cribrosa. *h.* Crystalline lens. *or.* Ora serrata. *pc.* Ciliary processes. The line, *O A*, indicates the optic axis; *S r*, the axis of vision; *r*, the position of the fovea centralis. *Kn.* Nodal point. *x.* Equator of lens. *t.* External rectus muscle. *s.* Internal rectus muscle. *Z.* Optic nerve-sheath. *H.* Sclerotic.



MUSCLES OF THE EYE. TENDON OR LIGAMENT OF ZINN.

1. Tendon of Zinn. 2. External rectus divided. 3. Internal rectus. 4. Inferior rectus. 5. Superior rectus. 6. Superior oblique. 7. Pulley for superior oblique. 8. Inferior oblique. 9. Levator palpebræ superioris. 10, 10. Its anterior expansion. 11. Optic nerve.

PREFACE TO FOURTH EDITION.

The fourth edition of this text-book has been carefully revised and an appendix has been incorporated which contains additional information on the subject of Refraction, as also descriptions and illustrations of new instruments.

The writer wishes to express his sincere appreciation of the generous reception which has been extended to this book and trusts that this edition may prove as meritorious as its predecessors.

J. T.

PHILADELPHIA, *February*, 1909.

PREFACE TO FIRST EDITION.

This book has been written at the request of the many students who have attended the author's lectures on "Refraction" at the Philadelphia Polyclinic; and while it is intended for all beginners in the study of Ophthalmology, yet it is especially for those practitioners and students who may have a limited knowledge of mathematics and who can not readily appreciate the classic treatise of Donders.

In the preparation of the manuscript and in arranging these pages the writer has planned to be systematic and practical, so that the student, starting with the consideration of rays of light, is gradually brought to a full understanding of optics; and following this, he is taught what is the standard eye, and then is given a description of ametropic eyes, with a differential diagnosis of each, until finally he is told how to place lenses in front of ametropic eyes to make them equal to the standard condition.

By being dogmatic rather than ambiguous, with occasional repetitions to avoid frequent references, and by simple explanations and a definite statement of facts, the writer has aimed to make the text more concise and comprehensive than if encumbered with lengthy mathematic formulas or with any discussion of disputed points.

The chapter on Retinoscopy embraces descriptions of that method of refracting, both with the plane and with the concave mirror; but no matter how carefully expressed, the student will frequently confuse the two, and he is therefore referred to the author's manual on "Retinoscopy with the Plane Mirror."

Of the two hundred illustrations used to elucidate this work, nearly all are newly made, and were drawn or photographed by the author. Those in colors, on page 145, and the diagrams of astigmatic eyes, as also several others, are original.

The author desires to tender his thanks to Dr. Helen Murphy, of Philadelphia, and to Dr. J. Ellis Jennings, of St. Louis, Mo., for many valuable suggestions.

120 S. 18th St., Philadelphia, Pa.

November, 1899.

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REFRACTION

AND

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CHAPTER I.

OPTICS.

Optics (from the Greek ὄπτομαι, meaning "to see") is that branch of physical science which treats of the nature and properties of light.

Catoptrics (from the Greek κάτοπτρον, meaning "a mirror") and **dioptrics** (from the Greek δίοπτρον, meaning "to see through") are subdivisions of optics; the former treating of incident and reflected rays, and the latter of the refraction of light passing through different media, such as air, water, glass, etc., but especially through lenses.

Light.—Light may be defined as that form of energy which, acting upon the organs of sight, renders visible the objects from which it proceeds. This form of energy is propagated in waves in all directions from a luminous body, and with a velocity in a vacuum of about 186,000 miles a second. In the study of a luminous body, such as a candle-, lamp-, or gas-flame, the substance itself must not be considered as a single source of radiation, but as a collection of minute points, from every one of which waves proceed in all directions and cross one another as they diverge from their respective points. **The intensity** of light decreases as the square of the distance from the light increases: for example, if an object is twice as far from a luminous body as another of the same size, it will receive one-fourth as much light as the latter. Figure 1 shows two cards, one is twice as far from the light as the other and receives only one-fourth as much light as the card nearest to the light.

Ray.—Ray (from "radius") is used in optics in preference to wave, and means the smallest subdivision of light traveling in a straight line. Rays of light are considered as incident, emergent, reflected, refracted, divergent, parallel, and convergent.

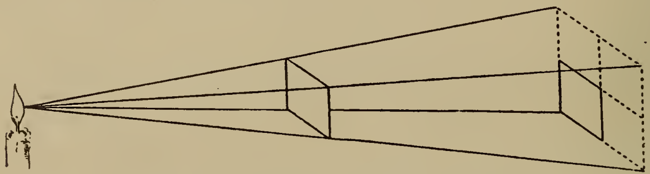


FIG. 1.—Illustrating Intensity of Light.

Incident Rays.—Rays of light are said to be incident when they strike the surface of an object. (See Fig. 8.)

Emergent Rays.—Rays of light are emergent when they have passed through a transparent substance. (See Fig. 13.)

Reflected Rays.—Rays of light are reflected when they rebound from a polished surface. (See Fig. 8.)

Refracted Rays.—A ray of light undergoes refraction when it is deviated from its course in passing through any transparent substance.

Divergent Rays.—Rays of light proceed divergently from any luminous substance, but, in the study of refraction, only those which proceed from a point closer than six meters are spoken of as divergent. (Fig. 1.)

Parallel Rays.—The greater the distance of any luminous point, the more nearly do its rays approach to parallelism; this is evident in a study of rays coming from such distant sources as the sun, moon, and stars. For all practical purposes in the study of refraction, rays of light which proceed from a distance of six meters or more are spoken of as parallel, although this is not an absolute fact, as rays of light at this distance still maintain a slight amount of divergence. If the pupil of the emmetropic eye is represented by a circular opening four millimeters in diameter, then rays of light from a luminous point at six meters (6000 mm.) will have a divergence of $\frac{4}{6000}$ when they enter such a pupil.

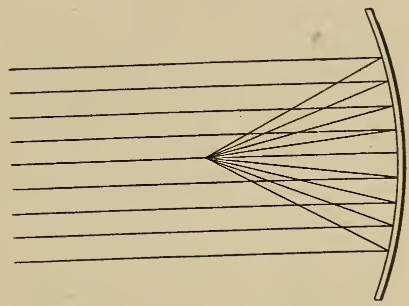


FIG. 2.—Parallel Rays Reflected by a Concave Mirror Forming a Convergent Pencil.

Convergent Rays.—Convergent rays are the result of reflection from a concave mirror or refraction through a convex lens. (See Figs. 2 and 3.)

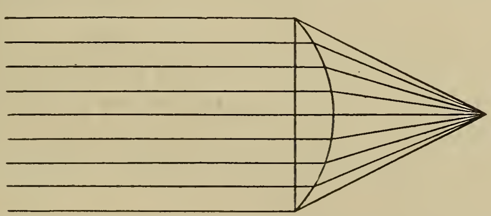


FIG. 3.—Parallel Rays Refracted by a Convex Lens Forming a Convergent Pencil.

A Beam.—This is a collection or series of parallel rays. (See Fig. 3.)

A Pencil.—A pencil of light is a collection of convergent or divergent rays. Convergent rays are those which tend to a common point (see Fig. 3), whereas divergent rays are those which proceed from a point and continually separate as they proceed. (See Fig. 4.) This point is called the radiant point.

A Focus.—This is the point of a convergent or divergent pencil ; the center of a circle ; the point to which converging rays are directed.

A Positive or Real Focus.—This is the point *to which* rays are directed after passing through a convex lens or after reflection from a concave mirror. (See Figs. 3 and 2.)

A Negative or Virtual Focus.—This is the point *from which* rays *appear* to diverge after passing through a concave lens (see Fig. 36), or after reflection from a convex mirror, or after refraction through a convex lens when the light or object is closer to the lens than its principal focus (see Fig. 43), or after reflection from a concave mirror when the light or object is closer to the mirror than its principal focus. (See Fig. 9.)

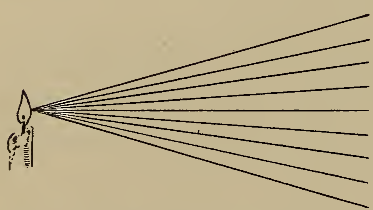


FIG. 4.—Illustrating a Divergent Pencil.

The principal phenomena of light are *absorption*, *reflection*, and *refraction*.

Absorption.—Rays of light from the sun falling upon the green grass are partly absorbed and partly reflected. The grass absorbs some of the rays and sends back or reflects only those rays which together produce the effect of green. A piece of red glass owes its color to the fact that it transmits only that portion of the light's rays whose combined effect upon the retina is that of red. The relative proportion of absorption and reflection of rays of light depends greatly upon the quality of the surface—whether light colored or polished, or dark colored or rough.

Reflection.—From the Latin *reflectere*, "to rebound." This is the sending back of rays of light by the surface on which they fall into the medium through which they came. While most of the rays falling upon the surface of a transparent substance pass through it, with or without change in their direction, yet some of the rays *are* reflected, and it is by these reflected rays that surfaces are made visible.

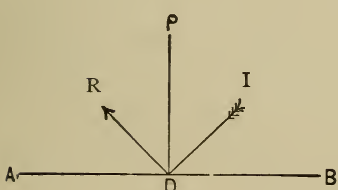


FIG. 5.

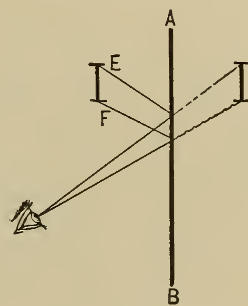


FIG. 6.

A substance that could transmit or absorb all the rays of light coming to it (if such a substance existed) would be invisible. Reflection, therefore, always accompanies refraction, and, if one of these disappear, the other will disappear also.

Laws of Reflection.—(1) The angle of reflection is equal to the angle of incidence. (2) The reflected and incident rays are in the same plane with the perpendicular to the surface. (See Fig. 5.)

If A B represent a polished surface and I the incident ray, then P D I is the angle of incidence; R being the reflected ray, then P D R, equal to it, is the angle of reflection. I D, P D, and R D lie in the same plane.

A reflecting surface is usually a polished surface (a mirror), and may be plane, concave, or convex.

Reflection from a Plane Mirror.—Rays of light are reflected from a plane mirror in the same direction in which they fall upon it: if parallel, convergent, or divergent before reflection, then they are parallel, convergent, or divergent after reflection. An object placed in front of a plane mirror appears just as far back in the mirror as the object is in front of it. (See Fig. 6.)

A B represents a plane mirror with E F, rays from the extremes of the object I, reflected from the mirror A B, and meeting at the observer's eye as if they came from the object I in the mirror. (See Visual Angle, p. 62.) The apparent distance of the object I from the observer is equal to the combined length of the incident and reflected rays.

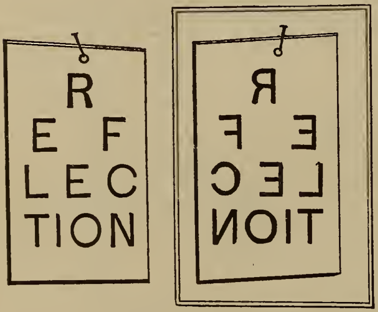


FIG. 7.—Lateral Inversion.

The *appearance* of an image in a plane mirror is not exactly the same as that of the object facing the mirror; it undergoes what is known as lateral inversion. This is best understood by holding a printed page in front of a plane mirror, when the words or letters will read from right to left. (See Fig. 7.) An observer facing a plane mirror and raising his right hand, his image apparently raises the left hand.

Tilting a plane mirror gives an object the appearance of moving in the opposite direction to that in which the mirror is tilted.

Spheric Mirrors.—A spheric mirror is a portion of a reflecting spheric surface ; its center of curvature is therefore the center of the sphere of which it is a part. Spheric mirrors are of two kinds—concave and convex.

Reflection from a Concave Mirror (Fig. 8).—Parallel rays are reflected from a concave mirror, and are brought to a focus in front of it. This point is called the principal focus (P.F.). The principal axis of a concave mirror is a straight line drawn from the mirror through the principal focus and

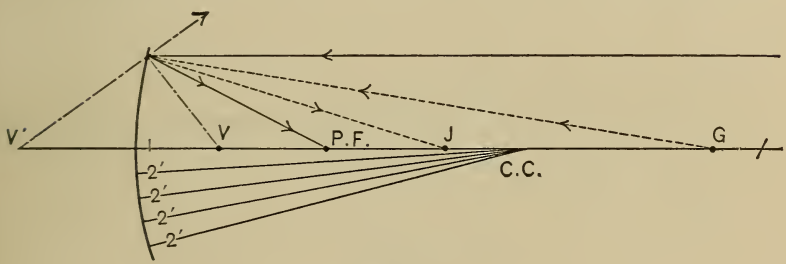


FIG. 8.

the center of curvature (1–1), and a secondary axis (2', 2', 2', 2') is any other straight line passing from the mirror to the center of curvature (C.C.). Rays which diverge from any point beyond the principal focus are reflected convergently (G J). Rays which diverge from any point closer than the principal focus are reflected divergently (V V').

Images Formed by a Concave Mirror.—To find the position of an image as formed by a concave mirror, two rays may be used : one drawn from a given point on the object to the mirror, and parallel to its principal axis, and reflected through the principal focus (P.F., Figs. 9 and 10); the other, the secondary axis, from the same point, passing through the center of curvature. The place where the secondary axis and the reflected ray or their projections intersect gives the position of the image. Unlike the plane mirror, which produces images at all times and at all distances, the concave mirror produces either an erect, virtual, and enlarged image, if an object is placed closer than its principal focus, or an enlarged inverted image if the object is between the principal focus and the center of curvature.

By withdrawing the mirror in the former instance the erect image increases slightly in size, and in the latter the inverted image diminishes in size. At the principal focus there is no image formed.

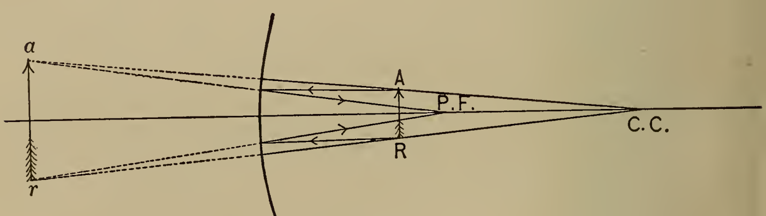


Fig. 9.

Figure 9 shows an erect, virtual, and enlarged image of A R which is closer to the mirror than the principal focus. Parallel rays from A and R are reflected to the principal focus, P.F. Lines drawn from the center of curvature through A and R to the mirror are secondary axes; these lines and those reflected to the principal focus do not intersect in front of the mirror, but if projected, will meet at *a* and *r* behind the mirror, forming a magnified image of A R. If the mirror is withdrawn from the object, the erect magnified image will increase in size, but at the principal focus no image will be formed, as the rays are reflected parallel.

Figure 10 shows a real inverted image of A R at *a r*; A R situated beyond the principal focus. Lines drawn from A and R through C.C. are secondary axes. Parallel rays from A and R converge and cross at the principal focus (P.F.).

Where D P and F E intersect the secondary axes, the inverted image *a r* of A R is situated. When the object, as in this instance, is situated beyond the center of curvature, the image is smaller than the object. As the image and object are conjugate to each other, they are interchangeable, and in such a case the image would be larger than the object and inverted. This is always true when the object is situated between the center of curvature and the principal focus. When an object is situated at the center of curvature, its image is equally distant and of the same size, but inverted.

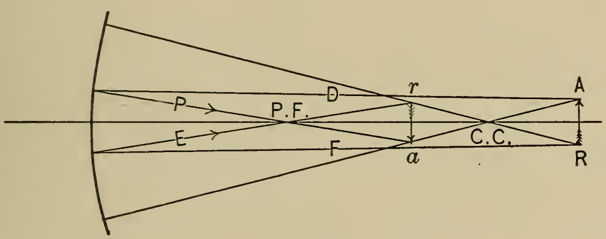


FIG. 10.

Tilting a concave mirror gives an object placed inside of its principal focus the appearance of moving as the mirror is tilted; but if the object is situated beyond the principal focus, the object appears to move in the opposite direction.

Reflection from a Convex Mirror.—All rays are reflected divergently from a convex mirror, and parallel rays diverge as if they came from the principal focus situated behind the mirror at a distance equal to one-half its radius of curvature. The principal focus of a convex mirror is therefore negative. The foci of convex mirrors are virtual.

Images Formed by a Convex Mirror.—These are always virtual, erect, and *smaller* than the object. The closer the object, the larger the image; and the more distant the object, the smaller the image. Tilting a convex mirror, the image does not appear to change position.

In figure 11 parallel rays from the object A R are reflected from the mirror as if they came from the principal focus situated at one-half the distance of the center of curvature, C.C. Lines drawn from the extremes of the object to C.C. are

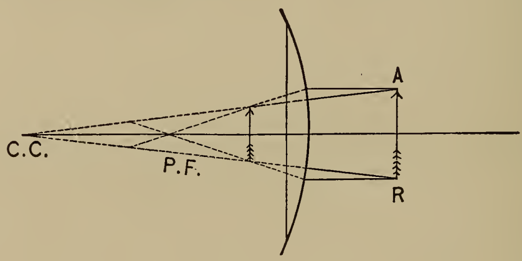


FIG. 11.

secondary axes, and the image is situated at the point of intersection of the secondary axes and the rays from the principal focus; and as these meet behind the mirror, the image is virtual and erect.

Refraction.—From the Latin *refrangere*, meaning "to bend back"—*i. e.*, to deviate from a straight course. Refraction may be defined as the deviation which takes place in the direction of rays of light as they pass from one medium into another of different density.*

* As ordinarily understood in ophthalmology, refraction has come to mean the optic condition of an eye in a state of repose or under the physiologic effect of a cycloplegic.

Two laws govern the refraction of rays of light:

1. A ray of light passing from a rare into a denser medium is deviated or refracted *toward* the perpendicular.

2. A ray of light passing from a dense into a rarer medium is deviated or refracted away *from* the perpendicular.

Aside from these laws, there are other facts in regard to rays of light that should have consideration. A ray of light will continue its straight course through any number of different transparent media, no matter what their densities, so long as it forms right angles with the surface

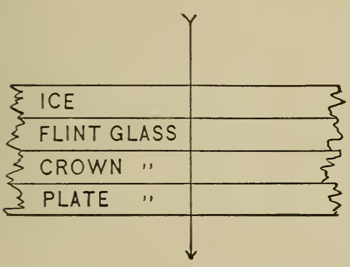


FIG. 12.

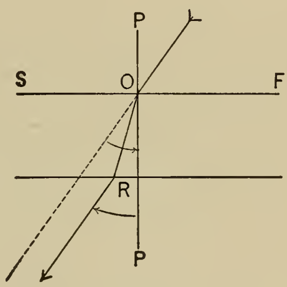


FIG. 13.

or surfaces. Such a ray is spoken of as the normal or perpendicular; such surfaces are plane, the surfaces and perpendicular forming right angles. (See Fig. 12.) In any case of refraction the incident and refracted rays may be supposed to change places.

Figure 13 shows the perpendicular (P P) to a piece of plate glass with plane surfaces. The ray in air incident at O on the surface S F is bent in the glass *toward* the perpendicular, P P. The dotted line shows the direction the ray would have taken had it not been refracted. As the ray in the glass comes to the second surface at R, and passes into a rarer medium, it is deviated *from* the perpendicular, P P. The ray now continues its original direction, but has been deviated from its course; it has undergone lateral displacement.

Critical Angle or Limiting Angle of Refraction.—This is the angle of incidence which just permits a ray of light in a dense medium to pass out into a rare medium. The size of the critical angle depends upon the index of refraction of different substances. Figure 14 shows an electric light suspended in water. The ray from this light which forms an angle of 48° 35′ with the surface of the water

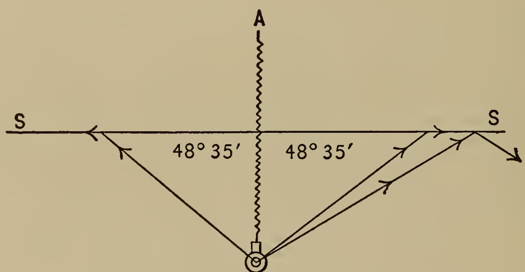


FIG. 14.—Critical Angle.

will be refracted and pass out of the water, grazing its surface; but those rays which form an angle greater than 48° 35′ will not pass out of the water, but will be reflected back into it. The surface separating the two media becomes a reflecting surface and acts as a plane mirror.

The critical angle for crown glass is 40° 49′.

Index of Refraction.—By this is meant the relative density of a substance or the comparative length of time required for light to travel a definite distance in different substances. **The absolute index** of refraction is the density or refractive power of any substance as compared with a vacuum. According to the first law of refraction, a ray of light passing from a rare into a dense medium is refracted toward the perpendicular; in other words, the angle of refraction is smaller, under these circumstances, than the angle of incidence. In the study of the comparative density of any substance it will be seen that the angle of refraction is usually smaller the more dense the substance; this is well illustrated in figures 15 and 16.

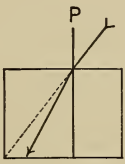


Fig. 15.

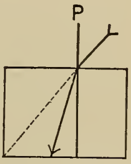


Fig. 16.

The greater the density, the slower the velocity or the more effort apparently for the wave or ray to pass through the substance. This is illustrated in figure 17, where a ray or wave of light is seen passing at right angles through different media. A ray passes through a vacuum without apparent resistance, but in its course through air it is slightly impeded, so that air has an index of refraction of

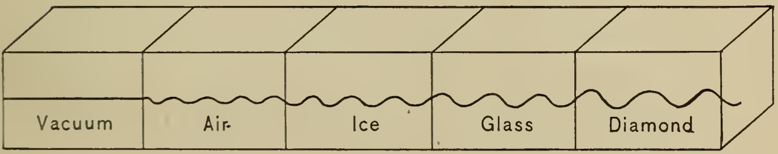


Fig. 17.

1.00029+ when compared with a vacuum; but as this is so slight, air and a vacuum are considered as one for all purposes in refraction. To find the index of refraction of any substance as compared with a vacuum or air, it is necessary to divide the sine of the angle of incidence by the sine of the angle of refraction.

In figure 18 the angle of incidence P C I is the angle formed by the incident ray I with the perpendicular, P P. The angle of refraction P C R is the angle formed by the refracted ray with the perpendicular, P P. Drawing the circle P H P O around the point of incidence C, and then drawing the sines D X and B F, perpendiculars to the perpendicular P P, divide the sine D X of the angle of incidence by the sine F B of the angle of refraction to obtain the index of refraction; in this instance, water as compared with air. D X equaling 4 and F B equaling 3, then 4 divided by 3 will equal $\frac{4}{3}$, or 1.33 +, the index of refraction of water as compared with air.

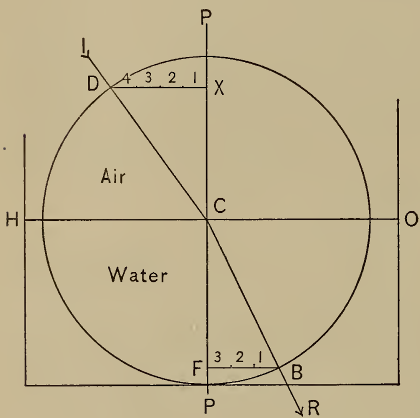


Fig. 18.

To find the index of refraction of a rare as compared with a dense substance, divide the sine of the angle of refraction by the sine of the angle of incidence—*i. e.*, air as compared with water would be ¾, or 0.75.

Indexes of Refraction.

Air,	1.00029
Water,	1.333
Cornea,	1.3333
Crown glass,	1.5
Flint glass,	1.58
Crystalline lens, nucleus,	1.43
" " intermediate layer,	1.41
" " cortical layer,	1.39

A prism is a wedge-shaped portion of a refracting medium contained between two plane surfaces. **The sides** of a prism are the inclined surfaces. **The apex** is where the two plane surfaces meet. **The base** of the prism is the thickest part of the prism. **The refracting angle** is the angle at which the sides come together.

Position of a Prism.—When a prism is placed in front of an eye, its position is indicated or described by the direction in which its base is situated : base down means that the thick part of the prism is toward the cheek ; base up means that the thick part of the prism is toward the brow ; base in means that the thick part of the prism is toward the

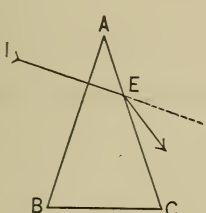


FIG. 19.

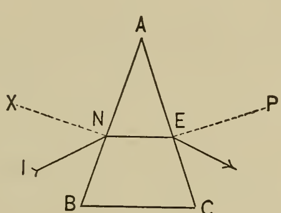


FIG. 20.

nose ; and base out means that the thick part of the prism is toward the temple.

Prismatic Action.—Rays of light passing through a prism are always refracted toward the base of the prism. If an incident ray is perpendicular to the surface of a prism, there will be only one refraction, and that takes place at the point of emergence. The angle of incidence in this instance will equal the angle of the prism, and the maximum deviation takes place, as all the refraction is done at one surface.

In figure 19 the incident ray (I) is perpendicular to the surface A B, and is not refracted until it comes to the surface A C at E, when it is bent toward the base B C, all the refraction taking place at the surface A C.

If an incident ray forms an angle other than a right angle with the first surface of the prism, then it will be refracted twice—as it enters and as it leaves the prism.

In figure 20 X N is the perpendicular to the surface A B. The ray (I) incident at N is refracted toward this perpendicular and follows the course N E inside of the prism. On emergence it is refracted from the perpendicular E P of the surface A C, and in the direction of the base of the prism. If the incident ray (I) so falls upon the surface A B that the refracted ray (N E) is parallel to the base (B C), and the emergent ray is such that the angle of emergence equals the angle of incidence (I N X), as in this instance, then the angles of incidence and of emergence are equal, and the deviation is at a minimum, or the least possible.

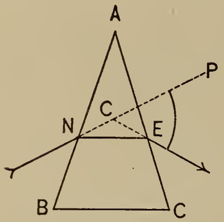


FIG. 21.

Angle of Deviation (Fig. 21).—This is the angle formed between the *directions* of the incident and emergent rays, and measures the total deviation. In all prisms of ten degrees or less the angle of deviation is equal to half the angle of the prism, but in prisms of more than ten degrees the angle of deviation increases.

Summary.—Prisms do not cause rays of light to converge or to diverge ; rays that are parallel before refraction are parallel after refraction. Therefore, prisms do not form images ; prisms have no foci.

Effect of a Prism.—An object viewed through a prism has the appearance of being displaced, and in a direction opposite to the base—*i. e.*, toward the apex.

Rays from the object (X, Fig. 22) strike the prism at C, undergo double refraction, and, falling upon the retina of the eye, are projected back in the direction in which they were received, and the apparent position of X is changed to X′, *away* from the base of the prism and *toward* the apex.

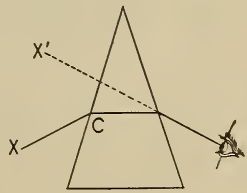


FIG. 22.

Numbering of Prisms.—Formerly, prisms were numbered by their refracting angles; now, however, two other methods are in use: Dennet's method, known as the centrad; and Prentice's method, known as the prism-diopter.

Dennett's Method (Fig. 23).—The unit, or centrad (abbreviated ▽), is a prism that will deviate a ray of light the $\frac{1}{100}$ part of the arc of the radian. This is calculated as follows: As much of the circumference of a circle is taken as will equal the length of its radius of curvature; this is called the arc of the radian, and equals 57.295 degrees. The arc of the radian is then divided into 100 parts. A

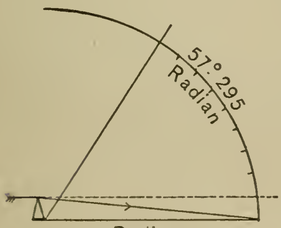


FIG. 23.

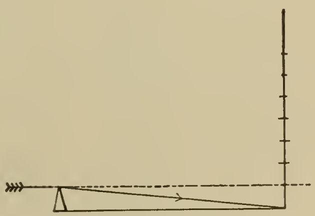


FIG. 24.

prism, base down, at the center of curvature that will deviate a ray of light downward just $\frac{1}{100}$ part of the arc of the radian is a one centrad, and equals $\frac{1}{100}$ of 57.295 degrees, or 0.57295 of a degree.

Ten centrads will deviate a ray of light ten times as much as one centrad, or $10 \times 0.57295 = 5.7295$ degrees, etc.

Prentice's Method (Fig. 24).—The unit, or prism-diopter (abbreviated P.D., or △), is a prism that will deviate a ray of light just 1 cm. for each meter of distance—that is, the $\frac{1}{100}$ part of the radius measured on the tangent. The deviation always being 1 cm. for each meter of distance, 1 P. D. will deviate a ray of light 2 cm. for 2 meters of distance; 3 cm. for 3 meters, etc. The comparative values of centrads and prism-diopters is quite uniform up to 20, but above 20 the centrad is the stronger.

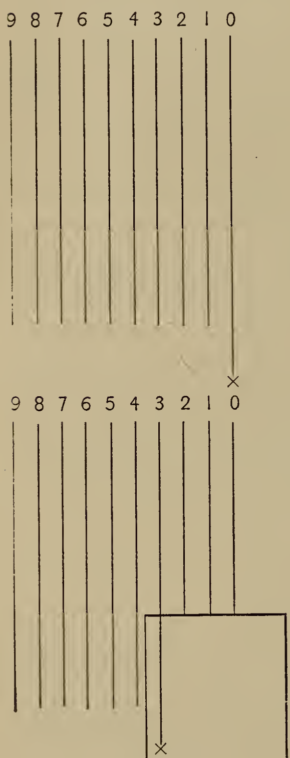


FIG. 25.

Neutralization of Prisms.—Knowing that rays of light are deviated by centrads and prism-diopters up to 20, in the ratio of 1 cm. for each meter of distance, then to find the numeric strength of any prism all that is necessary is to hold the prism over a series of numbered parallel lines, separated by an interval of 1 cm. or fraction thereof, and note the amount of displacement. For example, figure 25 shows a series of vertical lines ⅓ of a cm. apart, and numbered from 0 to 9; an × is placed at the foot of the 0 line. Holding a prism, base to the right, at a distance of ⅓ of a meter (as the lines are ⅓ of a cm. apart) and looking through the prism at the × on the o line, it will be seen that the × has been displaced to the line to the left corresponding to the number of centrads or prism-diopters in the prism; in this instance three.

TABLE SHOWING THE EQUIVALENCE OF CENTRADS IN PRISM-DIOPTERS AND IN DEGREES OF THE REFRACTING ANGLE (INDEX OF REFRACTION 1.54).

CENTRADS.	PRISM-DIOPTERS.	REFRACTING ANGLE.
1.	1.	1°.00
2.	2.0001	2°.12
3.	3.0013	3°.18
4	4.0028	4°.23
5.	5.0045	5°.28
6.	6.0063	6°.32
7.	7.0115	7°.35
8.	8.0172	8°.38
9.	9.0244	9°.39
10.	10.033	10°.39
11.	11.044	11°.37
12.	12.057	12°.34
13.	13.074	13°.29
14.	14.092	14°.23
15.	15.114	15°.16
16.	16.138	16°.08
17.	17.164	16°.98
18.	18.196	17°.85
19.	19.230	18°.68
20.	20.270	19°.45
25.	25.55	23°.43
30.	30.934	26°.81
35.	36.50	29°.72
40.	42.28	32°.18
45.	48.30	34°.20
50.	54.514	35°.94
60.	68.43	38°.31
70.	84.22	39°.73
80.	102.96	40°.29
90.	126.01	40°.49
100.	155.75	39°.14

Or a prism may be neutralized by placing another prism in apposition to it, with their bases opposite, so that in looking through the two prisms at a straight line, no matter at what distance, the straight line will continue to make one straight line through the prisms ; the strength of the neutralizing prism will equal the strength of the prism being neutralized.

Uses of Prisms.—1. To detect malingerers who profess monocular blindness so as to obtain damages for supposed injuries, or who wish to escape war service, or those cases of hysteric blindness wishing to create sympathy. This test or use of a prism is known as the diplopia test, and is practised as follows : A seven P. D., base up or down, with a blank are placed in the trial-frame corresponding to the "blind" eye ; nothing is placed in front of the seeing eye ; the trial-frame, thus armed (without the patient seeing what is being done), is placed on the patient's face and he is instructed to read the card of test-letters on the wall across the room. While he is thus busy reading, and purposely contradicted by the surgeon, so as to get his mind from his condition, the surgeon suddenly removes the blank from the "blind" eye. The patient exclaiming that he sees two cards and two of all the letters proves the deception.

2. Occasionally, to counteract the effects of strabismus, or diplopia due to a paralysis of one or more of the extra-ocular muscles. For example : A patient looking at a point of light focused on the macula (M) of the left eye (L), the right eye being turned in toward the nose, receives the rays upon the retina to the nasal side of the macula, and hence projects the rays outward to the right, giving a false image to the right side ; a prism of sufficient strength is then placed with its base toward the temple (base out) over the right eye, so that the rays from the light may fall upon the macula (M), and the diplopia will be corrected (See Fig. 26.)

3. To test the strength of the extra-ocular muscles : A patient looking with both eyes at a distant point of light is made to see one light just above another by placing a 3 P. D., base down or up, before either eye, and if a 2½ P. D. did not produce diplopia when similarly placed, the strength of his vertical recti is then represented by 2½ P. D. The strength of the prism placed base in which,

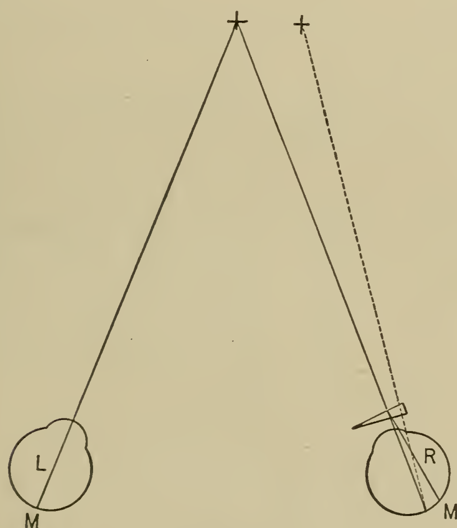


Fig. 26.

if increased, would produce diplopia is the strength of the externi ; and the strength of the prism or prisms placed base outward which, if increased, would produce diplopia is the strength of the interni.

4. For exercise of weak muscles. (See p. 191.)

Lenses.—A lens is a portion of transparent substance (usually of glass) having one or both surfaces curved. There are two kinds of lenses—spheric and cylindric.

Spheric Lenses.—Abbreviated S. or sph. Spheric lenses are so named because their curved surfaces are sections of spheres. A spheric lens is one which refracts rays of light equally in all meridians or planes. Spheric lenses are of two kinds—convex and concave.

A convex spheric lens is thick at the center and thin at the edge. (Figs. 27, 28, 29.) The following are synonymous terms for a convex lens: (1) Plus; (2) positive; (3) collective; (4) magnifying. A convex lens is denoted by the sign of plus (+).

Varieties or Kinds of Convex Lenses.—

1. *Planoconvex*, meaning one surface flat and the other convex. It is a section of a sphere. (See Fig. 27.)

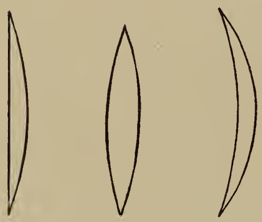


FIG. 27. FIG. 28. FIG. 29.

2. *Biconvex*, also called convexoconvex or bispheric, for the reason that it is equal to two planoconvex lenses with their plane surfaces together. (Fig. 28.)

3. *Concavoconvex*. This lens has one surface concave and the other convex, the convex surface having the shortest radius of curvature. (Fig. 29.) The following are synonymous terms for a concavoconvex lens: (1) Periscopic; (2) convex meniscus; (3) converging meniscus (meniscus meaning a small moon). (See Fig. 29.) A periscopic lens enlarges the field of vision, and is of especial service in presbyopia.

A Concave Spheric Lens.—Such a lens is thick at the edge and thin at the center. (Figs. 30, 31, 32.) The following are synonymous terms for a concave lens: (1) Minus; (2) negative; (3) dispersive; (4) minifying. A concave lens is denoted by the sign of minus (—).

Varieties or Kinds of Concave Lenses.—

1. *Planoconcave*, meaning one surface flat and the other concave. (Fig. 30.)

2. *Biconcave*, also called concavoconcave or biconcave spheric, for the reason that it is equal to two planoconcave lenses with their plane surfaces together. (Fig. 31.)

3. *Convexoconcave*. This lens has one surface convex and the other concave, the concave surface having the shortest radius of curvature. (Fig. 32.) The following are synonymous terms for a concavoconvex lens: (1) Concave meniscus; (2) diverging meniscus; (3) periscopic.

FIG. 30.

FIG. 31.

FIG. 32.

FIG. 33.

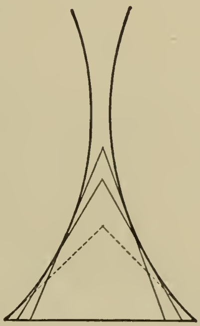


FIG. 34.

A spheric lens may be considered as made up of a series of prisms which gradually increase in strength from the center to the periphery, no matter whether the lens be concave or convex.

In the convex sphere the bases of the prisms are toward the center of the lens, whereas in the concave the bases of the prisms are toward the edge. (See Figs. 33, 34.)

Knowing that a prism refracts rays of light toward its base, it may be stated as a rule that every lens bends rays of light more sharply as the periphery is approached—*i. e.*, at the periphery the strongest prismatic effect takes place.

Lens Action.—As a ray of light will travel in a straight line so long as it continues to form right angles with surfaces, then the ray A in figure 35 passes through the biconvex lens unrefracted, or without any deviation from its course whatsoever, for at its points of entrance and emer-

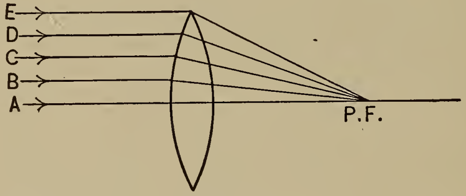


FIG. 35.

gence the surfaces of the lens are plane to each other. This ray is called the axial ray, and the line joining the centers of curvature of the two surfaces is called the principal axis. The axis of a planoconvex or planoconcave lens is the line drawn through the center of curvature perpendicular to the plane surface.

The ray B in figure 35, though parallel to the ray A, forms a small angle of incidence, and must, therefore, be refracted toward the perpendicular to the surfaces of the lens, and, passing through the lens, will meet the axial ray at P.F. The rays C, D, and E, also parallel to A and B, form progressively larger angles with the surface of the lens, and finally meet the axial ray at P.F. It will be seen at once that the rays all meet at P.F., showing the progressively stronger prismatic action that takes place as the periphery of the lens is approached.

In figure 36 we have similar rays, A, B, C, D, and E, passing through a concave lens. The axial ray A passes through the centers of curvature unrefracted, but the rays B, C, D, and E are progressively refracted more and more as the periphery is approached. The ray E in each instance is refracted the most.

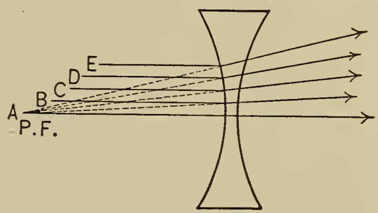


FIG. 36.

The action of a convex lens is similar to that of a concave mirror, and the action of a concave lens is similar to that of a convex mirror.

Principal Focus.—The principal focus of a lens may be defined (1) as the point where parallel rays, after refraction, come together on the axial ray; or (2) as the shortest focus; or (3) as the focal point for parallel rays.

Focal Length.—This is the distance measured from the optic center to the principal focus. The principal focus of an equally biconvex or biconcave lens of crown glass is situated at about the center of curvature for either surface of the lens. A lens has two principal foci, an anterior and a posterior, according to the direction from which the parallel rays come, or as to which radius of curvature is referred to. (See p. 60.) Figure 35 shows parallel rays, B, C, D, and E, passing through a convex lens and coming to a focus on the axial ray (A) at P. F.; and as the path of a ray passing from one point to another is the same, no matter what its direction, then if a point of light be placed at the principal focus of a lens, its rays will be parallel after passing back through the lens. This is equivalent to what takes place in the standard or emmetropic eye. An eye, in other words, which has its fovea situated just at the principal focus of its dioptric media, such an eye in a state of rest receives parallel rays exactly at a focus upon its fovea, and therefore is in a condition to project parallel rays outward.

Conjugate Foci.—Conjugate meaning "yoked together." The point from which rays of light diverge (called the radiant) and the point to which they converge (called the focus) are conjugate foci or points. For instance, in figure 37 the rays diverging from A and passing

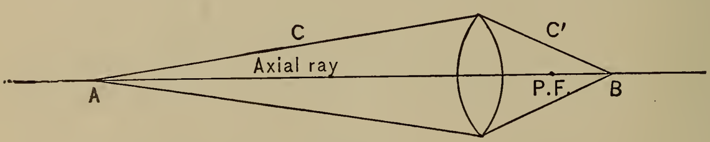


FIG. 37.

through the lens converge to the point B; then the points A and B are conjugate foci. They are interchangeable, for if rays diverged from B, they would follow the same path back again and meet at A. The path of the ray C C′ is the same whether it passes from A to B or from B to A: there is no difference. It is by the affinity of these points for each other, with respect to their positions, that they are called conjugate.

The conjugate foci are equal when the point of divergence is at twice the distance of the principal focus. The equivalent to conjugate foci is found in the long or myopic eye; an eye, in other words, which has its fovea situated further back than the principal focus of its dioptric media, the result being that rays of light from the fovea of such an eye would be projected convergently after passing out of the eye, and would meet at some point inside of infinity. In other words, only those rays which have diverged from some point inside of six meters will focus upon the fovea of this long eye. The fovea of the myopic eye represents a conjugate focus. A myopic eye is in a condition to receive divergent rays of light at a focus on its retina and to emit convergent rays.

Ordinary Foci.—When rays of light diverge from some point *inside* of infinity (six meters) they will be brought to a focus at some point on the other side of a convex lens, *beyond* its principal focus ; this point is called an ordinary focus. A lens may have many foci, but only two principal

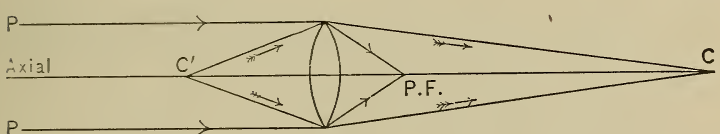


FIG. 38.

foci. The further away from a lens the divergent rays proceed, the nearer to the principal focus on the other side of the lens will they converge. As the divergent rays are brought closer to the lens they reach a point where they will not focus, but will pass parallel after refraction. This point is the principal focus. (See Fig. 38.) A lens, therefore, has as many foci as there are imaginary points on the axial ray between the principal focus and infinity.

When rays of light diverge from some point closer to a lens than its principal focus, they do not converge, but, after refraction, continue divergently; their focus now is negative or virtual, and is found by projecting these divergent rays back upon themselves to a point on the same side of the lens from which they appeared to come. (See Fig. 39.)

This is the equivalent of what takes place in a short or hyperopic eye, an eye which has its macula closer to its dioptric media than its principal focus. In a state of rest

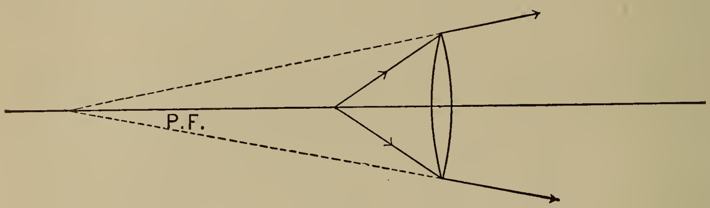


FIG. 39.

the fovea of such an eye would project outward divergent rays, and would be in a position to receive only convergent rays of light at a focus upon its fovea.

Secondary Axes.—In the study of the direction of a ray of light passing through a dense medium with plane sur-

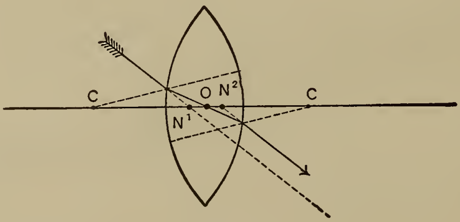


FIG. 40.

faces, it was found that it underwent lateral displacement (see Fig. 13), and so in lenses there is a place where rays undergo lateral displacement. Figure 40 shows a convex lens of considerable thickness, and on each side is drawn a radius of curvature (C C). The ray indicated by the arrow passed through the two surfaces, has undergone lateral displacement, but continues in its original direction; such rays are called secondary rays or axes. The incident ray is projected toward N^1 in the lens on the axial ray, and the emergent ray, if projected backward, would meet the axial ray at N^2. These points on the axial ray are such that a ray directed to one before refraction, is directed to the other after refraction. The points N^1 and N^2 are spoken of as nodal points. Every lens, therefore, has two nodal points, but in thin lenses the deviation of the secondary rays is so slight that, for all practical purposes, only

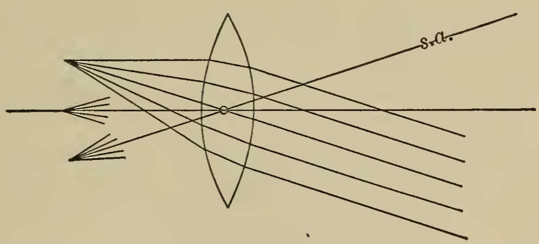


FIG. 41.

one nodal point is recognized. It is spoken of as the optic center. When writing prescriptions for glasses, this point of having the lenses or glasses made as thin as possible, must be borne in mind.

Optic Center.—This term is used synonymously with nodal point, and is the point where the secondary rays (*s. a.* in Fig. 41) cross the axial ray. It is not always the geometric center. Rays of light crossing the optic center in thin lenses are not considered as undergoing refraction. (See Fig. 41.)

Action of Concave Lenses.—Rays of light passing through a concave lens, no matter from what distance, are always refracted divergently, and its focus is, therefore, always negative or virtual, and is found by projecting these divergent rays backward in the direction from which they appear to come until they meet at a point on the axial ray. The principal focus and conjugate foci of concave lenses are found in the same way as in convex lenses. (See Figs. 36, 44.)

Images Formed by Lenses.—An image formed by a lens is composed of foci, each one of which corresponds to a point in the object. Images are of two kinds—real and virtual.

A Real Image.—This is an image formed by the actual meeting of rays; such images can always be projected on to a screen.

A Virtual Image.—This is one that is formed by the prolongation backward of rays of light to a point.

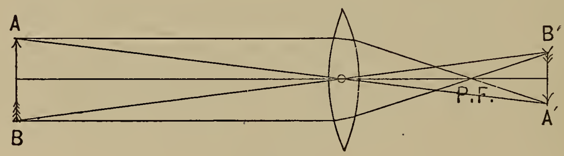


FIG. 42

To find the position and size of an image it is necessary to obtain the conjugate foci of the extremes of the object, as the image of an object is equal to the sum of its intermediate points. Only two rays are required for this purpose, one parallel to the axial ray, and one secondary ray passing through the optic center; the image of the extreme point of the object will be located at the point of intersection of these rays. In figure 42 A B is an object in front of a convex lens. o is the optic center and P. F. the principal focus. A ray drawn from A parallel to the axial ray o, and a secondary ray from the same point drawn through the optic center, will give at their point of intersection the conjugate focus of the luminous point A, which will be at A′. In the same way the conjugate focus of B and points intermediate in the object may be obtained. A′ B′ is a real inverted image of A B; the size of the image of A B depends upon the distance of the object from the lens. The relative sizes of image and object are as their respective distances from the optic center of the lens. For example, if an object ten millimeters high is three meters (3000 mm.) from the optic center of a lens, and its image is sixty millimeters from the lens, the image will be $\frac{60}{3000}$ or $\frac{1}{50}$ of the size of the object; that is, the image will be $\frac{1}{50}$ of ten millimeters (the height of the object)—namely, $\frac{1}{5}$ of a millimeter high.

As conjugate foci are interchangeable, then in figure 42 if A′ B′ was the object, the image A B would be the image of A′ B′, and, therefore, larger than the object.

Three facts should be borne in mind in the study of real images formed by a convex lens:

1. The object and image are interchangeable.

2. The object and the real image are on opposite sides of the lens, and,

3. As the rays which pass through the optic center cross each other at this point, the real image must be inverted.

Rays of light from an object situated at the distance of the principal focus would proceed parallel after refraction, and no image of the object would be obtained.

If an object is situated just beyond the principal focus, then the image would be larger than the object, real and inverted. (See Fig. 42, reversing image for object.)

If an object is situated at twice the distance of the principal focus, then its image would be of the same size, real, inverted, and at a corresponding distance, as these conjugate foci are equal.

If an object is situated at a greater distance than twice the principal focus, and nearer than infinity, its image will be real, inverted, and smaller than the object.

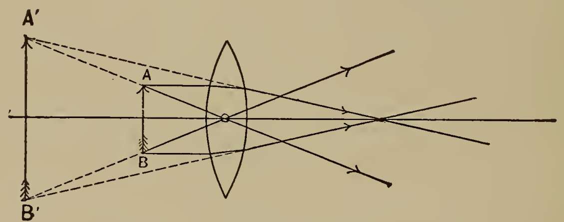


FIG. 43.

Rays of light from an object situated closer to a lens than its principal focus would be divergent after refraction, and could only meet by being projected backward; the image would, therefore, be larger than the object, erect, and

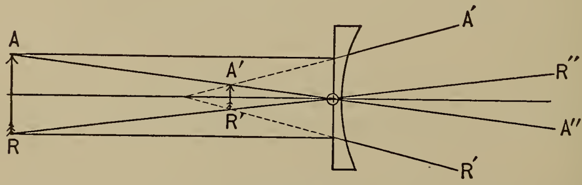


FIG. 44.

virtual. Such an image is only seen by looking through the lens; the lens in this instance being a magnifying glass. (Fig. 43.)

Images Formed by Concave Lenses.—These images are always erect, virtual, and smaller than the object. (See Fig. 44.) A concave lens is, therefore, a minifying lens.

Parallel rays from the extremes of the object A R form the divergent ray A′ and R′ after refraction. Secondary rays pass through the optic center o unrefracted, A″ and R″. At the points of intersection where these rays meet after being projected backward, the image of A R is found, erect, virtual, and diminished in size. This image is only seen by looking through the lens.

Numeration of Lenses.—Formerly, lenses were numbered according to their radii of curvature in Paris inches (27.07 mm.). The unit was a lens that focused parallel rays of light at the distance of one English inch (25.4 mm.) from its optic center.

As lenses for purposes of refraction were never as strong as the unit, they were numbered by fractions, thus showing their relative strength as compared to this unit; for instance, a lens that was one-fourth the strength of the unit was expressed by the fraction $\frac{1}{4}$, or a lens that was one-sixteenth the strength of the unit was expressed as $\frac{1}{16}$, etc., the denominator of the fraction indicating the focal length of the lens in Paris inches.

There are three objections to this nomenclature: (1) The difference in length of the inch in different countries; (2) the inconvenience of adding two or more lenses numbered in fractions with different denominators—$\frac{1}{144} + \frac{1}{36} + \frac{1}{12}$; (3) the want of uniform intervals between numbers.

In the new nomenclature, and the one that is now quite universal, known as the metric or dioptric system (diopter, abbreviated D.), a lens has been taken as the unit which has its principal focus at one meter distance (39.37 English inches), commonly recognized as 40 inches.

Lenses in the dioptric system are numbered according to their refractive power and not according to their radii of curvature. The strength or refractive power of a dioptric lens is, therefore, the inverse of its focal distance. To find the focal distance of any dioptric lens in inches or centimeters, the number of diopters expressed must be divided into the unit of 40 inches or 100 cm. For example, a 2 D. lens has a focal distance of 40 ÷ 2 equals 20 inches; or 100 cm. ÷ 2 equals 50 cm. A +4 D. has a focal distance of 40 ÷ 4, equaling 10 inches, or 100 ÷ 4, equaling 25 cm. Lenses that have a refractive power less than the unit are not expressed in the form of fractions, but in the form of decimals; for example, a lens which is only one-fourth, one-half, or three-fourths the strength of the unit is written 0.25, 0.50, 0.75, respectively, and their focal distances are found in the same way as in dealing with units: 0.25 D. has a focal distance of 40 ÷ 0.25 or 100 ÷ 0.25, equaling 160 inches or 400 cm.; 0.50 D. has a focal length of 40 ÷ 0.50 or 100 ÷ 0.50, equaling 80 inches or 200 cm.; 0.75 D. has a focal length of 40 ÷ 0.75 or 100 ÷ 0.75 equaling 53 inches or 133 cm. Unfortunately, 0.25 D., 0.50 D., and 0.75 D. are frequently spoken of as twenty-five, fifty, and seventy-five, which occasionally leads to confusion in the consideration of the strength and focal distance. The student should learn as soon as possible to change the old nomenclature into the new, as he will have to make these changes in reading other text-books.

To change the old "focal length" or inch system of numbering lenses into diopters, divide the unit (40 in.) by the denominator of the fraction, and the result will be an approximation in diopters; for example, $\frac{1}{10}$ equals $\frac{40}{10}$ or 4 D.; $\frac{1}{20}$ equals $\frac{40}{20}$ or 2 D. The following table, from Landolt, gives the equivalents in the old and new systems:

OLD SYSTEM.				NEW SYSTEM.			
I. No. of the Lens, Old System.	II. Focal Distance in English Inches.	III. Focal Distance in Millimeters.	IV. Equivalent in Diopters.	V. No. of the Lens, New System.	VI. Focal Distance in Millimeters.	VII. Focal Distance in English Inches.	VIII. No. Corresponding of the Old System.
72	67.9	1724	0.58	0.25	4000	157 48	166.94
60	56.6	1437	0.695	0.5	2000	78 74	83 46
48	45.3	1150	0.87	0.75	1333	52.5	55.63
42	39.6	1005	0.99	1	1000	39 37	41.73
36	34	863	1.16	1.25	800	31.5	33 39
30	28.3	718	1.39	1.5	666	26.22	27 79
24	22.6	574	1.74	1.75	571	22.48	23.83
20	18.8	477	2.09	2	500	19.69	20.87
18	17	431	2.31	2.25	444	17.48	18 53
16	15	381	2.6	2.5	400	15.75	16.69
15	14.1	358	2.79	3	333	13 17	13.9
14	13.2	335	2.98	3.5	286	11 26	11.94
13	12.2	312	3.20	4	250	9.84	10.43
12	11.2	287	3.48	4.5	222	8.74	9 26
11	10.3	261	3.82	5	200	7.87	8.35
10	9.4	239	4.18	5.5	182	7.16	7 6
9	8.5	216	4.63	6	166	6.54	6 93
8	7.5	190	5.25	7	143	5 63	5.97
7	6.6	167	5.96	8	125	4.92	5.22
6½	6.13	155	6.42	9	111	4.37	4.63
6	5.6	142	7.0	10	100	3.94	4 17
5½	5 2	132	7.57	11	91	3.58	3.8
5	4.7	119	8.4	12	83	3.27	3.46
4½	4.2	106	9.4	13	77	3.03	3.21
4	3.8	96	10.4	14	71	2.8	2.96
3½	3.3	84	11.9	15	67	2.64	2.8
3¼	3.1	79	12.7	16	62	2 44	2.59
3	2.8	71	14.0	17	59	2.32	2.46
2¾	2.6	66	15.1	18	55	2 17	2.29
2½	2.36	60	17.7	20	50	1.97	2.09
2¼	2.1	53	18.7				
2	1.88	48	20.94				

Cylindric Lenses.—Abbreviated cyl., c, or C. A cylindric lens, usually called a "cylinder," receives its name from being a segment of a cylinder parallel to its axis. (See Fig. 45.) Occasionally cylinders are made with both surfaces curved, and are then equivalent to two planocylinders with their plane surfaces together. *A cylinder may be defined as a lens which refracts rays of light opposite to its axis.* This definition should be carefully borne in mind in contradistinction to a spheric lens, which refracts rays of light equally in all meridians. A cylindric lens has no one common focus or focal point, but a line of foci, which is parallel to its axis.

Axis of a Cylinder.—That dimension of a cylindric lens which is parallel to the axis of the original cylinder of

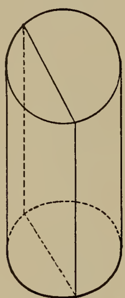


FIG. 45.

FIG. 46.

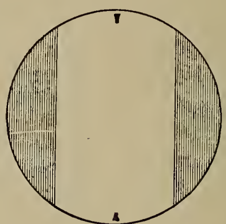


FIG. 47.

which it is a part is spoken of as the axis, and is indicated on the lens of the trial-case by a short diamond scratch on the lens at its periphery, or by having a small portion of

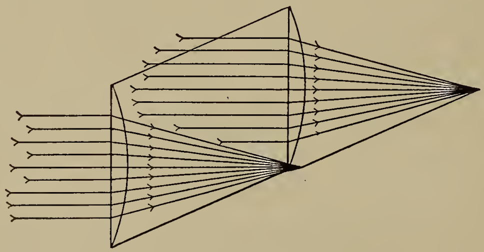


FIG. 48.

its surface corresponding to the axis ground at the edges, or it may be marked in both ways. (See Fig. 47.) Cylinders are of two kinds—convex and concave. (Figs. 45, 46.)

Cylinder Action.—A convex cylinder converges parallel rays of light so that after refraction they are brought into a straight line which corresponds to the axis of the cylinder; for instance, a +5 cyl. will converge parallel rays so that they come together in a straight line at the distance of eight inches, or twenty centimeters, and this straight line will be parallel to the axis of the cylinder. (Fig. 48.)

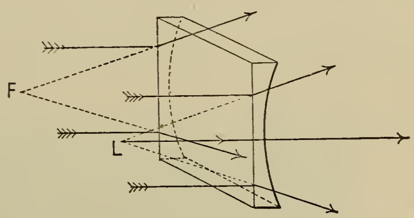


FIG. 4 .

A concave cylinder diverges rays of light opposite to its axis, as if they had diverged from a straight line on the opposite side of the lens. (Fig. 49.)

Spherocylinders.—A spherocylinder is a combination of a sphere and a cylinder, and is therefore a lens which has one surface ground with a spheric curve and the other surface cylindric. A spherocylindric lens is also spoken of as an astigmatic lens. (See Fig. 100.) A spherocylindric lens is one which has two focal planes. Spherocylinders have different curves: the spheric curve may be convex, with the cylindric surface convex; or the spheric surface may be concave, with the cylindric surface concave; or the spheric surface may be convex, with the cylindric surface concave; or the spheric surface may be concave, with the cylindric surface convex.

The Trial-case (see Fig. 50).—This case contains pairs of plus and minus spheres and pairs of plus and minus cylinders; also prisms numbered from ¼ or ½ to 20△. The spheres are numbered in intervals of 0.12 up to 2 S.; and from 2 S. up to 5 S. the interval is 0.25 S.; and from 5 S. to 8 S. the interval is 0.50 S.; and from 8 S. to 22 S.

the interval is 1 S. The cylinders have similar intervals, but seldom go higher than 6 or 8 cyl.

The trial-case also contains a trial-frame, which is used to place lenses in front of the patient's eyes. (See Fig. 51.) The eye-pieces of such a frame are numbered on the periphery in degrees of half a circle, so that the axis of a cylinder can be seen during refraction. The left of the

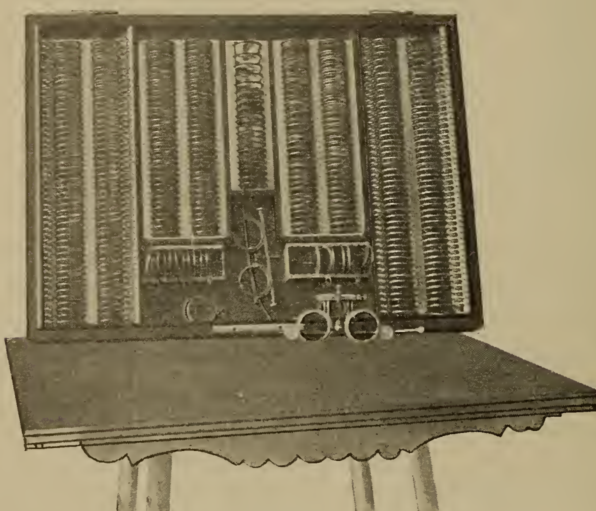


FIG. 50.

horizontal line in each eye-piece is recognized as the starting-place, or zero (0), and the degrees are marked from left to right on the *lower half*, counting around to the horizontal meridian, which at the right hand is numbered 180; this horizontal meridian is, therefore, spoken of as horizontal, zero (0), or 180 degrees. The meridian midway between zero and 180 is spoken of as vertical, or 90 degrees.

In some countries the meridians are differently numbered (see Fig. 52); for example, the vertical meridian is called zero, and the degrees are marked on each side of zero up to 90 degrees. Only the upper half of the eye-piece is thus numbered, so that when a cylinder has the upper end of its axis inclined toward the nose, the record would be so many degrees of inclination to the nasal side; or if the upper end of the cylinder was inclined toward the temple, the record would be so many degrees to the temporal side.

For example, in the right eye 15 degrees nasal would

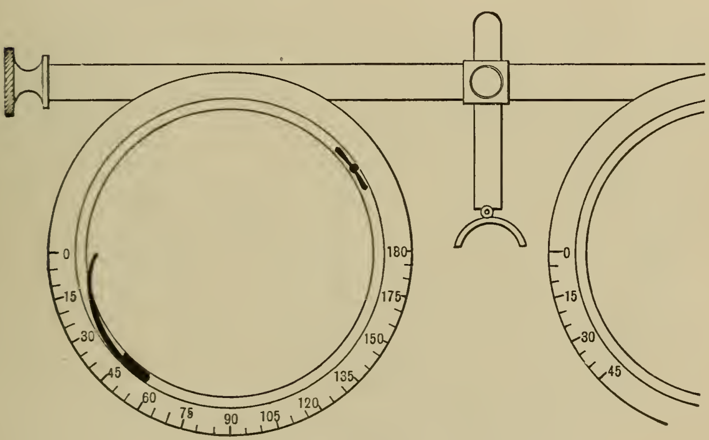


FIG. 51.

mean axis 75 on the ordinary trial-frame, and 15 degrees temporal would mean 105 degrees.

The trial-case also contains other accessories, such as blanks or blinders, a stenopeic slit, pin-hole disc, etc., all of which are referred to in the text.

Combination of Lenses.—The sign of combination is ⌒‿.

Combining Spheres.—Any number of spheric lenses placed with their optic centers over each other, and surfaces together, will equal one lens the value of their sum: for example, +2 S. ⌒ +1 S. ⌒ +3 S. will equal +6 S.; or a —2 S. ⌒ —1 S. ⌒ —3 S. will equal a —6 S.

If a plus and minus sphere, each of the same strength, be placed with their optic centers together, the refraction will be nothing, for the one will neutralize the effect of the other; for instance, +4 S. and —4 S. will be equivalent to a piece of plane glass, as the —4 S. will diverge rays of light as much as the +4 S. will converge them, and the result

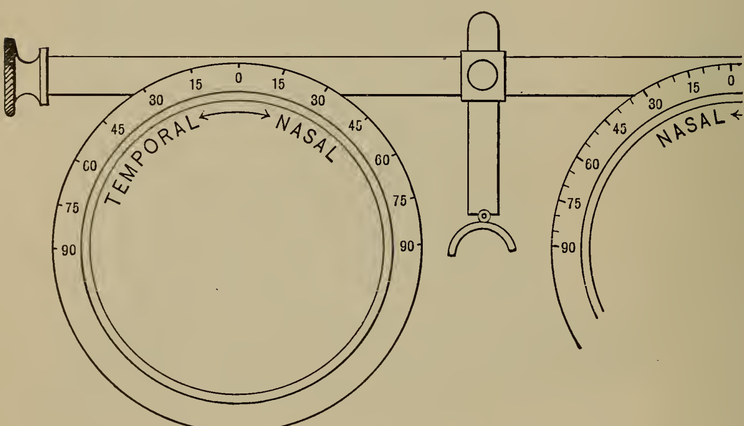


FIG. 52.

is, rays of light parallel before refraction are parallel after passing through such a combination. If, however, a plus and a minus sphere of different strengths are placed together, the value of the resulting lens will equal their difference, in favor of the higher number; for instance, +4 S. and —2 S. will equal a +2 S., the —2 S. neutralizing 2 S. of the +4 S., leaving +2 S.

Combining Cylindric Lenses.—Any number of cylindric lenses placed together, with their axes in the *same* meridian, are equal to a cylinder the value of their sum; for example: +2 cyl. axis 90 degrees and +3 cyl. axis 90 degrees will equal a +5 cyl. axis 90 degrees; or —2 cyl. axis 180 degrees and —3 cyl. axis 180 degrees will equal a —5 cyl. axis 180 degrees; or —2 cyl. axis 180 degrees and +1 cyl. axis 180 degrees will equal a —1 cyl. axis 180 degrees.

As a cylinder refracts rays of light only in the meridian opposite to its axis, this opposite meridian can always be found by the following simple rule:

"*Add 90 when the given axis is 90 or less than 90, and subtract 90 when the given axis is more than 90.*"

For example: +3 cyl. axis 90 refracts rays of light in the 180 degree meridian (90 + 90 = 180); or +3 cyl. axis 75 refracts rays of light in the 165 meridian (75+90 = 165). A —3 cyl. axis 135 refracts rays of light in the 45 meridian (135 less 90 = 45). A —2 cyl. axis 180 refracts rays of light in the 90 meridian (180 less 90 = 90).

Combining two cylinders of the same strength and same denomination, with their axes at right angles to each other, will equal a sphere of the same strength and same denomination. For instance, +3 cyl. axis 90 and +3 cyl. axis 180, placed together, will equal a +3 S. — *i. e.*, the +3 cyl. at axis 90 will converge parallel rays in the 180 meridian, while the +3 cyl. axis 180 will converge parallel rays in the 90 meridian, producing a principal focus; therefore any sphere is also equal to two cylinders of its same strength and same denomination with their axes at right angles to each other.

Combining cylinders of different strength, but of the same denomination, with their axes at right angles to each other, such a combination will equal a sphere and a cylinder of the same denomination. For example:

+2 cyl. axis 75 ⊃ +3 cyl. axis 165 will equal +2 S. ⊃ +1 cyl. axis 165. The +2 cyl. axis 75 takes +2 of the +3 cyl. axis 165 and makes a +2 S., leaving +1 cyl. axis at 165; the result is then +2 S. ⊃ +1 cyl. axis 165.

Or —3.50 cyl. axis 15 ⊃ —4.50 cyl. axis 105, will equal —3.50 S. ⊃ —1 cyl. axis 105. The —3.50 axis 15 takes —3.50 of the —4.50 and makes a —3.50 S., leaving —1 cyl. axis 105; this —1 cyl. axis 105 is now joined to the —3.50 sphere, making —3.50 S. ⊃ —1 cyl. axis 105.

Combining a sphere and a cylinder of the same strength, but of different denomination, will equal a cylinder of the opposite sign and opposite axis from the cylinder given. For example: +1 sphere ⊃ —1 cyl. axis 180 will equal +1 cyl. axis 90. The +1 S. equals two +1 cylinders, one at axis 90 and one at axis 180, and the —1 cyl. at axis 180 is neutralized by the +1 cyl. at the same axis, leaving the +1 cyl. axis 90. This may be better understood by the diagram (Fig. 49).

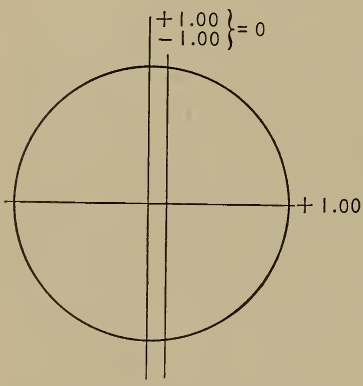


Fig. 53.

Or —3 S. ⊃ +3 cyl. axis 90 equals —3 cyl. axis 180. The —3 S. is equal to two —3 cylinders, one at axis 90 and one at axis 180; the one at axis 90 is neutralized by the +3 cyl. at the same axis, leaving —3 cyl. axis 180.

Combining a Sphere with a Weaker Cylinder of Different Denomination.—Such a combination should be changed to its simplest form of expression, and will equal a sphere of the same denomination, of the value of their difference, combined with a cylinder of the same strength as the cylinder given, but of opposite sign and axis. For example: +4 S. ⊂⊃ —1 cyl. axis 180. The minus one cylinder is refracting in the 90 degree meridian, therefore it reduces the strength of the +4 S. in this axis, making it a plus 3. The horizontal or 180 degree meridian of the plus 4 S. has not been altered, but still remains +4, and the result is, plus 3 in the vertical meridian and plus 4 in the horizontal meridian, equaling, therefore, +3 S. ⊂⊃ +1 cyl. axis 90.

The following rule will be of service in making this change, and, in fact, this rule will apply in any instance where the sphere and cylinder are of different denomination, no matter what their respective strengths may be:

Rule.—*Subtract the less from the greater, and to the result prefix the sign of the greater; combine with this the same strength cylinder, using the opposite sign and opposite axis.* Example: +2.25 S. ⊂⊃ —0.75 cyl. axis 75 degrees; subtracting the less from the greater (—0.75 from +2.25), and prefixing the sign of the greater (+), will leave +1.50 S.; and combining with this the same strength cylinder (0.75), with opposite sign and axis (+ and 165), will be +0.75 cyl. axis 165. Result, +1.50 S. ⊂⊃ +0.75 cyl. axis 165.

Combining a Sphere and Cylinder of the Same Denomination. — This is recognized as the minimum or simplest form of expression, and is *seldom* changed. For example: —2 S. ⊂⊃ —6 cyl. axis 180 is considered as the thinnest lens and the one with the least weight that can be made by such a combination. It may be changed, however, by the reverse of the rule above given, and will equal —8 S. ⊂⊃ +6 cyl. axis 90.

Combining Two Cylinders of Different Denominations with Opposite Axes.—Commonly called crossed cylinders. Such combinations can be written in three ways:

1. +Cyl. ⊂⊃ —cyl. axes opposite.
2. +Sphere ⊂⊃ —cyl. (cylinder stronger than sphere).
3. —Sphere +cyl. (cylinder stronger than sphere).

For example: —1.00 cyl. axis 180 ⊂⊃ +2.50 cyl. axis 90 may be changed to one of the following:

—1.00 S. ⊂⊃ +3.50 cyl. axis 90; or—
+2.50 S. ⊂⊃ —3.50 cyl. axis 180.

The first formula shows that the vertical meridian must always be —1 and the horizontal or 180 meridian must always be +2.50, and with this clearly in mind, the second and third formulas will be understood. In the second formula (—1.00 S. ⊂⊃ +3.50 cyl. axis 90) the +3.50 cyl. is only equal to +2.50, as it has 1 D. neutralized by —1 of the —1 sphere. In the third formula (+2.50 S. ⊂⊃ —3.50 cyl. axis 180) the —3.50 cylinder is only equal to —1.00 cylinder, as it has —2.50 neutralized by +2.50 of the sphere.

In any spherocylindric combination the meridian in which the axis of the cylinder lies has the strength of one lens, and the meridian opposite to the axis of the cylinder has the combined values of sphere and cylinder—i. e., —1.00 S. ⊂⊃ +3.50 cyl. axis 90 means —1.00 on the axis (90) of the cylinder, and opposite to the axis therefore at 180, it equals +2.50 (—1 and +3.50).

Crossed cylinders in themselves are seldom ordered in a prescription, preference being given to a spherocylindric combination. When to order a plus sphere with a minus cylinder, and when to order a minus sphere with a plus cylinder, depends upon the individual lenses. For example:

+0.50 cyl. axis 90 ⊃ —5.00 cyl. axis 180 equals +0.50 S. ⊃ —5.50 cyl. axis 180 or —5 S. ⊃ +5.50 cyl. axis 90.

Preference would be given to the plus sphere combination, on account of thinness and lesser weight of the lens. The following formula, —1 cyl. axis 180 degrees ⊃ +3 cyl. axis 90 degrees, equals —1.00 S. ⊃ +4 cyl. axis 90, or +3 S. ⊃ —4 cyl. axis 180, and for similar reasons preference would be given to the *minus* sphere combination. Whichever combination makes the thinnest and lightest weight of glass is the one to be ordered, as a rule.

The student should practise these combinations at the trial-case, and be able at a glance to change one formula into another without diagram or rule.

Prescription Writing.—In writing prescriptions for lenses the right eye is indicated by one of three signs—R, Rt, or O. D., the latter from the Latin for right eye, *Oculus Dexter*. The left eye is also indicated in one of three ways—L, Lt., or O. S., the latter from the Latin for left eye, *Oculus Sinister*.

A prescription may call for any one of the following:

+Sphere, written +4 D. or +4.00 D. S. or +4 S. or +4 sph.
—Sphere, written —2 D. or —2.00 D. S. or —2 S. or —2 sph.
+Cylinder, written +4.00 D. C. or +4 C. or +4 cyl. (axis as indicated).
—Cylinder, written —2.00 D. C. or —2 C. or —2 cyl. (axis as indicated).
+Sphere and +cylinder, written +2.00 S. ⊃ +2.00 cyl. axis 90 degrees.
—Sphere and —cylinder, written —2.00 S. ⊃ —2.00 cyl. axis 180 degrees.
+Sphere and —cylinder (cylinder stronger than sphere), +2.00 S. ⊃ —3.00 cyl. axis 180 degrees.
—Sphere and +cylinder (cylinder stronger than sphere), —2.00 S. ⊃ +3.00 cyl. axis 90 degrees.

A plus cylinder and minus cylinder *may* be prescribed, and, if so, their axes must be at right angles to each other. An occasional exception to this may be found in irregular astigmatism. Or a prism with its base indicated may be added in any one of the foregoing formulas ; for example : —2 S. ⊂⊃ —2.00 cyl. axis 180 ⊂⊃ 2 △ base in ; or the direction of the base may be abbreviated as follows : B. I., meaning base in ; B. O., meaning base out ; B. U., meaning base up ; and B. D., meaning base down.

Prescriptions are never written for two spheres.

Prescriptions are never written for two cylinders at the same axis.

Prescriptions are never written for two cylinders at axes other than those at right angles to each other, except, as just noted, in irregular astigmatism.

For obvious reasons prescriptions are never written for a sphere and two cylinders except in irregular astigmatism.

Recognition of Lenses.

A convex sphere is thick at the center and thin at the edge. It has the power of converging rays of light ; hence, if strong, it is a burning glass. Objects viewed through a convex lens as it is moved before the eye, from left to right and right to left or up and down, appear to move in an opposite direction to that in which the lens is moved. The weaker the lens, the slower the object appears to move ; and the stronger the lens, the faster the apparent movement of the object. A convex lens being a magnifier, has the effect of making objects appear larger and closer when it is moved away from the observer's eye ; or if brought toward the eye, objects already enlarged appear smaller and more distant.

To Find the Optic Center of a Convex Lens.—Looking at a vertical straight line and passing a convex lens before the eye from left to right has the effect of displacing toward the right edge of the lens that portion of the line seen through the lens (see Fig. 54), and as the lens is slowly moved still further to the right, the displaced portion of the line will finally coincide with the original straight line, making one continuous line through the lens. (See Fig. 55.) Marking this straight line on the surface of the lens, and then turning the lens to the opposite meridian and repeating the examination, and marking the lens as before, the optic center will be in the lens beneath the point of intersection of the two lines. (See Fig. 56.)

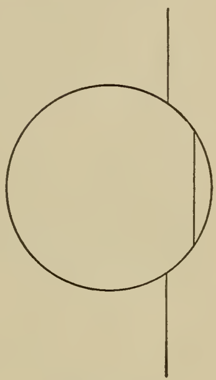


FIG. 54.

A concave sphere is thick at the edge and thin at the center, and has the power of causing rays of light to diverge. When moved before the eye from left to right and right to left or up and down, objects appear to move in the same direction as that in which the lens is moved.

A concave lens being a minifier, makes objects appear

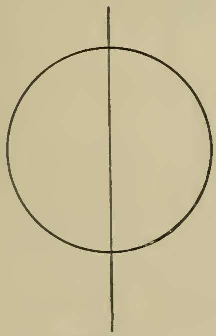


FIG. 55.

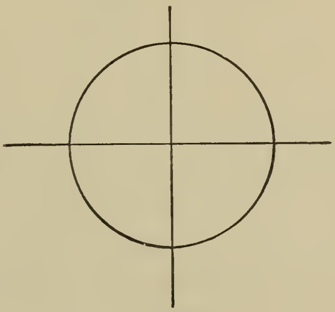


FIG. 56.

smaller and more distant as the glass is moved away from the eye, and if brought closer to the eye, makes objects apparently small appear somewhat larger and nearer.

Looking at a straight edge or line through a concave sphere, and passing the lens from left to right, the portion of the line seen through the lens appears displaced toward the center of the lens (see Fig. 57), and as the lens is still further moved to the right, the displaced portion of the line finally coincides with the original straight edge, as in figure 55.

The optic center of a concave lens is found in the same way as the center of a convex lens.

A Convex Cylinder.—When a convex cylinder is moved

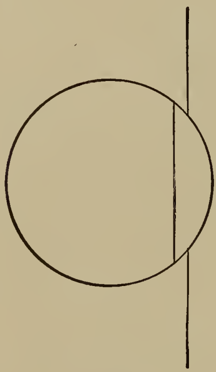


FIG. 57.

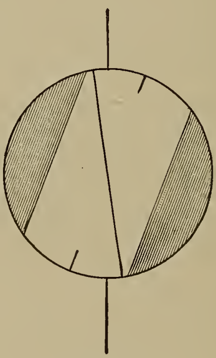


FIG. 58.

in front of the eye in the direction of its axis, objects looked at do not change their positions; but when the lens is moved in the direction opposite to its axis, the movement of the object is the same as that of a convex sphere. Looking at a straight edge through a convex cylinder, and rotating it, has the effect of displacing away from its axis that portion of the straight edge seen through the lens. (See Fig. 58.)

A Concave Cylinder.—When a concave cylinder is moved in front of the eye in the direction of its axis, objects looked at do not change their positions ; but when the lens is moved in the direction opposite to its axis, the movement of the object is the same as that of a concave sphere. Looking at a straight line through a concave cylinder, and rotating it, has the effect of displacing toward its axis that portion of the straight line seen through the lens. (See Fig. 59.) A circle viewed through a strong concave cylinder appears as an oval with its long diameter corresponding to its axis. (See Fig. 60.) A circle viewed through a strong convex cylinder appears as an oval with its long diameter opposite to its axis. In place of using a

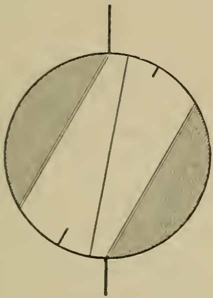


FIG. 59.

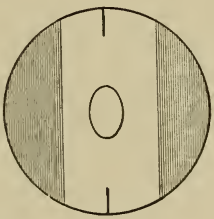


FIG. 60.

straight line or straight edge to find the optic center of a sphere or axis of a cylinder, two lines at right angles may be substituted (see Fig. 56) or a protractor may be used.

A Prism.—Objects viewed through a prism are displaced toward its apex, and that portion of a straight line seen through the prism never coincides with the straight line.

Neutralization of Lenses.—Having determined from the foregoing description what the character of an individual lens may be, then to neutralize its effect or find out its strength a lens of opposite character is taken from the trial-case and held in apposition to it, and the two lenses are moved in front of the eye as a distant object is observed. That lens or combination of lenses which stops all apparent movement of the object is the correct neutralizing lens. Spherocylindric lenses are neutralized by finding out what sphere will correct one meridian and what sphere will correct or neutralize the opposite meridian; for example, if a minus 2 S. stops all movement in one meridian and minus 3 S. stops all movement in the other meridian, then the lens being neutralized will be plus 2 S. combined with a plus 1 cylinder. Or after a sphere neutralizes one meridian, a cylinder may be combined until the other meridian is neutralized.

CHAPTER II.

THE EYE.—THE STANDARD EYE.—THE CARDINAL POINTS.—VISUAL ANGLE.—MINIMUM VISUAL ANGLE.—STANDARD ACUTENESS OF VISION.—SIZE OF RETINAL IMAGE.—ACCOMMODATION.—MECHANISM OF ACCOMMODATION.—FAR AND NEAR POINTS.—DETERMINATION OF DISTANT VISION AND NEAR POINT.—AMPLITUDE OF ACCOMMODATION.—CONVERGENCE.—ANGLE GAMMA.—ANGLE ALPHA.

The Eye.—While the eye is considered as the organ of vision, yet its function is to form upon its retina an inverted image of any object looked at; and if the retinal image is distinct, the object will appear distinct; if the retinal image is blurred, the object will appear blurred. By means of the optic nerve and tract the retinal impression or image is placed in communication with the brain, which interprets the image and completes the visual act.

The Standard Eye.—For purposes of exact calculations it has been found necessary to project a standard or schematic eye, whose nodal point (optic center) shall be seven millimeters back of the anterior surface of the cornea and fifteen millimeters from the fovea (Helmholtz). Allowing one millimeter for the thickness of the choroid and sclera, such an eye would have an anteroposterior measurement of about twenty-three millimeters. Parallel rays of light passing into such an eye in a state of rest would focus on the macula.

Cardinal Points (Fig. 61).—Images formed upon the retina are the result of refraction by three refracting surfaces and three refracting media. The refracting surfaces are the anterior surface of the cornea and the anterior and posterior surfaces of the crystalline lens. The refracting media are the cornea (and aqueous humor forming a convex lens), the crystalline lens, and the vitreous humor. These refracting surfaces and media represent a compound dioptric system, centered upon the optic or principal axis—*i. e.*, a line drawn from the pole of the cornea to a point between the nerve and fovea.

On the principal axis are situated the anterior and posterior principal foci (see p. 33), the anterior and posterior nodal

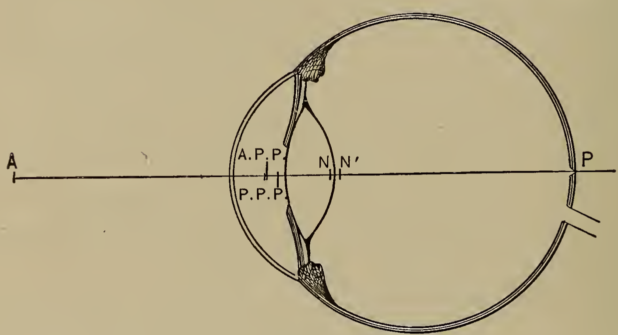


FIG. 61.

points, and the anterior and posterior principal points. The anterior principal focus is situated upon the optic axis 13.745 + mm. in front of the corneal apex. The posterior principal focus is situated 15.61 + mm. back of the posterior surface of the lens. The nodal points are situated about 7 mm. back of the cornea, and correspond approximately to the optic center of this compound refracting system; and as they are so close together, they are considered as one for all purposes in the study of the formation of images. The first or anterior principal point is situated 1.75 mm. back of the anterior corneal surface, and the second or posterior principal point is situated 2.10 mm. behind the anterior surface of the cornea. The principal points are so closely situated that they are considered as one. The anterior focal distance equals 15.49+ mm. and the posterior focal distance equals 20.71+ mm.

The Visual Angle, or Angle of View.—The visual angle is the angle formed by rays of light from the extremes of an object passing to the nodal point of the eye; or the visual angle may be defined as the angle which the object subtends at the nodal point of the compound refracting system of the eye. Rays of light from the extremes of an object

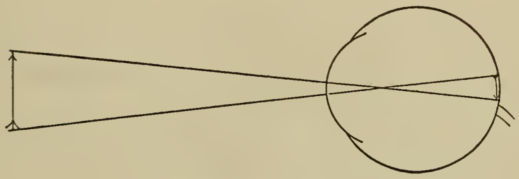


FIG. 62.

directed to the nodal point of the eye pass through unrefracted, and continuing their straight course, fall upon the retina, forming an inverted image of the object. (See Fig. 62.)

The size of the retinal image depends upon the size and the distance of the object from the nodal point of the eye. Objects, therefore, which are seen under the same visual angle must have the same sized retinal image. (See Fig. 63.)

If the arrows 1, 2, 3, and 4 represented a child, a man, a tree, and a church, respectively (some distance apart), they would form the same sized retinal images, and if the eye were guided alone by the size of the retinal image, it would judge erroneously; but, by experience, distance and comparison of size are brought into judgment.

If, however, arrows 2, 3, and 4 are placed at the side of arrow 1, then their resulting images would increase in size according to the size of their respective visual angles. (See Fig. 64.)

The nearer an object to the eye, the larger the visual

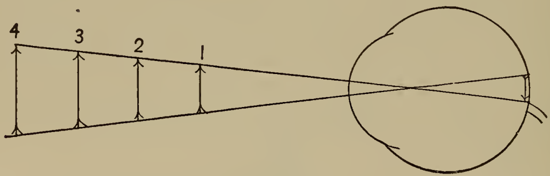


FIG. 63.

angle and retinal image; the further away an object from the eye, the smaller the visual angle and retinal image. An object, to retain the same sized visual angle, must, therefore, be made larger the further it is removed from the eye; this is demonstrated in figure 63, where arrow 1, to be seen

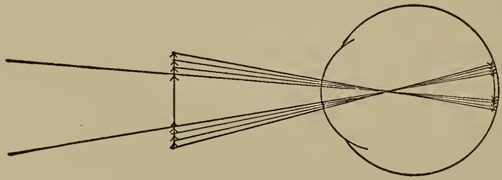


FIG. 64.

under the same visual angle which it has at present, would have to be as large as arrow 4, at the distance of arrow 4.

Minimum Visual Angle.—This is the smallest visual angle in which a standard eye can still recognize an object and give it a name; this angle is also spoken of as the limiting angle of vision. In figure 65, for example, the letter D at a distance of six meters is recognized as the letter D: it is plainly seen; but if placed beyond six meters, it would form a smaller visual angle, and could not with certainty be called D.

To be seen at a distance of twelve meters and still occupy this same visual angle, D would have to be made twice as large—*i. e.*, the size of F; and to be seen at twenty-four meters, it would have to be four times its present size, or the size of P. Thus, while the letter D, seen clearly at six meters, would have to be made proportionately larger as it is removed from the eye, then to occupy

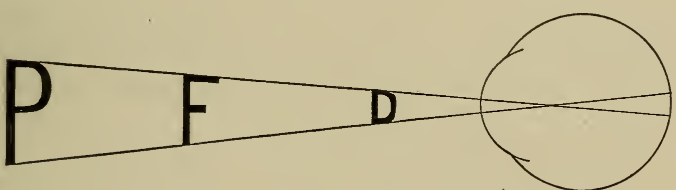


FIG. 65.

the same visual angle it would have to be made smaller if brought closer to the eye and kept within this limiting angle. In figure 65 D, F, and P can be seen closer to the eye than their respective distances call for; but the purpose is to find the *greatest* distance from the eye at which they can be seen, as this represents the maximum acuteness of vision, or maximum sharpness of sight.

Standard Acuteness of Vision.—As it was necessary for purposes of calculation to have a standard or emmetropic eye, so it is essential to have a standard acuteness of vision which will be consistent with the standard or emmetropic eye, and thus have some method of recording numerically any departure from this standard visual condition.

The standard acuteness of vision is the power of the eye to distinguish letters and characters occupying an angle of five minutes. Every letter is, therefore, so proportioned that it will measure just five minutes in the vertical and horizontal meridians, and be reducible to twenty-five parts or squares, each measuring one minute vertically and horizontally.* (See Fig. 66.)

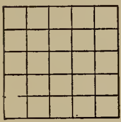


FIG. 66.

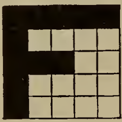


FIG. 67.

Figure 67 shows the letter F drawn in a five-minute square, and each stroke of the letter, and space between the strokes, measuring just one minute in width. As the tangent of half the angle of five minutes is expressed by the decimal .001454, then to calculate the size of any letter or character which should be seen clearly and distinctly by the standard eye at a certain definite distance, it is necessary to multiply the distance in millimeters by this tangent of the angle of five minutes. Letters or characters made on this scale are called standard letters. For example, letters to be seen under an angle of five minutes at a distance of one meter (1000 mm.) would have to be 1.454 mm. square (1000 × .001454). At six meters (6000 × .001454) = 8.7 mm., etc.

Size of Retinal Images.—The size of the retinal image depends upon two factors—the size of the object itself and its distance from the nodal point. In the standard eye it has been stated that the nodal point was 7 mm. back of the cornea and 15 mm. in front of the retina; then an object 8.7 mm. square situated 6000 mm. in front of the

*There are two letters in the alphabet which are exceptions to this rule, L and O. L can be seen under an angle of two minutes and O can be seen under an angle of three minutes.

eye would have a retinal image $\frac{15}{6000}$ of 8.7, or 0.02+ mm., and this is the size of the retinal image in a standard eye, looking at a standard letter at six meters' distance. A good rule for finding the size of the retinal image is to multiply the height of the object by the nodal distance and divide by the distance. In other words, the size of the retinal image is to the size of the object as their respective distances from the nodal point.

Refraction in ophthalmology has most to do with eyes whose measurements are not according to the standard or emmetropic condition, and which have their retinas closer to or further from the nodal point than 15 mm. (spoken of as ametropic). The retinal images in such eyes will be smaller in the former and larger in the latter. (See Fig. 68.)

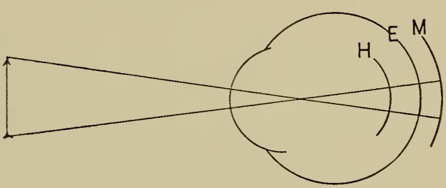


FIG. 68.

Accommodation.—This may be described as the power of the eye to focus rays of light upon its retina from different distances at different times. In other words, the eye can not focus rays of light upon its retina from different points at one and the same time. For example, the point of a pencil held six inches in front of the eye is not seen clearly (is hazy) as the eye looks at a printed page thirteen inches beyond; and, vice versâ, the printed page is not seen distinctly if the point of the pencil is looked at. In the study of convex lenses it was noticed that when an object was brought closer than infinity, the focus of the lens was correspondingly lengthened; and so, in the photographer's camera, to keep the focus on the ground-glass or sensitive plate as the object is brought toward the camera, it is necessary to push the lens forward by means of the accordion plaits; but the human eye does not lengthen or shorten in this way. Normally, the eyeball is inextensible, and to accomplish this same purpose the ciliary muscle must contract, causing the crystalline lens to become more convex, and thus keep the rays of light entering the eye at a focus upon the fovea.

The Mechanism of Accommodation.—To appreciate this, it is necessary to understand something of the anatomy of the ciliary body, of which the ciliary muscle is a part. The ciliary body is circular in form and occupies a small (3 mm.) area in the eye, just beneath the sclera, at its corneal junction. (See Fig. 61.) In section the ciliary body is triangular in shape, the base of the triangle measuring about 0.8 mm. and facing toward the anterior chamber, the apex of the triangle extending backward beneath the sclerotic. The ciliary body lies in apposition to the sclera, but has only a very minute attachment to it, at the sclerocorneal junction, called the ligamentum annulare, or pectinatum. That portion of the ciliary body lying next to the hyaloid membrane of the vitreous humor is composed of folds, known as the ciliary processes, seventy or more in number.

A portion of the ciliary body is composed of muscular fibers disposed in flat bundles, which interlace with each other, forming a sort of plexus, and called the ciliary muscle. This muscle, by the character of its fibers, has been subdivided into three parts: (1) Meridional; (2) radiating; and (3) circular or sphincter fibers. The meridional are the longest, lie next to the sclerotic in lamellæ, parallel with it, and pass back to join the choroid coat of the eye, forming what is known as the tensor choroideæ, or muscle of Brücke or Bowman. The radiating fibers are fan-shaped, few in number, and scattered through the ciliary body.

The circular or sphincter fibers—also called annular—are sometimes referred to as the muscle of Müller, or compressor lentis, and are the most important fibers in the consideration of accommodation; they form a sphincter ring concentric with the equator of the lens. Attached to the ciliary body, well forward on its inner side, near the base of the triangle, is the ligament of the lens (zonule of Zinn), and it in turn sends fibers to the anterior and posterior capsule of the lens. This ligament of the lens occupies an interval of about 0.5 mm. between the ciliary body and the periphery of the lens, and is a *constant* factor in all conditions of the healthy eye.

During the act of accommodation the following changes take place in the eye:

1. The ciliary muscle contracts.

2. The ciliary muscle (sphincter), by contracting, makes a smaller circle.

3. The tensor choroideæ draws slightly upon the choroid (compressing somewhat the vitreous body), and these two sets of fibers, sphincter and meridional, acting together, relax the ligament of the lens, with the result that—

4. The lens fibers, no longer held in check, become relaxed, and by their own inherent quality (elasticity) allow the lens to become more convex, especially on its anterior surface.

5. The anterior surface of the lens being made more convex, approaches the cornea.

6. The posterior surface of the lens becomes slightly more convex, but retains its position at the pole.

7. The lens axis is lengthened, but the equatorial diameter diminishes, thus keeping up the uniform interval between the equator of the lens and the ciliary body, as previously referred to. *The lens does not increase in volume.*

8. The anterior chamber becomes slightly shallower at the center and deeper in the periphery.

9. That portion of the iris resting upon the anterior capsule of the lens is pushed forward, especially at its pupillary edge.

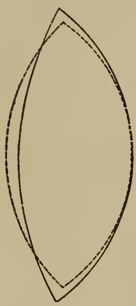


FIG. 69.

10. The iris contracts, producing a smaller pupil; but it must be remembered that contraction of the iris is not an essential condition in accommodation. The shape of the cornea is not changed during contraction of the ciliary muscle.

The following table shows the comparative measurements of a lens at rest and during the height of accommodation in a healthy emmetropic eye of ten years. The dotted lines in figure 69 indicate the changes in the shape of the lens at the height of accommodation.

	At Rest.	Height of Accommodation.
Radius of curvature of anterior surface of lens,	10 mm.	6 mm.
" " posterior " " .	6 "	5.5 "
Distance from anterior surface of cornea to anterior surface of lens, ...	3.6 "	3.2 "
Anteroposterior diameter, on axis, ...	3.6 "	4 "
Distance from anterior surface of cornea to posterior surface of lens, ...	7.2 "	7.2 "
Equatorial diameter, ...	8.7 "	8.2 "

Far Point.—Latin, *punctum remotum;* abbreviated p. r. or r. The far point may be defined as the greatest distance at which an eye has maximum sharpness of sight, or the most remote point at which the eye, in a state of rest, has maximum acuity of vision. **Infinity** (sign of infinity, ∞) is the far point of an emmetropic eye.

The standard or emmetropic eye, when looking at distant objects, receives parallel rays of light at a focus upon its fovea (Fig. 70), and also emits parallel rays; under these conditions the ciliary muscle is not acting, the eye is in a condition of complete repose, of rest, of minimum refraction, and is adapted for its far point.

Near Point.—Latin, *punctum proximum;* abbreviated p. p. or p. This may be defined as the nearest point at which an eye has maximum sharpness of sight, or the nearest point to the eye at which it has distinct vision, the lens is in the condition of greatest convexity, of maximum refraction.

Amplitude of Accommodation.—This is also called the **range** * or **power** † **of accommodation,** and may be defined as the difference between the refraction of the eye in a state of rest (or adapted for its far point) and in a condition of maximum refraction, or adapted for its near point. For example, an emmetropic eye has infinity for its far point, and if 10 cm. distance is its near point, then the difference between the lens adapted for infinity and 10 cm. will be 10 D., as 10 cm. represents the focal length of 10 D. In other words, there is no accommodation used for infinity, but there is an accommodation of 10 D. for the near point, which is the amplitude or power of accommodation. The emmetropic eye in a state of accommodation adds on to the anterior surface of its lens what is equivalent to a convex meniscus. Figure 70 shows an emmetropic eye at rest receiving parallel rays of light at a focus upon its retina,

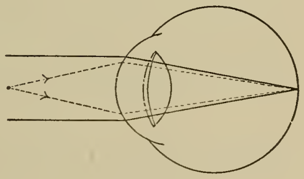


FIG. 70.

* Range applies to the space between the far and near points.

† Power applies to the force or strength or diopters necessary to change the refraction from the far to the near point.

and it also shows the same eye in its maximum state of accommodation for a point 10 cm. distant; the broken line representing what is equivalent to a convex meniscus, added to the anterior surface of its lens.

When the distance of the near point is known in inches or centimeters, the equivalent in diopters is found by dividing 40 by the near point in inches, or by dividing 100 by the near point in centimeters. The near point being 10 cm., or 4 inches (10 into 100 or 4 into 40) the amount of accommodation will be 10 D.

In the study of healthy emmetropic eyes it has been found that the power of accommodation gradually diminishes as the eye passes from youth to old age. This is the result of one or more changes: the lens fibers lose their elasticity, becoming sclerosed, or the ciliary muscle grows weak, or both of these changes may exist together. Rarely the cornea may flatten. A knowledge of the power of accommodation is absolutely essential, so that any variations from the standard condition may be noted. The following table gives the ages from ten to seventy-five years, respectively, with five-year intervals, and the near point consistent with each, as also the amplitude of accommodation for each period.

Year.	Near Point.	Amplitude in Diopters.	Year.	Near Point.	Amplitude in Diopters.
10	7 cm.	14	45	28 cm.	3.5
15	8.5 "	12	50	40 "	2.5
20	10 "	10	55	55 "	1.75
25	12 "	8.5	60	100 "	1
30	14 "	7	65	133 "	0.75
35	18 "	5.5	70	400 "	0.25
40	22 "	4.5	75	∞	

This table of near points applies *only* to emmetropic eyes or those eyes which are made emmetropic by the adjustment of suitable correcting lenses. The table of amplitudes, however, is the same, with a few exceptions, for all eyes of whatever degree or amount of ametropia.

For a better appreciation of the amplitude of accommodation it is necessary to understand the two forms of eyes already referred to in figure 68.

First, the eye which has its retina closer to its refractive media than the principal focus; such an eye is spoken of as a short or hyperopic eye. (H in Fig. 68.) (Hyperopia: Greek, ὑπερ, over; and ὤψ, eye.)

This eye in a state of rest (under the influence of atropin) will emit divergent rays of light, and is, therefore, in a

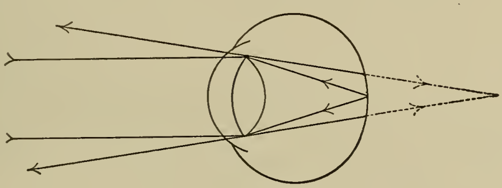


FIG. 71.

condition to receive only convergent rays of light at focus upon its retina. (See Fig. 71.) Parallel rays would not focus upon the retina of such an eye, but, if possible, would focus back of the retina.

Second, the eye that has its retina beyond the principal focus of its dioptric media (M in Fig. 68); such an eye is spoken of as a long or myopic eye (Greek, μύειν, to close; ὤψ, eye). This eye always emits convergent rays, and is, therefore, in a state to receive divergent rays of light at a focus upon its retina. (See Fig. 72.) Parallel rays would not focus upon the retina of a myopic eye, but in the vitreous in front of the retina.

The Far Point of a Hyperopic Eye.—This must necessarily be negative (see Fig. 71), and is found by projecting the divergent emergent rays backward to the imaginary point behind the retina from which they appear to have diverged. A hyperopic eye, to receive parallel rays of light at a focus upon its retina, must, therefore, accommodate, and the amount of accommodation thus exerted will remove the near point just that much from the eye as compared with an emmetropic eye. For example, according to the table of amplitudes just given, an eye at twenty years has 10 D. of accommodation, but if it uses 2 D. of this to make rays of light parallel, then it only has 8 D. left to accommodate inside of infinity, with the result that the near point comes to only (8 into 100) 12.5 cm.; or an eye which is

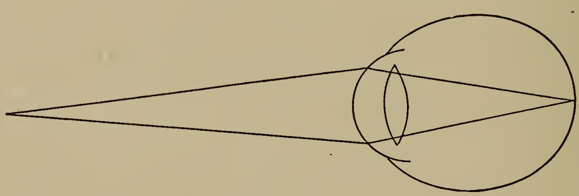


FIG. 72.

twenty-five years old has an amplitude of accommodation of 8.5 D., and if it has to use 4.5 D. for infinity, it would have (4 into 100) a near point of 25 cm. (10 inches).

The Near Point of a Hyperopic Eye.—From the description just given it will be seen at once that the near point in hyperopic eyes is always *further* removed than in the emmetropic eye for a corresponding age, and that the near point depends upon the amount of accommodation that is left after the eye has accommodated for infinity.

The Far Point of a Myopic Eye.—This is always positive and situated some place inside of infinity. It is found by uniting the convergent emergent rays. (See Fig. 72.)

The far point of a myopic eye is the result of its strong refracting power or the distance of its retina beyond the principal focus of its dioptric media. The retina and far point of a myopic eye are conjugate foci. (See Fig. 72.) The myopic far point is equivalent to just that much refraction in excess of the emmetropic eye. An emmetropic eye under the influence of atropin would require a + 2 S. placed in front of it to make rays of light focus upon its retina from a distance of 50 cm., and rays of light from the retina of this eye with a +2 S. in front of it would focus at 50 cm. This eye, then, equals a myopic eye of 2 D. This myopic eye would have a far point of 50 cm. Where the rays of light meet as they come from a myopic eye in a state of rest is its far point.

The Near Point of a Myopic Eye.—This is always closer than in the emmetropic eye for a corresponding age, and depends upon the distance of its far point. For example, an eye at twenty-five years has 8.5 D. amplitude of accommodation, but if it has a far point of 70 cm., then its near point will be represented by 8.5 D. and 70 cm.,—*i. e.*, 1.5 D., which would equal 10 D., or a near point of 10 cm. The following table gives the comparative near points in an emmetropic eye, a hyperopic eye of 2 D., and a myopic eye of 2 D.:

AGE.	10	15	20	25	30	35	40	45	50	55	60	65	70	75
Emmetropia, p.p.	7	8.3	10	12	14	18	22	28	40	55	100	133	400	∞
2 D. Hyperopia, "	8.3	10	12 5	16	20	28.5	40	66	200	∞	—	—	—	
2 D. Myopia, "	6	7	8.3	10	11	13	15.3	18	22	25	33	36	44	50

Determining the Vision.—This may be considered as the method of finding out what an eye can see without any lenses placed in front of it; in other words, determining the vision may be defined as ascertaining the seeing quality of the

7

unrefracted eye. The refraction of an eye should never be confounded with the visual quality, as refraction applies to the refractive media ; for example, an emmetropic eye with a hemorrhage at the fovea would be practically without visual quality, and yet its refraction or refractive condition would be standard. The most acute vision is at the fovea and the region immediately surrounding it, but this sensibility diminishes as the fovea is departed from and the peripheral portion of the retina approached ; this is due to the fact that the cones are as close as 0.002 mm. at the macula, and not so close or numerous in the forepart of the eye-ground.

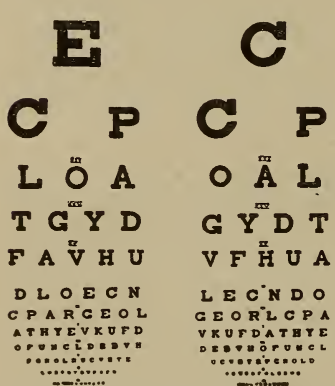


FIG. 73.—Randall's Test-letters. Block letters in black on cream-colored cards.

Test-type or Test-letters for Distant Vision.—To determine the vision we employ cards on which are engraved test-type or letters of various sizes, constructed so that each letter subtends an angle of five minutes, as suggested by Snellen, and described on page 64. Figure 73 shows such cards of test-letters, reduced in size. The Roman characters just over the top of the letters indicate the distance in meters that the letters should be seen by the standard eye, and the little figures at the left of the letters indicate the equivalent distance in English feet. The top letter should be seen at 60 meters, and the bottom letters at 3 meters ; the intervening letters are to be seen at the respective distances indicated. As it is not unusual to find eyes that have a seeing quality better than that obtained with Snellen's type constructed on the angle of five minutes, Dr. James Wallace has constructed letters which subtend an angle of only four minutes. Such a card is shown in figure 74 and has a large field of usefulness. While test-cards are usually white or cream-colored, with black letters, Gould has white letters constructed on black cards. (See Fig. 77.) As white stimulates the retina and black does not, it will be recognized at once that in one instance the card, and in the other the letters, produce the retinal stimulation. The white letters seem to stand out from the black card almost as if they were embossed, giving a clear-cut edge and most soothing effect to the eye under examination, and can be recognized when subtending a much smaller angle than the black letters. To avoid reflection, this card should be hung at an angle.

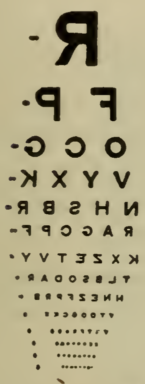


FIG. 74.—Four Minute Letters of Dr. J. Wallace. This card is constructed principally for reflection purposes. (See Fig. 7.)

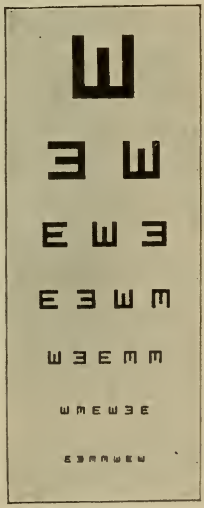


FIG. 75.

For aliens who do not know the English letters, and for illiterates, a special card has been made, known as the illiterate or "dummy" card, with characters consisting of lines shaped like the capital letter "E," and made to conform to the five-minute angle. As these letters are variously placed, the patient is asked to tell, or indicate with his finger or fingers, the direction in which the prongs of the "E" point: up, down, to the right or left. This illiterate card (see Fig. 75) is much to be preferred to the German, Hebrew, and "figure" cards occasionally displayed in clinics.

Kindergarten Card.—To keep the attention of children who do not know the alphabet, or who attend a Kindergarten school, the author has prepared a card of test objects as shown in figure 76. These objects have been drawn up to the angle of five minutes, though some of their component parts do not measure up to one minute.

FIG. 76.—Author's Test Objects or Kindergarten Card for Children and Illiterates.

Selection of Test-cards.—The surgeon should have several of these in duplicate with the order of the letters changed (Figs. 73, 77), as patients not infrequently and unintentionally commit them to memory. Care should be exercised in the selection of test-cards, to see that each letter on the card measures up to the standard square of five minutes, as many of the A's and R's and N's, etc., on the old cards as seen in the shops measure six and seven minutes horizontally. It is a matter of choice with the surgeon whether to use test-cards with the block or Gothic letters. It is well to have both.

Method of Procedure.—The test-card should be hung on the wall with its $\frac{VI}{VI}$ line five or six inches below the level of the patient's eyes, and illuminated by means of reflected artificial light. This is always a certain quantity, whereas daylight is too variable and not to be depended upon. The patient should be placed with his back toward any bright light, and at a distance of six meters from the card.

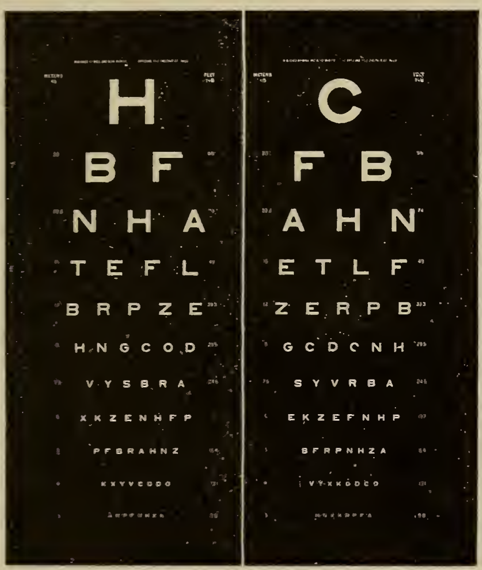


FIG. 77.—Gould's Test-letters. Gothic letters in white on black cards.

Sometimes the surgeon's office is not six meters long, and this distance must be obtained by using diagonal corners of the room or by using a plane plate-glass mirror and a specially prepared test-card with reversed letters (see Fig. 74), the card being hung as many meters in front of the mirror as will make six meters when added to the length of the office. While a distance of six meters is always to be preferred, yet if this can not be obtained, the surgeon may use a distance of four meters, but never less than this. Each eye should be tested separately, the fellow-eye being shielded or covered by a card or opaque disc held in front of it or placed in the trial-frame. The eye should never be held shut, and any pressure upon the eyeball must be avoided.

The record of the visual acuity is usually made in the form of fractions, using Arabic or Roman notation; figures usually indicate feet, and Roman letters usually signify meters, though there is no fixed rule for this. However expressed, the denominator indicates the size of the type which the eye reads, at the distance indicated by the numerator. For example, if at VI meters the eye reads the line of letters marked VI, then the record would be $\frac{VI}{VI}$. This would be $\frac{20}{20}$ if the numerator and denominator were expressed in feet. If the eye, at a distance of VI meters, reads only the letters on the XII line, then the record would be $\frac{VI}{XII}$, or $\frac{20}{40}$ (feet). If the top letter was the only one recognized at the distance of six meters, then the record would be $\frac{VI}{LX}$ (meters), or $\frac{20}{200}$ (feet). If the eye reads the VI line, miscalling two letters, then the record could be made in one of three ways, each indicating the same thing. $\frac{VI}{VI}$? ? (one question mark for each miscalled letter), or "$\frac{VI}{VI}$ partly," would indicate that the eye saw $\frac{VI}{VI}$, but not each letter correctly. This way of making the record is not so explicit as that with question marks. Or, $\frac{VI}{VIIss}+$ would mean that the eye saw all of $\frac{VI}{VIIss}$ and some of the letters of $\frac{VI}{VI}$; but this, too, is not so definite as the first record and the one recommended.

If the eye can not recognize any letter on the card at the distance of VI meters, then the card should be brought toward the patient, or the patient told to approach the card, until the eye can *just* make out the top letter and no more. If this is seen at IV meters, then the record will be $\frac{IV}{LX}$; if at one meter, the record would be $\frac{I}{LX}$, etc. While it has been stated that the visual record is usually made in the form of common fractions, as just described, yet there are some who prefer to make the record in the form of decimals; namely, a vision of $\frac{VI}{VI}$ would be 1.0, a vision of $\frac{VI}{XII}$ would be 0.50, or a vision of $\frac{VI}{XXIV}$ would be 0.25, or a vision of $\frac{VI}{LX}$ would be 0.1. Most authorities prefer to make their records in the form of common fractions.

In some instances the eye may not be able to distinguish any letter on the card, no matter how close it may be brought to the eye, and in such a case the vision is tested by holding the outstretched fingers between the patient's eye and a bright light (an open window), and a note is made of the greatest distance at which the eye can count fingers; if at ten inches, the record would be "fingers counted at ten inches," or whatever the distance may be. This ability to recognize form is spoken of as "qualitative light perception." Eyes that are not able to recognize form may still be able to distinguish light from darkness, and this ability is tested by alternately covering and uncovering the eye as it faces a light, or as light is reflected into it from a mirror. If "qualitative light perception" is present, the vision is recorded L. P., which means "light perception," or the record may be made L. & S., which means practically the same thing, "light and shade."

Determining the Near Point.—Having obtained and recorded the distant vision of an unrefracted eye, it is well to also find out and note what is the nearest point to the eye at which small type can be made out; this is spoken of as determining the near point.

Test-type or Test-letters for Near Vision.—To determine the near point, we employ cards on which are printed or engraved words or sentences, or a series of letters, so that each letter in each word or sentence shall subtend an angle of five minutes, at a given distance from the standard eye; for instance, letters that are to be seen at one meter and occupy the angle of five minutes, must be 1.425 mm. square; letters that are to be seen at half a meter distance must be 0.712 mm. square, etc. Most of the "near" cards in the market are very defective in this respect, and the near types of Jaeger are becoming obsolete, as they are not standard letters, but merely represent the various fonts of printers' type. The writer's card is one of Gothic type, as shown in figure 78. Another card in block letters is shown in figure 79. Above each series of letters is marked the greatest distance (D) at which the respective letters can be seen; these distances vary from 0.25 to 2 meters (25 to 200 cm.), which are ample for all purposes in estimating the near point.

Method of Procedure to Find the Near Point.—The patient is seated so that the light entering the room will come over his shoulder and fall upon the card of test-type held in front of him. The surgeon, to one side of the patient, holds the card in one hand and a meter stick in the other, the eye which is not being tested is covered with a card, and the patient is told to select the *smallest* type on the card which he can read or spell, and as he continues to do so (aloud), the surgeon gradually approaches the card to the eye until the patient says that the letters commence to grow "hazy" and he can scarcely decipher them; or

D·25

....

D·50

1ANOXPLRD 4FORTDLNX 7ECHTDNLC

2DRLPXONA 5CXNDLORP 8KOLTCNRX

3GAONXLPR 6HLROXCDA 9BRLPAXON

D·75

1VLEHCTR 4HCTUPEO 7GLUVHOE

2CDGREVL 5PERLCTZ 8VORTEGD

3OXPLRNA 6NOLPHTR 9RVKFTDA

D-1

1ONLXP 4ROXLH 7NODHA

2TDHNO 5DTCRE 8GPLFZ

3CRLPH 6KNOTR 9OHETD

D-1.25

1DRLP 4XNLD 7CLND

2ANOX 5TROL 8XRNC

3RPLX 6ADCX 9LPON

D-1.50

1LOR 4ROE 7EDT

2VCH 5NRF 8UHR

3LTC 6PHC 9ADL

D-2

1OL 4HU 7GE

2HT 5GP 8FD

3CP 6RH 9NF

FIG. 78.

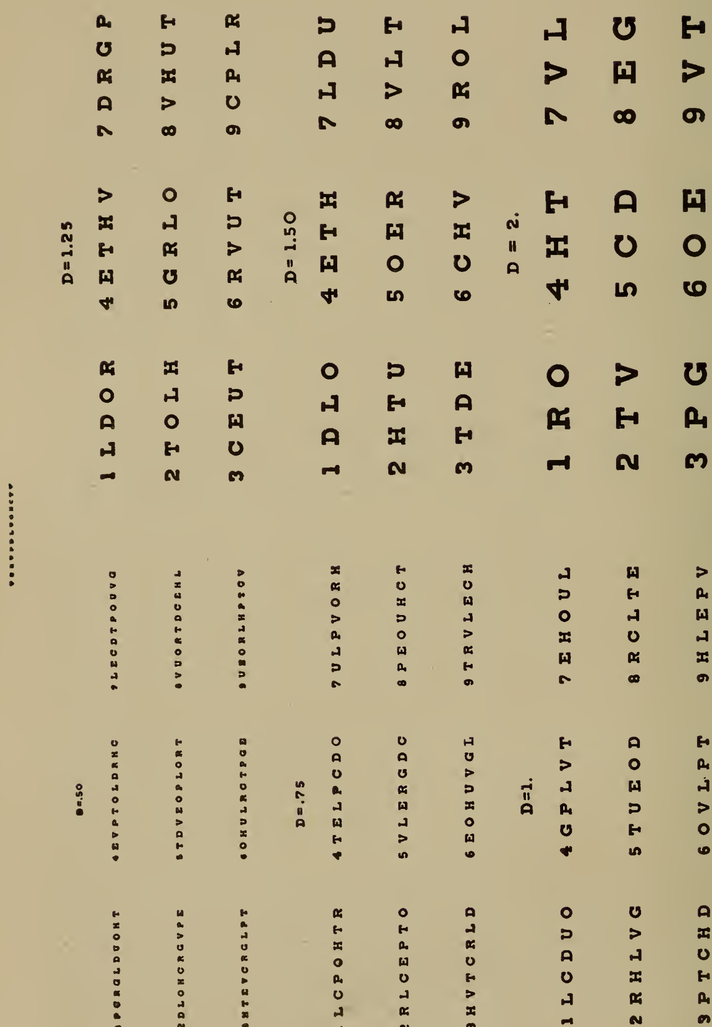

D=.75
1 L C P O H T R
4 T E L P C D O
7 U L P V O R H
2 R L C E P T O
5 V L E R G D C
8 P E O U H C T
3 H V T C R L D
6 E O H U V G L
9 T R V L E C H
D=1.
1 L C D U O
4 G P L V T
7 E H O U L
2 R H L V G
5 T U E O D
8 R C L T E
3 P T C H D
6 O V L P T
9 H L E P V
D=1.25
1 L D O R
4 E T H V
7 D R G P
2 T O L H
5 G R L O
8 V H U T
3 C E U T
6 R V U T
9 C P L R
D= 1.50
1 D L O
4 E T H
7 L D U
2 H T U
5 O E R
8 V L T
3 T D E
6 C H V
9 R O L
D = 2.
1 R O
4 H T
7 V L
2 T V
5 C D
8 E G
3 P G
6 O E
9 V T

FIG. 79.

another way is to hold the card close to the patient's eye and gradually withdraw it until he can just recognize the letters; when this point is reached, *the distance from the eye to the card is measured* with the meter stick, and this distance, as also the size of the type which was read, is carefully recorded. For example, the patient selecting the type marked 0.50 D. and is able to read it as close as 8 cm. and no closer, the record will be "near point equals type 0.50 D. at 8 cm."; or abbreviated, would be "type 0.50 D. = 8 cm."

In some instances the patient may not be able to read any of the near type without the aid of a glass, and if so, it will be necessary to place a plus sphere in front of the eye to assist in finding the near point; for example, if a +2 S. was employed, then the record might be "near point equals type 0.50 D. at 12 cm. with +2 S.," or "+2 S. = type 0.50 D. at 12 cm."

Convergence. — *Con*, "together," and *vergere*, "to turn"; literally, turning together. This is the power of the internal recti muscles (especially) to turn the eyes toward the median line; to "fix" an object closer than infinity. Standard eyes, when looking at an object at a distance of six meters or more, are not supposed to converge; the visual lines are spoken of as parallel and the power of convergence is in a state of repose. The angle which the visual line makes in turning from infinity (∞) to a near point is called the angle of convergence, and the angle which is formed at one meter distance by the visual axis with the median line is called the meter angle, or the unit of the angle of convergence. (See 1, in Fig. 80.)

If the visual line meets the median plane at ½ of a meter, it has then two-meter angles of convergence; at ¼ of a meter, four-meter angles of convergence, etc. Or five-meter angles means that the eye is converging to a point $\frac{1}{5}$ of a meter distant.

The size of the meter angle varies; it is not the same in all individuals; in fact, the meter angle is smaller in children than in adults, as a rule, on account of the shorter inter-ocular distance. In children this distance is about 50 mm., whereas in adults it is, on the average, 60 or 64 mm.

While standard eyes, to see a point one meter distant would converge just one meter angle, they would also accommodate just one diopter; to see a point at ⅓ of a

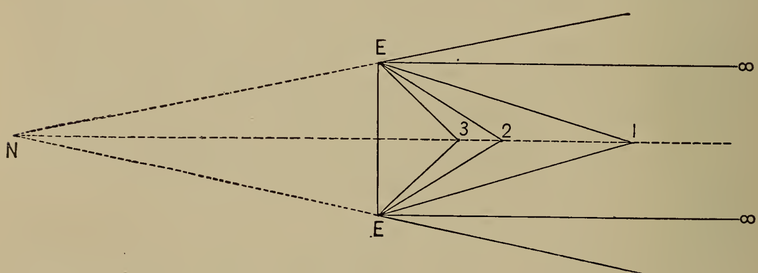


FIG. 80.

meter they would converge just three meter angles, and at the same time would accommodate three diopters, etc., thus showing how intimately the powers of convergence and accommodation are linked together, though it is possible to converge without accommodation (see Presbyopia) or to accommodate without convergence (paralysis of the interni).

Far and Near Points of Convergence.—Just as we have a far and a near point of accommodation, we also have a far and a near point of convergence. The far point of convergence is the point to which the visual lines are directed when convergence is at rest, or at a minimum. The near point of convergence is the point to which the visual lines are directed when the eyes are turned inward to their utmost degree.

Infinity, or parallelism, is the position of the visual lines in the standard eyes in a state of rest (E ∞, in Fig. 80). Visual lines that diverge in a state of rest can only meet by being projected backward, and, therefore, meet at an imaginary point behind the eyes (N, in Fig. 80); convergence is then spoken of as negative, or minus (—).

If the visual lines meet in a state of rest, then convergence is spoken of as positive (+).

The amplitude of convergence is the distance measured from the far point to the near point of convergence, and is

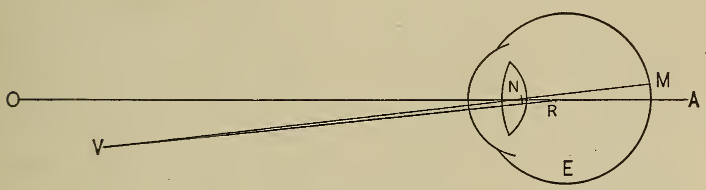


FIG. 81.

represented by the greatest number of meter angles of convergence which the eyes can exert.

Angle Gamma.—An understanding of what is known as the angle gamma is important, that the observer may understand and appreciate the real or apparent position of the eyes when looking at a near or distant point. Figure 81 shows the line O A (optic axis) and the optic center, or nodal point (N), is situated on this line in the posterior part of the crystalline lens. The line V M is really a secondary axis to this dioptric system of the eye, and unites the object (V) with the fovea centralis at M; this line is known as the visual line. The angle formed by the visual line with the optic axis at the nodal point *may* be considered as the angle gamma.*

If the fovea centralis at M was situated on the optic axis at A, then the visual line and optic axis would coincide, and there would not be any angle gamma.

In hyperopic and emmetropic eyes the outer extremity of the visual line lies 5, 7, or, in some instances, as much as 10 degrees to the nasal side of the optic axis (averaging about 5 degrees), and is spoken of as positive, and given the plus sign. In some long myopic eyes, however, the outer extremity of the visual line may lie to the outer side of the optic axis, when it is spoken of as negative, and given the minus sign.

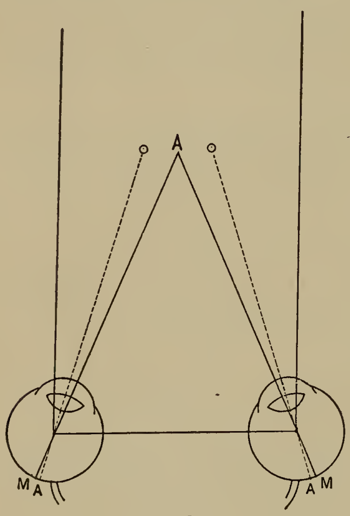


FIG. 82.

To demonstrate the angle gamma, the patient is told to look at the point of a pencil or pen held in the hand of the surgeon, about 13 inches distant (A in Figs. 82 and 83). If the angle gamma is positive, the eyes will appear divergent to the observer, who looks at the position

* This is not a perfectly correct statement, as the real angle gamma is the angle formed by the line of fixation V R with the optic axis, R being the center of rotation. The angle V N O and the angle V R O being so nearly equal, are, for all intents and purposes, considered as the same.

of the poles of the corneas or centers of the pupils. (See Fig. 82.)

If the angle gamma is negative the eyes will appear convergent—that is, they appear to converge to a point in front of the pencil. (See Fig. 83.)

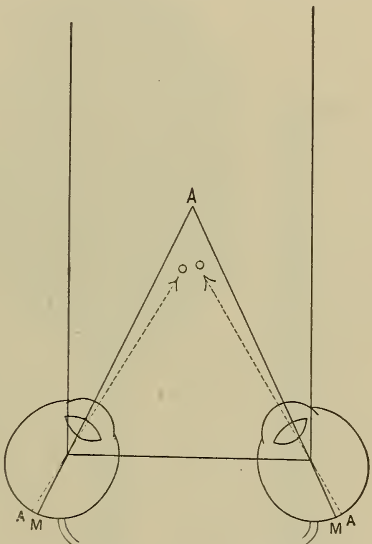


Fig. 83.

The amount of the angle gamma can be measured by using the arc of the perimeter held horizontally, the patient being placed in the same position as when having his field taken. To do this, while the eye fixes the central point, the surgeon passes a candle-flame along the arc until the catoptric image of the flame is seen at the center of the pupil ; this position of the candle-flame on the arc is noted in degrees, which is the size of the angle gamma.

Angle Alpha.—This is the angle formed by the long axis of the corneal ellipse with the visual axis. In the consideration of this angle it must be remembered that the cornea resembles, in its central area, at least, an ellipsoid of revolution, with the shortest radius usually in the vertical meridian. The angle alpha is spoken of as positive when the outer extremity of the long axis of the cornea is to the outer side of the visual line, and negative when it is to the nasal side.

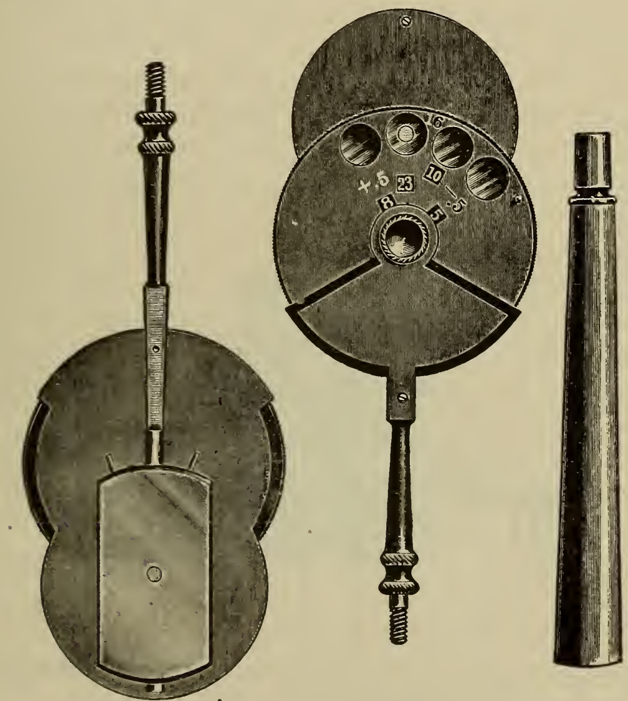
CHAPTER III.

OPHTHALMOSCOPE.

Direct and Indirect Method.

Ophthalmoscope.—From οφθαλμος, "eye," and σκοπεῖν, "to observe" or "view"; literally, "to view an eye." An instrument used for studying the media and interior of the eye. The pupil of an eye in health appears to an observer as black; this is due to the fact that the observer's eye does not ordinarily intercept any of the rays of light which return from the eye. Rays of light entering an eye are returned toward their immediate source, and, therefore, if an observer wishes to see into or study the interior of an eye, he must have his own eye in the path of the returning rays. To accomplish this, the observer places a mirror in front of his eye, so that the reflected rays entering the eye are returned toward the mirror. There is an infinite variety of these instruments in the market, but for the general student the modified instrument of Loring appears to meet with most favor. (See Fig. 84.)

This has a concave mirror with a radius of curvature of 40 cm., giving a principal focus, therefore, at 20 cm. The sight-hole is round and about 3½ mm. in diameter, cut through the glass; this mirror can be tilted to an angle of 25 degrees. As an improvement over such a mirror, and to take its place, the writer would recommend the mirror used on his own ophthalmoscope, which has a radius of curvature of 15 cm.; and the sight-hole, 2½ mm. in diameter, is not cut through the glass, but is made by removing the quick-silver. The glass at the sight-hole gives additional reflecting surface, and at the same time does away with much annoying aberration which results when the glass is perforated.



FRONT BACK

FIG. 84.

The small sight-hole is an advantage, also, in looking into small pupils. The mirror, oblong in shape, 18 by 33 mm., is secured at the center of its ends, by two elevated screws, to a hollow disc 4½ cm. in diameter, in which is a revolving milled wheel, containing small spheres, each about 6 mm. in diameter. The series of spheres ranges from —1 D. to —8 D., and from +1 D. to +7 D. The central aperture does not contain a lens, but is left open.

When it is desirable to use any lens stronger than —8 D. or +7 D., there is an additional quadrant, which can be superimposed and turned into place at the sight-hole; it contains four lenses, —0.50 D. and —16 D., also +0.50 D. and +16 D. With this quadrant and the spheres in the milled wheel, any spheric combination can be made from zero to —24 D. or to +23 D. An index below the sight-hole of the instrument records the strength of lens

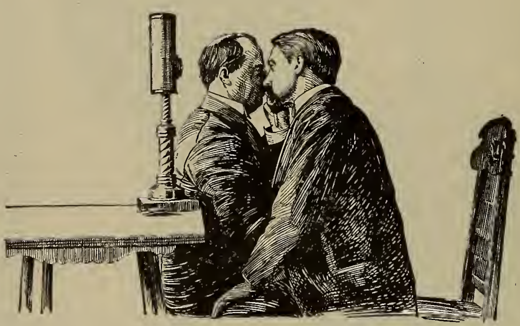


FIG. 85.

that may be in use; minus lenses are usually marked in red and plus lenses in white.

How to Use the Ophthalmoscope.—There are two ways or methods by which the ophthalmoscope may be used—the direct and the indirect.

The Direct Method (see Fig. 85).—Proficiency with the ophthalmoscope does not come except from long and constant practice, and several important matters should receive very careful attention before the student attempts to study the interior of an eye.

The Room.—This should be darkened by drawing the shades or closing the blinds; the darker the room, the better.

The Light.—This should be steady, clear, and bright; a good lamp is suitable, but an Argand burner gives more intense light, and is to be preferred, especially if it is placed on an extension bracket that can be raised or lowered and is capable of lateral movement.

Position of Light and Patient.—The light should be several inches to one side and back of the patient, and on a level with the patient's ear, so as to illuminate the outer half of the eyelashes of the eye to be examined; it may even be well to have the tip of the patient's nose illuminated.

The patient should be seated in a comfortable chair (without arms), and is instructed to look straight ahead into vacancy, or at a fixed object if necessary, and is only to change the direction of his vision when told to do so. Under no circumstances should the patient be allowed to look at a light, as this will contract the pupil.

For the beginner, it may be well to dilate the patient's pupil with a solution of cocain or homatropin. The student, however, should learn as soon as possible to see into an eye without the aid of a mydriatic, as many patients seriously object to the slight inconvenience that results from the drugs mentioned.

The Observer.—If the observer has any decided refractive error, he should wear his correcting glasses; the reason for this will be explained later. The observer should be seated at the side of the patient corresponding to the eye he is to examine. Examining the right eye, the observer should be on the patient's right; if the left eye, then on the patient's left.

When examining the right eye, the ophthalmoscope is held in the right hand, before the right eye; and in the left hand, and before the left eye, when examining the left eye. The surgeon's eye should be a little higher than the patient's. Patient and observer should keep both eyes open. The one exception to this is when the patient has a squint, when it will be necessary for him to cover the eye not being examined, and in this way the eye under observation will look straight ahead.

The surgeon holds the ophthalmoscope perpendicularly, so that the sight-hole in the mirror is directly opposite to his pupil and close to his eye. The side of the instrument rests on the side of his nose or the upper margin is in the hollow of the brow. The mirror is tilted toward the light. The surgeon's elbow should be at his side, and not form an angle with his body.

With these several details carefully executed, the surgeon begins his examination at a distance of about 25 or 30 cm., never closer; and at this distance he reflects the light from the mirror into the eye, and observes a "red glare," which occupies the previously black pupil. This is called the "reflex," and is due to the reflection from the choroidal coat of the eye. The *color* of the reflex varies with the size of the pupil, transparency of the media, the refraction, and the amount of pigment in the eye-ground.

Having obtained the "reflex," it will be well for the beginner to practise keeping the reflected light upon the pupil by changing his distance, approaching the eye as close as an inch or two; this must be done slowly, and *not* with a rush.

What the Observer Sees.—Having learned to keep the light on the pupil, the next thing is to study the transparency of the media—*i. e.*, to find out if there is any interference with the free entrance and exit of the reflected rays, such as would be caused by opacities in the cornea, lens, lens capsule, or vitreous ; and, if present, to note their character and exact location, whether on the visual axis or to one side, etc. The next objective points will be mentioned individually, and with the idea of systematizing the study.

The Optic Nerve.—Also called the disc or nerve head or papilla.

Color of the Optic Disc.—This has been described as resembling in color the marrow of a healthy bone, or the pink of a shell, etc. ; yet this is not by any means a true statement or description, as the apparent color of the nerve is controlled in great part by the surrounding eye-ground—whether this is heavily pigmented or but slightly so, or whether there is an absence of pigment, as in the albino. The student should be ready to make allowances for these contrasts.

The shape of the disc varies : it may appear round, oval, or even irregular in outline. Usually it is a vertical oval.

The vessels on the disc which carry the blood to and from the retina are not of the same caliber, nor do they have the same curves and branches in all eyes or in the same pair of eyes. The central artery may be single or double (if it has branched in the nerve before entering the eye), and enters the eye at the nasal side of the center of the disc.

Approximating the central artery on its temporal side is the retinal vein, which may also be double. The relative normal proportion in size between arteries and veins is generally recognized as about two to three. The veins are usually recognized by their larger size and darker color. At or near the center of the disc is often seen a depression, known as the physiologic cup ; this may be shallow or deep ; it may have shelving or abrupt edges ; it may even be funnel-shaped.

At the bottom of the cupping is frequently seen a gray stippling, the membrana cribrosa ; openings in the sclera for the passage of the transparent optic nerve-fibers which go to form the retina. Surrounding the disc proper is often seen a narrow white ring ; this is sclera, and is known as the scleral ring. Just outside of this ring is frequently seen a ring of pigment ; this is called the choroidal ring. In many cases the choroidal ring is not complete, the pigment being quite irregular, or possibly there may be just one large mass of pigment to one side of the disc ; this is not pathologic.

The retinal arteries and veins, while possessing many anomalies, and while occasionally an artery and vein are seen to twine around each other, usually pursue a uniform course up and down from the disc, and are named accordingly—*i. e.*, upper nasal vein and artery ; upper temporal vein and artery ; lower nasal artery and vein ; lower temporal artery and vein.

The retina itself, in health being transparent, is not seen. The fovea centralis, occupying the center of the macular region, is about two discs' diameter to the temporal side of the disc and slightly below the horizontal meridian. The fovea is recognized because it is a depression, and its edges give a reflex ; it is very small, and appears as a bright spot one or two mm. in diameter. The "macular region" is the part of the eye-ground immediately surrounding the fovea ; it contains minute capillaries, but it is impossible, in healthy eyes, to recognize them with the ophthalmoscope.

The Choroid.—This is distinguished by the character of its circulation, the vessels being large, numerous, and flattened, and without the light streak which characterizes the retinal vessels. Pigment areas between the vessels are also diagnostic of this tunic. The choroidal circulation is best studied in the blond or albino, and may be seen in many eyes toward the periphery of the eye-ground.

In the foregoing description of the use of the ophthalmoscope, etc., it is presumed that the instrument has been used without any lens in position, and that the observer's eye and the eye under examination are healthy emmetropic eyes with the accommodation at rest. Figure 86 shows the position of the light, L, the ophthalmoscope, the examiner's and the examined eye under these conditions.

The divergent rays from the light (L) are reflected con-

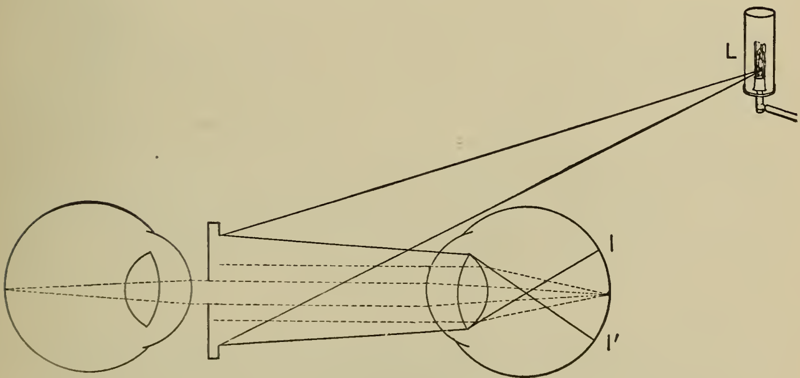


FIG. 86.

vergently from the concave mirror, and focusing in the vitreous, they cross and form an area of illumination on the retina at I I′. The retina, situated at the principal focus of the dioptric media, naturally projects out from its individual points rays of light which are parallel as they leave the eye; some of these pass through the sight-hole of the mirror and meet upon the retina of the observer's emmetropic eye.

There are two very important points which must be considered when using the ophthalmoscope in the direct method : one is the direction which the rays of light take as they leave the eye under examination, and the other is for the observer to keep his own eye emmetropic ; in other words, the observer wearing his correcting glasses should not accommodate.

Figure 87 shows that rays of light passing out of an eye divergently must be made parallel, so as to focus upon the surgeon's own retina (emmetropic), and to do this it is

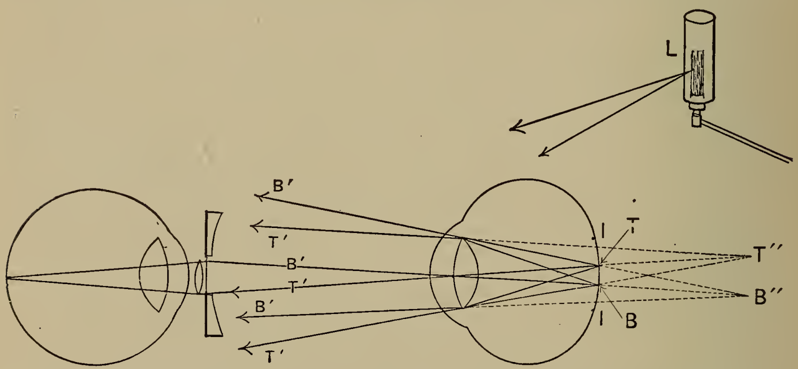


FIG. 87.—T B indicate points at the edge of the disc from which rays pass out of the eye divergently in the direction T′ B′, T′ B′, T′ B′, and being received by the observer's eye, are projected backward, forming an erect magnified image at T″ B″. This image is not so large as that seen when looking into a myopic eye. (Fig. 88.)

necessary to turn a plus lens in front of the sight-hole of the ophthalmoscope ; the strength of the convex lens thus employed, other things being normal, is the amount of the refractive error of the eye being examined.

Figure 88 shows rays of light passing out of an eye convergently, and to have them parallel, so as to focus upon his own retina (emmetropic), it is necessary to turn a concave lens in front of the sight-hole of the ophthalmoscope; the strength of the concave lens thus employed, other things being normal, is the amount of the refractive error of the eye under examination.

The Observer's Accommodation.—It has already been stated that, when using the ophthalmoscope, the observer should wear any necessary correcting lenses. If the observer has a refractive error and does not wear his glasses, he must deduct this amount from the lens used in the ophthalmoscope. If he has two diopters of hyperopia

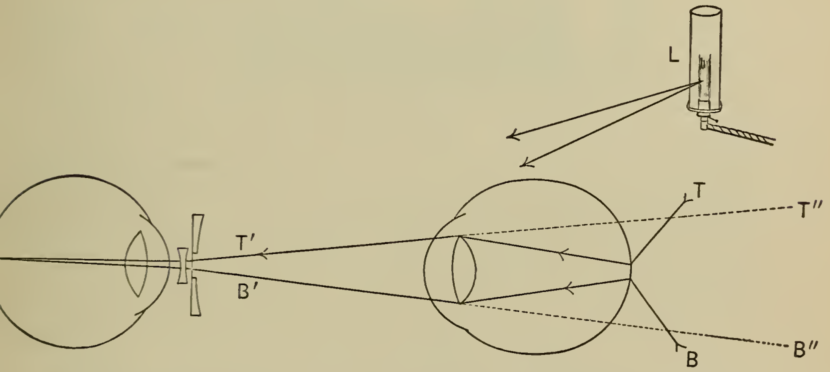


FIG. 88.—T B indicate points at the edge of the disc from which rays pass out of the eye convergently in the direction T′ B′, and, being received by the observer's eye, are projected backward, forming an erect magnified image at T″ B″. This image is much larger than that seen when looking into the hyperopic eye. (Fig. 87.)

himself, and the lens used in the ophthalmoscope is plus four diopters, then the eye under examination has only two diopters. It is not unusual for beginners to see the eye-ground (disc) in hyperopic eyes with a strong concave lens; this is due to the fact that they accommodate. Practice will overcome this habit, and it should be mastered as soon as possible. There are several ways of doing this: one is to begin the examination at a distance of 30 or 40 cm. from the eye, with both eyes open, and to gradually approach the eye as close as 3 cm., imagining all the time that one is looking for some *remote* point; otherwise, if one begins the examination close to the eye, and imagines he is going to see an object about an inch away, he will most invariably accommodate several diopters, with the result that he turns a strong concave lens in front of the sight-hole of the ophthalmoscope to neutralize his accommodation.

This explains how so many beginners diagnose all cases of hyperopia as myopia. An excellent way to learn to relax the accommodation is to practise reading fine print at a distance of about thirteen inches through a pair of plus three lenses, placed before the surgeon's emmetropic eyes. Another good way to learn to relax the accommodation is to practise on one of the many schematic eyes found in the shops. (Fig. 143.)

Size of the Image of the Eye-ground (Figs. 87 and 88).—In concluding the subject of the direct method of examination it may be interesting to note the apparent size of the image of the eye-ground, which, it must be remembered, is virtual, erect, and enlarged; in fact, it seems to be at some distance behind the eye, and if the student has paid close attention to the study of images as formed by convex lenses, detailed in chapter 1, he need not have any difficulty in appreciating these facts.

The optic disc of an emmetropic eye, as seen through the ophthalmoscope, appears to be about 25 mm. in diameter, and about 250 mm. away. The retina of the emmetropic eye is about 15 mm. from its nodal point; then the actual size of the emmetropic disc is $\frac{15}{250}$ of 25, or $\frac{3}{2}$, or 1.5 mm.; then 15 is to 250 as 1.5 is to 25, or 16.6—the magnification, in other words, when the emmetropic disc is observed, it appears about 16.6 times larger than it actually is.

The Indirect Method (see Fig. 89).—Practising this method, the observer sees a larger part of the eye-ground

FIG. 89.

at one time, but it is not so perfect in detail nor is it magnified to the same extent as in the direct method. The observer does not have to get so close to his patient, which is a decided advantage in some clinical cases. Unfortunately, as a preliminary step, it is often necessary to dilate the pupil. In addition to the ophthalmoscope, there is also required a convex lens of known strength and large aperture; the one which comes in the case with the

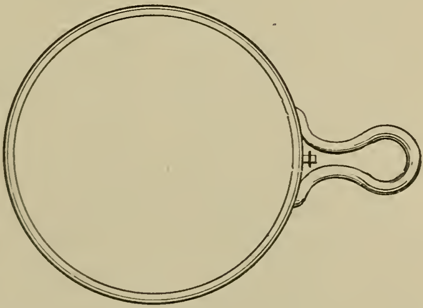


FIG. 90.

scope is usually too small and too strong for general use. The writer prefers his plus 13 D. with metal rim and convenient handle, shown in figure 90 (reduced one-third in size).

This is held at about three inches in front of the eye under examination, the observer resting his little and ring fingers on the temple of the patient. The light may be over the patient's head, or to the side corresponding to the eye under examination, the patient being instructed to look with both eyes open toward the surgeon's right ear when the right eye is being examined, and toward the surgeon's left ear when the left eye is examined.

With a +4 D. in the ophthalmoscope held close to his eye, the surgeon seats himself in front of the patient at about sixteen inches distant, and reflects the light through the condensing lens into the patient's eye, and then approaches or moves away from the eye until he recognizes clearly a retinal vessel or the disc; he must remember, however, that he is not looking into the eye, but is viewing an aerial image formed between the convex lens and the ophthalmoscope; this image is not only inverted, but undergoes lateral inversion, so that the right side of the disc becomes the left side of the image, and vice versa; the upper side of the disc becomes the lower side of the image, and vice versa. *As the direct method gives an erect, virtual, and enlarged image, the indirect method produces an inverted, real, and small image. The principle of the direct method is similar to a simple microscope, and the indirect to a compound microscope.*

The size of the image depends upon the refraction of the eye and the distance of the convex lens from the eye under examination. In the standard eye this is always the same, no matter how far away from the eye the convex lens is held. To estimate the size of the image in the standard eye, all that is necessary to know is the principal focal distance of the lens employed; if a +13 D., then the image is formed at 75 mm. (three inches), and remembering that the retina in the eye is 15 mm. back of the nodal point, the size of the image will be to the size of the disc (if that is

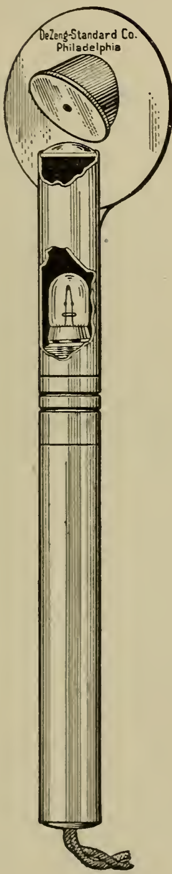


FIG. 91.

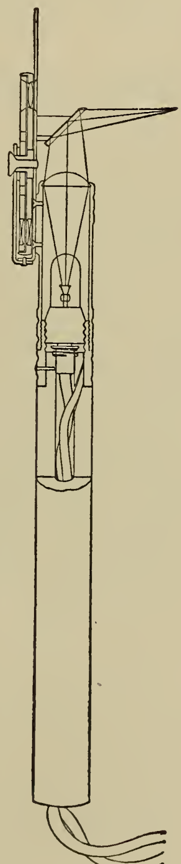


FIG. 92.

FIGS. 91 and 92.—DeZeng Luminous Ophthalmoscope. Two-thirds size.

what is looked at) as their respective distances, or as 15 is to 75, which equals 5, the magnification.

The purpose of the +4 D. in the scope is to take the place of the eye-piece in the microscope, and, therefore, to magnify the image at the same time it relieves the observer's accommodation. In high myopia the +4 D. may be dispensed with.

The Luminous Ophthalmoscope (Figs. 91 and 92).—*DeZeng Patent* (Model 1908).—This instrument is a combination of the Loring ophthalmoscope just described, with the addition of an electric light attachment. The mirror is somewhat different from the mirror on the Loring instrument. It is plane, circular in form, and 14 millimeters in diameter. The mirror is placed at an angle of 43 degrees. The handle of the instrument carries the electric wires to a small lamp, and between the lamp and the mirror is placed a very strong convex lens. The rays of light from the filament falling upon the convex lens are refracted very convergently, and after reflection from the mirror converge to a point one inch distant. (See Fig. 92.)

This instrument is ideal for both the direct and indirect method and has the following points of merit: The mirror and light are stationary, thus giving the observer any liberty of movement necessary without any loss of reflection from the mirror; the mirror never requires any tilting; the brilliancy or intensity of the illumination at the fundus, by virtue of the light being so close to the mirror, far exceeds that of the nonluminous instrument; for the same reason the size of the retinal illumination is made about five times larger than that by the old style instrument. The heat from the electric lamp ($2\frac{1}{2}$ volts, $\frac{3}{4}$ ampere) is infinitesimal.

CHAPTER IV.

EMMETROPIA.—HYPEROPIA.—MYOPIA.

Emmetropia.

Emmetropia (ἐν, "in"; μέτρον, "measure"; ὤψ, "eye") literally means an eye in measure, or an eye which has reached that stage of development where parallel rays of light will be focused on its retina without any effort of accommodation. As the emmetropic eye is the ophthalmologist's ideal unit of measurement or goal in refraction, the beginner should know this form of eye thoroughly, so that he may recognize any departure from this standard condition. The emmetropic eye may be described in various ways, and while these descriptions may appear like repetitions, they are given for purposes of illustration:

The standard or schematic eye: Authorities differ somewhat in the exact measurements of a schematic eye, but the one suggested by Helmholtz is certainly worthy of careful consideration. (See p. 59.)

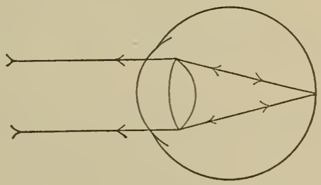
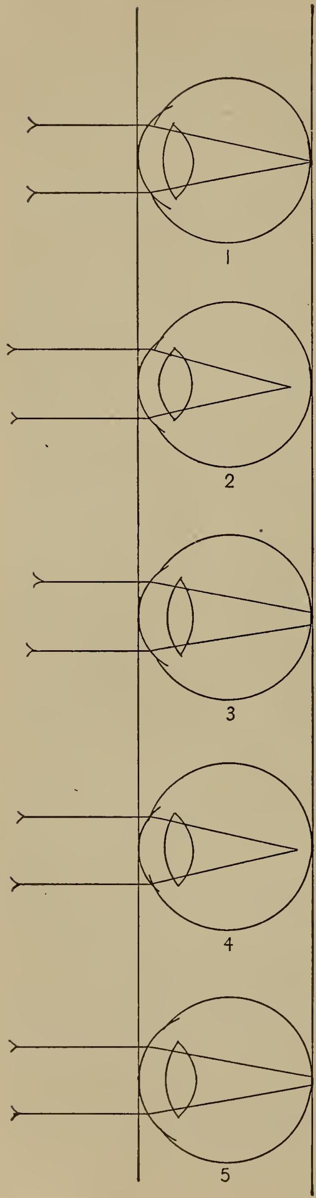


Fig. 93.

An emmetropic eye is one which, in a state of rest (without any effort of accommodation whatever), receives parallel rays of light exactly at a focus upon its fovea. (See Fig. 93.)

An emmetropic eye, therefore, is one which, in state of rest, emits parallel rays of light. (See Fig. 93.)



An emmetropic eye is one whose fovea is situated exactly at the principal focus of its refractive system. (See Fig. 93.)

An emmetropic eye is one the vision of which, in a state of rest, is adapted for infinity.

An emmetropic eye is one which has its near point consistent with its age. (See p. 70.)

An emmetropic eye is one which does not develop presbyopic symptoms until forty-five or fifty years of age. (See p. 272.)

An emmetropic eye, in contradistinction to a myopic eye (see p. 115), is spoken of as a healthy eye, or one which shows the least amount of irritation in its choroid and retina.

Because we refer to Helmholtz's schematic eye as an emmetropic eye, it will not do to say that all eyes that measure just 23 mm. in their antero-posterior diameter are emmetropic (Fig. 94); for while an

FIG. 94.—1. Emmetropia. 2. Myopia due to a strong lens. 3. Hyperopia due to a weak lens. 4. Myopia due to a short radius of curvature of cornea. 5. Hyperopia due to a long radius of curvature of cornea. The anteroposterior diameter of all these eyes is just 23 mm.

eye may be just 23 mm. in length, it may have its refractive system stronger or weaker than is consistent with its length, making it, if stronger, a myopic or long eye, and, if weaker, a short or hyperopic eye. An eye, to be emmetropic, therefore, no matter what its length, *must* have its refractive apparatus of just such strength that, in a state of rest, the principal focus will coincide exactly with the cones at the fovea. (Fig. 93.)

Ametropia.

Ametropia (ἀ priv.; μέτρον, "a measure"; ὄψις, "sight") literally means "an eye out of measure." An ametropic eye is one which, in a state of rest, does not form a distinct image of distant objects upon its retina. An ametropic eye may be defined as one which, in a state of rest, does not focus parallel rays of light upon its fovea. An eye which is not emmetropic is ametropic. There are two forms of ametropia—axial and curvature ametropia.

Axial ametropia is the condition in which the dioptric apparatus refracts equally in all meridians, but the retina of the eye, when at rest, is either closer to, or further away from, the nodal point than the principal focus. (See Figs. 95 and 97.) The refraction is measured on the length of the anteroposterior axis of the eye; hence its name, axial ametropia.

Curvature ametropia, in contradistinction to axial ametropia, is the condition in which the dioptric apparatus does not refract equally in all meridians, and with the result that there is no focusing of all the rays at any one point; or curvature ametropia may be considered as that condition in which parallel rays of light entering an eye have two focal planes for two principal meridians at right angles to each other. Curvature ametropia is commonly spoken of as astigmatism. (See Chap. v.)

Varieties of Axial Ametropia.—Axial ametropia is of two forms: one in which the eye has its fovea closer to the dioptric apparatus than its principal focus (see Fig. 95), known as the hyperopic, short, or flat eye; and the other form of the eye in which the fovea is further away than its principal focus, known as the myopic or long eye. (See Fig. 97.)

Hyperopia or Hypermetropia.

Hyperopia (ὑπέρ, "over"; ὤψ, "eye") literally means an eye which does not equal the standard condition, or an eye which is less than the standard measurement. Hyperopia is often abbreviated H. About twenty per cent. of all eyes have simple hyperopia. The hyperopic eye is spoken of as far-sighted, and the condition as one of far-sightedness. The hyperopic eye may be described in many different ways:

1. The "natural eye," or "the eye of nature."
2. The "short eye." This term is used on account of its fovea lying closer to the dioptric apparatus than the principal focus.
3. Parallel rays of light passing into a hyperopic eye in a state of rest fall upon its retina or fovea before they focus. (See Fig. 71.)
4. Rays of light from the fovea of a hyperopic eye in a state of rest pass out divergently (see Fig. 95), and the condition is equivalent to a convex lens refracting rays of light which proceed from a point closer to the lens than its principal focus. (See Fig. 39.)
5. A hyperopic eye is one which, in a state of rest, can receive only convergent rays of light at a focus upon its fovea (Fig. 95); therefore, to repeat: the hyperopic eye, in a state of rest, emits divergent rays and receives convergent rays at a focus upon its fovea.

6. As convergent rays are not found in nature, and are, therefore, artificial, a hyperopic eye is one which, in a state of rest, requires a convex lens to focus parallel rays of light on its fovea. (See Fig. 96.)

7. A hyperopic eye is one which must accommodate for infinity, and, in fact, for all distances ; in other words, a hyperopic eye in use is in a *constant* state of accommodation.

8. A hyperopic eye having to use some of its accommodative power for infinity, must, in consequence, have its near point removed beyond that of an emmetropic eye of corresponding age. (See p. 72.)

9. From the description contained in 3, it follows that

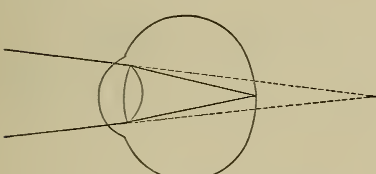


FIG. 95.

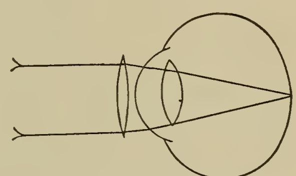


FIG. 96.

the far point of a hyperopic eye in a state of rest is negative (—), and is found by projecting the divergent rays backward to a point behind the retina. (See Fig. 95.)

10. From the description contained in 6, and the description of accommodation on page 67, it is natural to find the retina and choroid of many hyperopic eyes in a state of irritation.

11. From the description contained in 6 and 7, and on page 273, it follows that symptoms of presbyopia manifest themselves earlier in hyperopic than in any other form of eyes.

12. From the description contained in 5,—and this may

appear like repetition), it follows that a hyperopic eye will accept a plus glass for distant vision. (See Fig. 96.)

13. From 6 it is evident that the circular fibers of the ciliary muscle must become highly developed; much more so than the longitudinal fibers. Microscopically, a section of the ciliary muscle on this account will bear evidence of the character of the eye from which it came.

Causes of Hyperopia.—It is a well-known fact that the eyes of the new-born are, with comparatively few exceptions, hyperopic; such eyes are supposed to grow in their anteroposterior diameter, and at adolescence to reach that stage of development called emmetropia. It is also a well-known fact that this ideal condition of emmetropia is very rarely attained, the length of the eyeball not increasing in proportion to the strength of its refractive system.

Eyes may approximate the emmetropic condition, but very seldom remain so, passing into the condition in which the fovea lies beyond the principal focus, becoming what is known as long, or myopic.

A standard eye may be made hyperopic by removing its lens; the condition following cataract extraction. (See Fig. 174.)

An eye may possibly become hyperopic in old age, from flattening of the lens due to sclerosis of its fibers.

Any disease which will cause a flattening of the cornea in a standard eye will produce hyperopia.

A diminution in the index of refraction of the media of the standard eye will produce hyperopia.

Subdivisions of Hyperopia.—For purposes of study hyperopia has been divided into six classes or forms:

1. **Facultative hyperopia** (abbreviated Hf.) is a condition of the eye in which the patient can overcome the error by using his accommodation. It is a condition of early

life, and is voluntary. The patient can see clearly, with or without a convex glass.

2. **Absolute hyperopia** (abbreviated Ha.).—This is hyperopia that can not be overcome by the accommodative effort. It is generally a condition of old age, and is involuntary; facultative hyperopia in youth becomes absolute in old age. Old age, in fact, may develop each variety except latent hyperopia. Absolute hyperopia exists whenever the defect is of so high a degree that it can not be overcome by the accommodation or when the accommodative power itself is gone.

3. **Relative hyperopia** (abbreviated Hr.) is where accommodation is assisted in its efforts by the internal recti muscles; in other words, the eyes squint inward.

4. **Manifest hyperopia** (abbreviated Hm.) is represented by the strongest convex lens through which an eye can maintain distinct distant vision. Manifest hyperopia, therefore, includes facultative and absolute.

5. **Latent hyperopia** (abbreviated Hl.) is the amount of hyperopia which an eye retains when a plus lens is placed in front of it. Or latent hyperopia is the difference between the manifest hyperopia and that lens which an eye would select if its accommodation was put at rest with a cycloplegic (atropin). For example, an eye accepts a +1.25 S. as its manifest H., and, when atropin is instilled, would accept +2.75 S. for the same distant vision; then the difference between the manifest +1.25 S. and +2.75 S. (the total) is +1.50 S., which is the latent hyperopia.

6. **Total hyperopia** (abbreviated Ht.) is the full amount of the hyperopia; or is represented by the strongest glass which an eye will accept, and have clear, distinct vision when in a state of rest.

Symptoms and Signs of Hyperopia.—These are many and various; the principal one, however, and the one that generally causes the patient to seek relief, is *headache*. Headache caused by the eyes is usually frontal, and is denominated "brow ache"; it may be frontotemporal; the pain or discomfort starting in or back of the eyes may extend to the occiput or all over the head, and be accompanied with all kinds of nervous manifestations. The most characteristic distinguishing feature of ocular headache is that it comes on while using the eyes, and gradually grows worse as the use of the eyes is persisted in; and, likewise, the headache gradually ceases after a few minutes' or hours' rest of the eyes. Vertex headache, or a feeling of weight on the top of the head, has been preempted by the gynecologist, and is not usually classed as ocular. The ciliary muscle being the prime factor in causing the headaches, the writer feels justified in calling it the "headache muscle." "Sick headaches" are largely due to eye-strain. Various functional disorders, such as dyspepsia, constipation, biliousness, lithemia, chorea, convulsions, epileptoid diseases, hysteria, melancholia, etc., are, according to some few authorities, attributable to this condition. See Asthenopia, page 219.

Blepharitis marginalis, styes, and conjunctivitis are frequently present, and in truth the hyperopic eye on this account can often be diagnosed in public outside of the surgeon's office. A feeling as of sand in the eyes, ocular pains or postocular discomfort, a dryness of the lids, as if they would stick to the eyeballs, are common complaints, and part of the conjunctivitis. Other patients have their eyes filling with tears (epiphora) as soon as they begin reading, etc. A drowsiness or desire to sleep often comes on after or during forced accommodation.

Congestion of the choroid and retina, as evidenced by the ophthalmoscope, often go together with the blepharitis and conjunctivitis.

The patient complains that the print blurs or becomes dim after reading, and this is especially apt to occur by artificial light. When the "blur" comes on, he has to stop and rub his eyes or bathe them; and then, with additional light, he is able to continue the reading for a short time longer, when the blur again returns and the effort must be given up. Strong light stimulates the accommodation. The "hyperopic blur" is nothing more or less than a relaxation of the accommodation.

In children hyperopia sometimes simulates myopia, from the fact that the child in reading holds the print very close to the eyes. He does this in order to get a larger retinal image and to relieve his accommodation; the retinal image is not clear, and the child has to read slowly; the retinal image is composed mostly of diffusion circles. The child holds the print close to his eyes to avoid using his total accommodation, which he might have to do if he held the print at a respectable distance.

He also calls into play the orbicularis palpebrarum, and narrows the palpebral fissure, looking through a stenopeic slit, as it were. These cases of simulated myopia can be quickly diagnosed by:

1. The narrow palpebral fissure during the act of reading, and reading very slowly, as each letter has to be studied.

2. The fact that very few children have myopia.

3. The comparatively good distant vision, as a rule, which myopes never have, unless the myopia is of very small amount.

4. The ophthalmoscope.

The beginner in ophthalmology should be on his guard for these "pseudo-myopias," and not be guilty of putting concave lenses on hyperopic eyes.

Diagnosis of Hyperopia.—This form of ametropia may be recognized in many ways:

1. Blepharitis marginalis, if present, is generally due to hyperopia.

2. Hyperopic eyes are said to be small, and to have small pupils, which facts are *generally* confirmed; but myopic eyes *sometimes* appear small, and have small pupils also.

3. A narrow face and short interpupillary distance are quite indicative of hyperopia, but these indexes are not infallible.

4. A child with one eye turned inward toward the nose (convergent squint) has hyperopic eyes, as a rule; the hyperopia generally not being of the same amount in the two eyes, the squinting eye *usually* being the more hyperopic.

5. It has been authoritatively stated that light-colored irises are seen in hyperopic eyes and dark irises are to be found in myopic eyes, and yet this is not always correct. German students, with their blue irises, will average from 50 per cent. to 60 per cent. of myopia.

6. Hyperopic eyes, with few exceptions, have excellent distant vision: often $\frac{VI}{VI}$, or even better. The student should be on his guard for this, and not imagine, because a patient has $\frac{VI}{VI}$ vision, that he is emmetropic; on the contrary, hyperopic eyes accommodate for distance, and obtain this acute vision by effort.

7. The patient gives a history of accommodative asthenopia, with or without headaches coming on during or after the use of the eyes.

8. The distant vision of a hyperopic eye may remain

unchanged or may be improved with the addition of a convex lens, which latter would be impossible in emmetropia and myopia.

9. The near point of a hyperopic eye without glasses lies beyond that of an emmetropic eye for a corresponding age.

10. A hyperopic eye can see fine print clearly through a convex lens at a greater distance than its principal focus, which would not be the case in any other form of eye.

Other tests for determining hyperopia are with (11) the ophthalmoscope, (12) the retinoscope, (13) Scheiner's test, (14) Thomson's ametrometer, and (15) the cobalt-blue glass test, commonly spoken of as the chromo-aberration test. These tests are described in the text.

Myopia.

Myopia (*μύειν*, "to close"; *ὤψ*, "eye") means, literally, "to close the eye," and this origin of the name has arisen from the fact that many long eyes (myopic) squint the eyelids together when they endeavor to see beyond their far point. Brachymetropia is another name occasionally mentioned for the same kind of eye. Myopia is abbreviated M. About 1.5 per cent. of all eyes have simple myopia. The myopic eye is spoken of as near-sighted, and the condition as one of near-sightedness. The myopic eye may be described in many different ways:

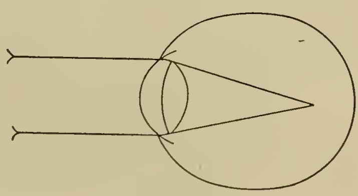


Fig. 97.

1. The long eye. The origin of this name is purely anatomic, the fovea lying beyond the principal focus of the refracting system. (See Fig. 97.)

2. Parallel rays of light entering a myopic eye focus in

the vitreous humor before they can reach the fovea. (See Fig. 97.)

3. Rays of light from the fovea of a myopic eye pass out of the eye convergently (see Figs. 72 and 98), focusing at

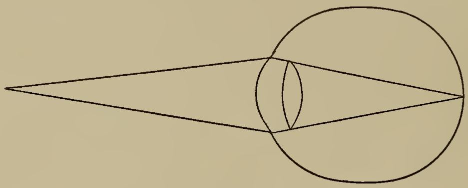


FIG. 98.

some point inside of infinity. The refractive condition of a myopic eye is similar or equivalent to a convex lens refracting rays of light which proceed from some point further away than its principal focus. (See Fig. 37.) The nearer the emergent rays of light focus to the eye (in a state of repose), the longer the eye; and the further away the emergent rays focus from the eye, the nearer the eye approaches to emmetropia, or normal length.

4. A myopic eye is one which receives rays of light which diverge from some point closer than six meters at a focus on its fovea and which emits convergent rays. (See Fig. 37, and also description of conjugate foci.)

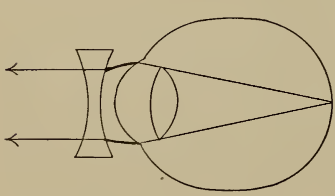


FIG. 99.

5. As parallel rays can not focus on the fovea of a myopic eye, it is necessary to give parallel rays entering the eye a certain amount of divergence, so as to place the focus at the fovea; and to accomplish this, a concave lens must be used. (See Fig. 99.) A myopic eye, therefore, is one

which requires a concave lens to improve distant vision. (See Fig. 99.)

6. A myopic eye is one whose distant vision is made worse by the addition of a convex lens.

7. A myopic eye is one which does not accommodate for distance.

8. A myopic eye having a refracting system stronger than is consistent with its length, or vice versâ, greater length than is consistent with its dioptric system, naturally does not use any accommodation except for points inside of its punctum remotum, and with the result that its amplitude of accommodation is used near by ; consequently, a myopic eye is one which has a near point closer than an emmetropic eye of corresponding age. (See p. 73.)

9. From the description contained in 3 it follows that the far point of a myopic eye is positive (+).

10. From the description contained in 3 and 7, it also follows that the myopic eye does not develop presbyopic symptoms until late in life.

11. From 6 and 9 it follows that the circular fibers of the ciliary muscle are not used to the same extent in a myopic eye as in the emmetropic and especially in the hyperopic eye. Microscopically, a section of a ciliary muscle on this account will bear evidence of the character of the eye from which it came, and have the longitudinal fibers more in evidence. In some very long myopic eyes there may not be any circular fibers recognized.

12. Eyes in which the myopia is progressive are spoken of as "sick eyes."

Causes of Myopia.—Any disease or injury which will so alter the refracting system of an eye that parallel rays must focus in front of the fovea will produce the form of eye known as long or myopic. This may be brought about in different ways: A shortening in the radius of curvature of the cornea, such as comes with conic cornea and staphyloma of the cornea; an increase in the refractive power of the lens from swelling, as often precedes cataract, and is spoken of as "false" second sight; cyclitis and iridocyclitis, which diseases cause a relaxation of the lens ligament, allowing the lens to assume a greater convexity; or ciliary spasm may produce temporarily the same condition.

Technically, however, myopia is quite universally understood to mean a permanent elongation of the visual axis of the eye beyond the principal focus of its refracting system.

Heredity is certainly a predisposing factor to myopia, but this does not mean that the babe is necessarily born with long eyes. On the contrary, the eye is very likely hyperopic at birth, and what the child may inherit is weak eye tunics. Such eyes, when placed under strain or what to them is overuse, soon become elongated. This may also be brought about or assisted by poor hygienic surroundings, poor health, or develop after an attack of typhoid or one of the eruptive fevers.

Three causes for the elongation of eyes have been brought forward by able authorities and expounded as theories, any one of which, or all three, may appear conspicuously in individual cases.

1. **Anatomically,** the size of the orbit and the broad face give a long interpupillary distance and cause excessive convergence (turning inward of the eyes) when the eyes fix at the near point.

2. **Mechanically,** when the eyes are far apart and attempt to converge, the external recti muscles press upon the outer side of the globes, flattening the eyes laterally,

with the result that the point of least resistance for the compressed contents of the globes is at the posterior pole of the eye, and here it is that the pressure shows itself, by an elongation of the eye backward in its anteroposterior diameter. This combination of the anatomic and mechanic theories may explain in great part the presence of myopia in the average German student or any broad-faced individual.

3. **The inflammatory** theory is that a low grade of inflammation attacks the tunics of the eye, especially at the posterior pole, and is spoken of as macular choroiditis ; this is brought about by faulty use of the eyes, in the school or in the home, in a poor light or too glaring a light improperly placed, or by using the eyes with the head bent over the work so that the return circulation from the retina and choroid is interfered with. This inflammation or congestion of the tunics of the eye may be primary in itself or secondary to the anatomic and mechanic causes. Be this as it may, the conditions exist, and go to show more and more that myopia is actually acquired and not *per se* congenital. "The inherited congenital anomalies of refraction, particularly astigmatism, are responsible for the myopic eye, by virtue of the pathologic changes they occasion in hard-worked eyes rather than any inherited predisposition to disease." (Risley, "School Hygiene.")

Symptoms and Signs of Myopia.—While the myope may complain of headache and symptoms of accommodative asthenopia, yet the principal visual complaint will be the inability to see objects distinctly which lie beyond the far point. The myope's world of clear vision is limited to the distance of the far point, where the rays of light leaving his eye come to a focus. Every object situated beyond the far point is blurred and indistinct, and the further the object from the far point, the more indistinct it becomes. The myopic child at school soon ranks high in the class, is fond of study, of books, music, or needlework, according to the sex. The myope, in other words, is usually literary in taste. Myopes avoid out-of-door sports, such as foot-ball, base-ball, golf, etc.

Diagnosis of Myopia.—This form of ametropia may be recognized in various ways :

1. The prominent eyeball. This is not a positive sign of myopia, though this and other signs are mentioned for the reason that they are often present in the myopic condition.

2. The broad face and (3) long interpupillary distance are quite significant of myopia, and yet the broadest face with longest interpupillary distance the writer ever saw was in a hyperopic subject.

4. Divergent squint usually indicates myopia, and this condition is often brought about by an inability to converge, or one eye may be more myopic than its fellow, with the result that the more myopic eye turns out and soon becomes amblyopic.

5. It has been stated that myopic eyes usually have dark-colored irises, but this is often a fallacy, as is only too evident in the German student with his blue iris.

The foregoing are but signs of myopia, and are recognized by inspection ; they should be looked for and carefully estimated, and each given its due consideration. Subjective and objective symptoms are the true tests of myopia, and are as follows :

6. Poor distant vision ; inability to see numbers on the houses across the street or on the same side of the street ; history of passing friends without speaking to them. The myope enjoys close work and takes little or no interest in

sports. A history, in other words, that is in keeping with a vision of short range.

7. Good near vision; ability to see the finest print or to thread the finest needle or do the finest embroidery.

8. The near point is closer than that of an emmetropic eye of corresponding age. (See p. 73.)

9. Distant vision is made worse by the addition of a convex lens. The writer prefers to teach the diagnosis of myopia in this way, and not to say that a concave lens will improve distant vision; of course it will, but he does not want the student to put concave lenses before the eye of the young "pseudo-myope," referred to under Hyperopia.

10. The far point is brought nearer by the addition of a convex lens. Objective methods of determining myopia are by means of the—

11. Ophthalmoscope.
12. Retinoscope.
13. Scheiner's method.
14. Thomson's ametrometer.
15. Chromo-aberration test.

Direct Ophthalmoscopy in Axial Ametropia.—Proficiency in this method comes only by perseverance and long practice. It should not be employed to the exclusion of other and more exact methods. To estimate with the ophthalmoscope which lens is required to give an eye emmetropic vision, three very important facts should receive careful attention:

1. The distance between the surgeon's and patient's eye.
2. The surgeon's and patient's accommodation.
3. The surgeon's own refractive error.

First, the surgeon should have his eye as close to the patient's eye as possible, usually at 13 mm.; this is the anterior principal focus of the eye, and is the distance at which the patient will wear his glasses.

Second, as already explained, the observer's and patient's accommodation should be in repose. The most difficult part for the student to learn is to relax his accommodation. The ambitious student strains his accommodation (ciliary muscle) in his haste, and with the result that he thinks all eyes myopic and all eye-grounds as affected with "retinitis."

Third, the surgeon, if not emmetropic, must wear any necessary correcting lenses; otherwise, the lens in the ophthalmoscope will record his and the patient's error together, and deductions must be made accordingly. For instance, if the surgeon is hyperopic +2 S., and does not wear his glasses, and the ophthalmoscope records the fundus as seen clearly with +5 S., this would mean that the patient had +3 S. (2 of the 5 S. being the surgeon's error); or if the fundus is seen without any lens in the ophthalmoscope, then the patient's error would be —2 S. (the surgeon's +2 S. from 0 leaving —2 S.); or if the ophthalmoscope showed —2 S., then the patient's error would be —4 S.; or if the ophthalmoscope registered +2 S., then the patient would be emmetropic, and this +2 S. is the surgeon's error.

Rules.—1. When the surgeon and patient are both hyperopic or both myopic, the surgeon must subtract his correction from the lens which shows at the sight-hole in the ophthalmoscope.

2. When the surgeon's eye is hyperopic or myopic, and the eye of the patient is the opposite, he must add his correction to the lens at the sight-hole in the ophthalmoscope.

With the foregoing details clearly in mind and carefully executed, the surgeon selects small vessels near the macula for his observations. If it is impossible to see these on account of the small pupil, then he will have to observe the larger vessels at the disc (nerve-head, or papilla).

Whenever the vessels in the macular region are seen clearly with one and the same glass in the ophthalmoscope, the refractive error can be approximated as one of axial ametropia, and every three diopters, plus or minus, or any multiple of three diopters, represent very closely one millimeter of lengthening or shortening of the anteroposterior diameter of the eye. For example, any eye that takes a plus 3 S. to make it emmetropic is just 1 mm. too short; any eye that takes a minus 3 S. to make it emmetropic is about 1 mm. too long. It will be observed, however, under the head of curvature ametropia (astigmatism), that every 6 D. cylinder represents about 1 mm. in length, as measured on the radius of curvature of the cornea. The following table, from Nettleship, gives the exact equivalents in millimeters for axial ametropia :

H.	1 D.=0.3	mm.	M.	1 D.=0.3	mm.
	2 D.=0.5	"		2 D.=0.5	"
	3 D.=1	"		3 D.=0.9	"
	5 D.=1.5	"		5 D.=1.3	"
	6 D.=2	"		6 D.=1.75	"
	9 D.=3	"		9 D.=2.6	"
	12 D.=4	"		12 D.=3.5	"
				18 D.=5	"

Indirect Method.—See page 99 for a full description of this method. Slowly withdrawing the objective lens, and the disc remaining unchanged in size, signifies emmetropia ; if the disc grows uniformly smaller, it means H., and if it grows uniformly larger, it means M. (See Fig. 142.) This is merely a method of diagnosis, and is never used for definite measurements.

CHAPTER V.

ASTIGMATISM, OR CURVATURE AMETROPIA.—TESTS FOR ASTIGMATISM.

Astigmatism (from the Greek, *ἀ*, priv.; *στίγμα*, "a point").—Optically, astigmatism may be defined as the refractive condition in which rays of light from a point, passing through a lens or series of lenses, do not focus at a point.*

In ophthalmology astigmatism is recognized as that condition of the refractive system of an eye in which rays of light are not refracted equally in all meridians, and the resulting image of a point becomes an oval, a line, or a circle. (See Fig. 100.)

Or astigmatism is that condition of an eye in which there are two principal meridians, of greatest and least ametropia, each having a different focus.

In the standard eye the cornea is represented as a section of a sphere; anatomically, however, the cornea is generally found to be an ellipsoid of revolution, with its shortest radius of curvature (normally 7.8 mm.) in the vertical meridian.

In the study of astigmatism the meridians of minimum and maximum refraction alone are considered; they are spoken of as the principal meridians, and are at right angles to each other.

With very few exceptions most eyes have some degree of astigmatism. The standard or emmetropic eye is an

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*In an article published by Dr. Swan M. Burnett, in "The American Journal of Ophthalmology," for December, 1903, entitled "Astigmia or Astigmatism," he draws attention to the fact that astigmatism is an erroneous word, and gives the true origin of the word from *στιγμη-ης*, meaning a mathematic point, whereas "*στιγμα*" really means a "blemish" or "brand." He therefore urges the change from astigmatism to astigmia, with the word "astigmic" as the adjective.

extremely rare condition, and plain myopic eyes (long eyes) *without* any astigmatism are almost as rare as the emmetropic condition; and while plain hyperopic eyes are seen, yet statistics show that fully eighty per cent. of hyperopic eyes have astigmatism.

Astigmatism is located in the cornea or lens, or it may be a condition of both structures in one and the same eye. Astigmatism of the lens may increase, diminish, or neutralize the corneal astigmatism. Astigmatism, however, is more often a condition of the cornea than of the lens.

Figure 100 shows parallel rays of light passing through an astigmatic lens in which the vertical meridian has the

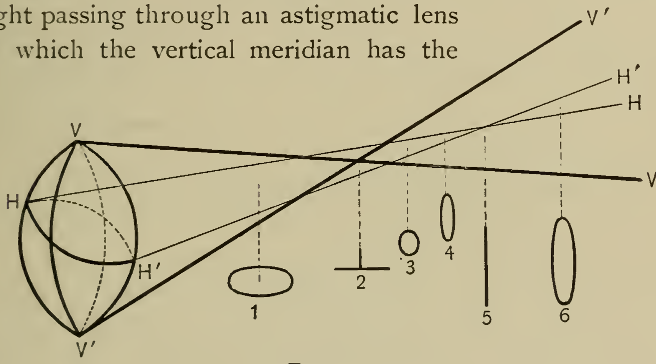

FIG. 100.

shortest radius of curvature, with the result that those rays which pass through the vertical meridian V V′ come to a focus before those in the horizontal meridian H H′, which has the longest radius.

Intercepting the refracted rays at 1, 2, 3, 4, 5, and 6, the image would be at 1 a horizontal oval, at 2 a horizontal line, at 3 a circle, at 4 a vertical oval, at 5 a vertical line, and at 6 a vertical oval. The space between the points of foci of the two meridians (2 and 5) is known as Sturm's interval. The importance of this space or interval is that it represents astigmatism. Sturm's interval is the quantity which *must* be found in correcting astigmatism.

Causes of Astigmatism.—Most cases of astigmatism are congenital, and some can be traced to heredity. Acquired astigmatism may result from conic cornea, cicatrices following ulcers or wounds of the cornea, or be a temporary condition from pressure of a chalazion or other growth ; and, in fact, astigmatism may develop from any disease or injury that will cause a lengthening or shortening or inequality in one or more of the meridians of the cornea or lens. Swelling of the different sectors of the lens will cause astigmatism. The visual line not passing through the center of the cornea is a cause of astigmatism, and astigmatism is the usual result following extraction of the lens. Tenotomy of one or more of the extraocular muscles will often change the corneal curvature.

Irregular Lenticular Astigmatism.—This is a normal condition of all clear lenses. It is often infinitesimal in amount, and on this account does not interfere with vision. It is caused by the different sectors of the lens or by the individual lens-fibers themselves not being uniform in their refracting power. In this form of astigmatism a light does not appear to have a distinct edge, but, on the contrary, the edge has radiations passing from it, giving the light a stellate appearance. There is no known glass that will correct this variety of astigmatism.

Physiologic Astigmatism.—This is due to lid pressure, or temporarily to extreme pulling or contraction of the extraocular muscles. It is a voluntary astigmatism, and therefore not constant. It is not a condition of all eyes. The writer has demonstrated with the retinoscope and ophthalmometer that the condition can be produced in eyes not otherwise astigmatic. Drawing the lids together in the act of squinting or frowning, the patient can press the cornea from above and below, and give the horizontal meridian of the cornea a longer radius of curvature and the vertical meridian a shorter radius; or with the eye looking into the telescope of the ophthalmometer, no overlapping of the mires is noted, but in some instances when told to open the eye widely and "stare" into the instrument, as much as ½ or ¾ of a diopter of astigmatism may be recorded.

This "transient" astigmatism should never be corrected with a glass.

Subdivisions of Astigmatism.—In addition to the astigmatisms just described, curvature ametropia has been further considered as:

1. Irregular.
2. Regular.
3. Symmetric.
4. Asymmetric.
5. Astigmatism with the rule.
6. Astigmatism against the rule.
7. Homonymous.
8. Heteronymous.
9. Homologous.
10. Heterologous.

1. **Irregular Astigmatism.**—This is usually located in the cornea, and is due primarily to some breach in the continuity of one or more of its meridians; for example, the vertical meridian may appear regular, but the horizontal meridian is not a uniform curve, but is irregular at some point or points. Such meridians can not produce clear retinal images, but, on the contrary, the resulting retinal image is hazy or irregular.

2. **Regular Astigmatism.**—In this variety the cornea and lens are regular in their curvatures, from the maximum to the minimum radius, and the retinal image can be made clear with correcting glasses.

Before entering upon the study of the various forms of regular astigmatism, the student's attention is called to two important facts: (*a*) That, *as a rule*, the shortest radius of curvature of the cornea is in the vertical meridian—that is to say, the vertical meridian has a stronger refracting power than the horizontal.

(*b*) The student should bear in mind that in the measurement of curvature ametropia each millimeter of lengthening or shortening of the radius of curvature is equivalent to a 6 D. cylinder. For instance, an eye which requires a +6 D. cylinder axis 90 degrees has the horizontal radius of curvature about one millimeter longer than the vertical radius; or an eye that requires a —6 D. cylinder axis 180 degrees has its vertical radius of curvature about one millimeter shorter than the horizontal. In *axial* ametropia, however, it was shown that every three diopter *sphere* represented about one millimeter in length, as measured on the axis.

Varieties of Regular Astigmatism.—There are five different forms of regular astigmatism:

(*a*) Simple hyperopic. (*c*) Compound hyperopic.
(*b*) Simple myopic. (*d*) Compound myopic.
(*e*) Mixed astigmatism.

(*a*) **Simple Hyperopic Astigmatism.**—Abbreviated As. H., or H. As., or Ah. About 5½ per cent. of eyes have this form of refraction. This is a condition where one meridian of the eye is emmetropic, and the meridian at right angles to it is hyperopic (see Fig. 101); the vertical meridian focuses parallel rays on the retina, and the horizontal meridian would focus back of it. The retinal image of a point is a line, usually horizontal. (See 2, in Fig. 100.) The correcting lens is a plus cylinder with its axis usually at 90 degrees,

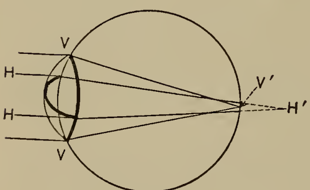

Fig. 101.

or within 45 degrees of 90 degrees. Example, +2.00 cylinder axis 90 degrees.

(*b*) **Simple Myopic Astigmatism.**—Abbreviated As. M., or M. As., or Am. This is not a common condition. About 1½ per cent. of all eyes have this form of astigmatism. This is a condition where one meridian of the eye is emmetropic, and the meridian at right angles to it is myopic (see Fig. 102); the horizontal meridian focuses parallel rays on the retina, and the vertical meridian focuses parallel rays in front of the retina (in the vitreous), with the result that they cross before reaching the retina. The retinal image of a point is a line, usually vertical. (See Fig. 100.) The correcting lens is a minus cylinder with its axis at 180 degrees, or within 45 degrees of 180 degrees. Example, —2.50 cylinder axis 180 degrees.

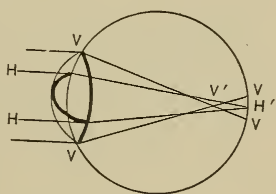

FIG. 102.

(*c*) **Compound Hyperopic Astigmatism.**—Abbreviated H. As. Co., or Comp. Has., or H+Ah (hyperopia combined with astigmatism hyperopic). This condition represents nearly forty-four per cent. of all eyes; it is the most common of all forms of refraction.

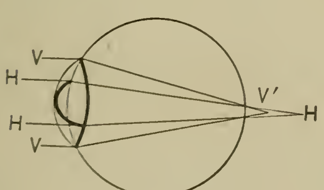

FIG. 103.

The retinal image of a point is an oval; never a line and never a circle. (See 1, in Fig. 100.)

The correcting lenses are a plus sphere and a plus cylinder. Example, +2.00 S. ⁐ +3.00 cylinder axis 90 degrees. Compound hyperopic astigmatism is a combination of axial ametropia (short eye) and simple hyperopic astigmatism (curvature ametropia). In this form of astigmatism both meridians have their foci back of the retina—one further back than the other. The retina intercepts the rays before they can focus. Figure 103 shows this condition. Usually the vertical meridian focuses nearer the retina than the horizontal.

(*d*) **Compound Myopic Astigmatism.**—Abbreviated M. As. Co., or Comp. Mas., or M.+Am. (myopia combined with astigmatism myopic). This is by far the most common condition of all myopic eyes, and represents about eight per cent. of all eyes.

The retinal image of a point is always an oval; never a line or a circle. (See 6, in Fig. 100.)

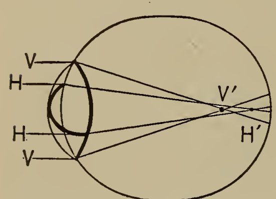

FIG. 104.

The correcting lenses are a minus sphere and a minus cylinder. Example, —1 sph. ⊃ —2 cylinder axis 180 degrees. A combination of axial ametropia (long eye) and simple myopic astigmatism.

Figure 104 shows that parallel rays have two points of foci in front of the retina—one further front than the other.

(*e*) **Mixed Astigmatism.**—This form of refraction is found in about 6½ per cent. of all eyes, and is abbreviated in three different ways:

1. Ah+Am. (astigmatism hyperopic with astigmatism myopic).
2. H+Am. (hyperopia with astigmatism myopic).
3. M+Ah. (myopia with astigmatism hyperopic).

The retinal image of a point is an oval or a circle; never a line. (See 3 and 4 in Fig. 100.)

The correcting lenses are one of three combinations, and spoken of as crossed cylinders. Examples :

1. +1.00 cyl. axis 90 degrees ⊃ —2.00 cyl. axis 180 degrees.
2. +1 S. ⊃ —3 cyl. axis 180 degrees (cylinder always stronger than the sphere).
3. —2 S. ⊃ +3 cyl. axis 90 degrees (cylinder always stronger than the sphere).

The condition of mixed astigmatism is one of simple hyperopic astigmatism, with simple myopic astigmatism : one meridian focuses parallel rays in front of the retina and the other meridian (at right angles) focuses parallel rays

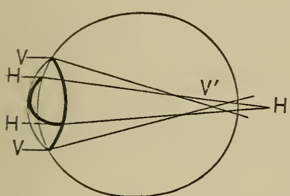

FIG. 105.

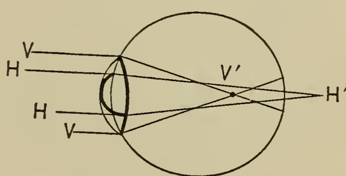

FIG. 106.

back of the retina. Figures 105 and 106 show this arrangement.

The remaining subdivisions of astigmatism are merely classifications of the different forms already described, and arise from a study of the axis of shortest radius of curvature.

3. **Symmetric Astigmatism.**—When the combined values, in degrees, of the meridians of shortest or longest radii of curvature in both eyes equal 180 degrees (no more and no less), then the astigmatism in the two eyes is spoken of as symmetric. For example, if the cylinder in the right eye is at axis 75 degrees, and in the left eye at 105 degrees ; 75 degrees and 105 degrees added together will

make 180 degrees. (See Fig. 107.) Or if each eye takes a cylinder axis at 90 degrees, they are also symmetric, 90 degrees and 90 degrees making 180 degrees. If both eyes have axes 180 degrees, they are symmetric also, one meridian being considered as zero (0).

4. **Asymmetric astigmatism** is the reverse of symmetric, and is, therefore, the condition in which the combined values, in degrees, of the cylinder axes do not make 180 degrees. For instance, if the right eye has a cylinder at axis 75 degrees and the left at 120 degrees, these

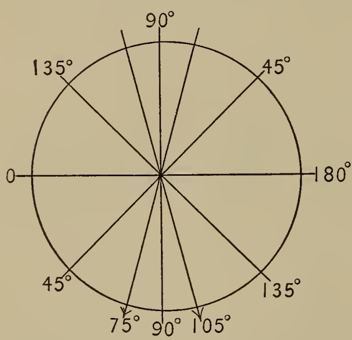

FIG. 107.—Illustrating Symmetric Astigmatism.

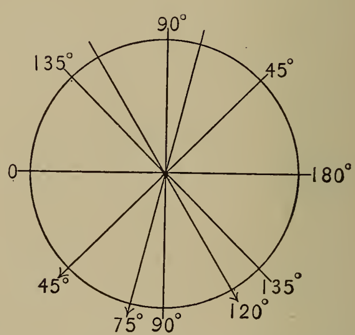

FIG. 108.—Illustrating Asymmetric Astigmatism.

added together would not make 180 degrees, but more than 180 degrees. (See Fig. 108.) Or, if the astigmatism in the right eye was at 35 degrees, and the left at 90 degrees, these added together would not make 180 degrees.

Symmetric astigmatism generally accompanies a regular physiognomy, the center of each pupil being at an equal distance from the median line of the face. Asymmetric astigmatism usually accompanies an asymmetric physiognomy, the center of one pupil being further from the median line of the face than the other.

Muscular insufficiency, hereafter to be described, is much more common, and, in fact, should be looked for or anticipated in cases of asymmetric astigmatism.

5 and 6. **Astigmatism with the Rule and Astigmatism Against the Rule.**—Astigmatism with the rule and astigmatism against the rule refer to the condition already described as that in which the vertical meridian of the eye, as a general rule, has the shortest radius of curvature.

Statistic tables on astigmatism show that most eyes accept a plus cylinder at axis 90 degrees, or within 45

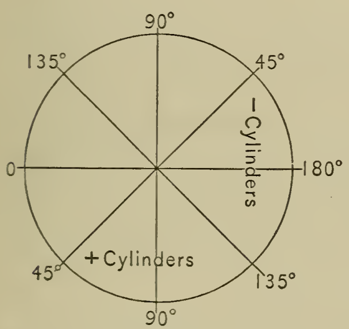

FIG. 109.—Illustrating Astigmatism with the Rule.

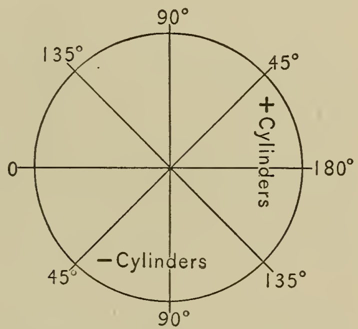

FIG. 110.—Illustrating Astigmatism against the Rule.

degrees (inclusive) either side of 90 degrees (see Fig. 109); or a minus cylinder at axis 180 degrees, or within 45 degrees (inclusive) either side of 180 degrees. For example, if an eye requires a plus cylinder at 45 degrees, or at any axis from 45 degrees up to 135 degrees (inclusive), taking axis 90 as the median line, then the astigmatism is *with the rule*. But if an eye should require a plus cylinder within 45 degrees either side of 180 degrees, then the condition is one of *astigmatism against the rule*. (See Fig. 110.) A plus or minus cylinder at 45 degrees or 135 degrees is recognized as *astigmatism with the rule.*

7. **Homonymous astigmatism** is the condition in which the cylinder axis in each eye is the same.

8. **Heteronymous astigmatism** is the condition in which the astigmatism in one eye is with the rule, and in the other eye against the rule. For example:

O. D. +2 cyl. axis 90 degrees, and O. S. +2.00 cyl. axis 180 degrees.

9. **Homologous astigmatism** is symmetric astigmatism with the rule—*i. e.:*

O. D. +1.00 cyl. axis 60 degrees, O. S. +1.00 cyl. axis 120 degrees.

10. **Heterologous astigmatism** is symmetric astigmatism against the rule—*i. e.:*

O. D. +1.00 cyl. axis 15 degrees, O. S. +1.00 cyl. axis 165 degrees.

Meridians of the Eye.—The various axes or meridians of the eye are indicated by degree markings on the periphery of the trial-frame, and by corresponding imaginary lines drawn around the eyeball from the anterior pole or apex of the cornea to the posterior pole.

Either eye (right or left) is *exactly like its fellow*, and is numbered by starting from zero (0) on the left-hand side of the horizontal meridian and counting downward to the right-hand side until this same line is again reached. This makes half a circle (hemicircle) of 180 degrees. (See Fig. 109.) As the degrees in this half-circle are all carried across the eye, they maintain their individual numbering, so that axes 5, 10, 15, etc., are the same whether above or below the horizontal meridian. Hence there is no reason for having a complete circle of 360 degrees. Some trial-frames have the upper, while others have the lower, half numbered; this makes no difference in the exact numbering; in one instance the count is made from left to right, and in the other the count is made from right to left. The foreign trial-frame, as represented on page 48, may be confusing if not studied.

Symptoms of Astigmatism.—More aggravated symptoms of accommodative asthenopia are apt to be detailed by the patient, but there are, in truth, no definite symptoms whereby the presence of astigmatism can be *positively* differentiated from axial ametropia. The diagnosis of astigmatism by the physiognomy is confirmed only because most eyes are astigmatic; the simple hyperopic eye squints the eyelids together just the same as the eye that is astigmatic, so that the writer would not diagnose astigmatism by the patient's individual history of his eyes.

How to Diagnose Astigmatism.—This is one of the very early questions of the beginner in ophthalmology. Astigmatism being the prominent factor in almost all refractive work, the writer feels justified in giving this part of refraction extensive explanation. Of the various methods of diagnosing astigmatism the writer would mention the following:

1. Corneal reflex.
2. Confusion letters.
3. Placido's disc.
4. Stenopeic slit.
5. Astigmatic chart.
6. The pointed line test.
7. Perforated chart or disc.
8. Pray's letters.
9. Scheiner's Test.
10. Chromo-aberration or cobalt-blue glass test.
11. Thomson's ametrometer.
12. The ophthalmometer.
13. Direct ophthalmoscopy
14. Indirect ophthalmoscopy.
15. Cylindric lenses.
16. Retinoscope.

1. The Corneal Reflex Test.—The cornea and underlying aqueous representing a spheric mirror, naturally furnish a small image of surrounding objects. If the cornea is astigmatic, the catoptric image must be correspondingly distorted. To make the examination, the patient stands facing a window, and the surgeon at one side observes the image of the window-panes in the corneal mirror; these will be broadened or lengthened, or they may appear inclined to one side, according to the axis and character of the astigmatism. This test is not commonly used, is often overlooked; in fact, unless the astigmatism is of considerable degree, is not a valuable test.

2. **Confusion Letters.**—Letters on the card which is used for testing distant vision are arranged in such order that those which have a resemblance are placed next to each other. (Fig. 74.) For example, X and K, Z and E, O and D, C and G, P and F, S and B, V and Y, H and N, A and R, etc. The patient, in deciphering these letters in the line corresponding to his best vision, often miscalls them, and can not tell an X from a K, or a Z from an E, etc. These letters are, therefore, spoken of as confusion letters. This is a very good general test, but is not infallible, as a patient with opacities in the media will make similar mistakes.

3. **Placido's Disc or Keratometer** (see Fig. 111).—To a wooden handle is secured a round piece of thin sheet-iron eight inches in diameter, and at its center is a small, round 5 mm. opening. On one side the disc is painted in alternate concentric circles or bands in black and white; these circles are not equidistant, the radii of the several circles being calculated according to the law of tangents, so that when reflected on a cornea of spheric curvature they appear equidistant in the image. On the reverse side is placed a slot to hold a convex lens for magnifying purposes. To use this disc, the patient is placed with his back to a strong light from a window, or an artificial light may be placed over his head. The surgeon holds the disc with the sight-hole close in front of his own eye, and with the light illuminating the disc, the patient is instructed to look into the perforation. The sur-

geon then approaches the eye until the corneal image of the outer edge of the instrument corresponds to the outer edge of the patient's cornea. When this distance is reached, a convex 2, 3, or 4 D. sphere may be placed in the slot of the disc so as to magnify the corneal image. If the cornea is not astigmatic, then the black and white circles will appear uniform throughout; but if there is astigmatism, the circles will appear more or less oval. If irregular astigmatism or conic cornea is present, the circles will appear broken or distorted in certain parts. This test has become almost obsolete.

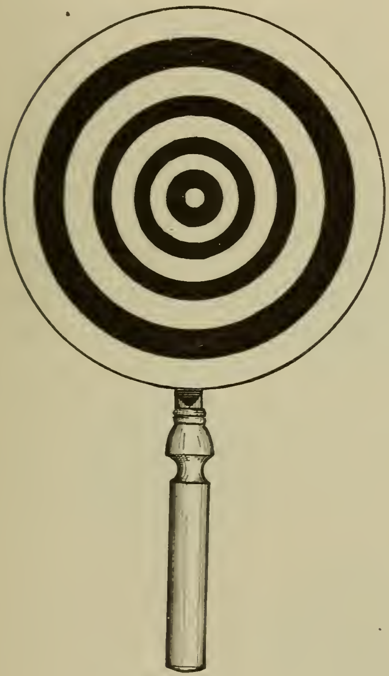

FIG. 111.

FIG. 112.

4. Stenopeic Slit (see Fig. 112).—This is a round metal disc of the size of the trial-lens, and contains a central slit or opening about 25 mm. long and 1 or 2 mm. wide. The stenopeic slits sold in the shops have various breadths of openings, from ½ to 2 mm.; that with the 1 mm. opening is the one recommended. The purpose of the slit is to cut off or exclude all rays of light at right angles to its position in front of the eye. When placed at axis 90, all rays in the horizontal meridian are excluded; when placed at axis 180, all rays in the vertical meridian are cut off, etc. To use the stenopeic slit, place it in the trial-frame in front of the eye to be examined, the fellow-eye being covered. The patient is instructed to read the letters on the distant test-card, and as he does so, the slit is slowly turned through the different meridians. If the vision remains the same, no matter through which meridian the patient reads, astigmatism may be absent; but if the patient selects one meridian in which he sees best, and another meridian at right angles in which he does not see so well, astigmatism is usually present. For instance, if the slit is at axis 75 degrees and the patient reads $\frac{VI}{IX}$, and at axis 165 he reads $\frac{VI}{XV}$, then he is astigmatic in the 165 meridian. The amount of the astigmatism can be calculated by placing spheric lenses back of the slit and finding the difference in strength of the spheres which bring the vision up to the normal. For example, when the slit is at axis 75 and the patient reads $\frac{VI}{IX}$, if a +1.50 S. is used, and the vision becomes $\frac{VI}{VI}$, then 1.50 corrects axis 75. Turning the slit to axis 165, and proceeding in the same way, if +2.50 S. brings the vision from $\frac{VI}{XV}$ to $\frac{VI}{VI}$, then +2.50 corrects axis 165, the difference between the +1.50 and +2.50 being 1 D., and the formula would be +1.50 sph. ⊂⊃ +1.00 cyl. axis 75 degrees. This test is not often used, and when resorted to, the eyes should be under the influence of a cycloplegic. This test is of special service in some cases of mixed astigmatism, irregular astigmatism, presbyopia, and aphakia.

5. Astigmatic Chart.—There is an infinite variety of these cards (see Fig. 113), and the student is puzzled

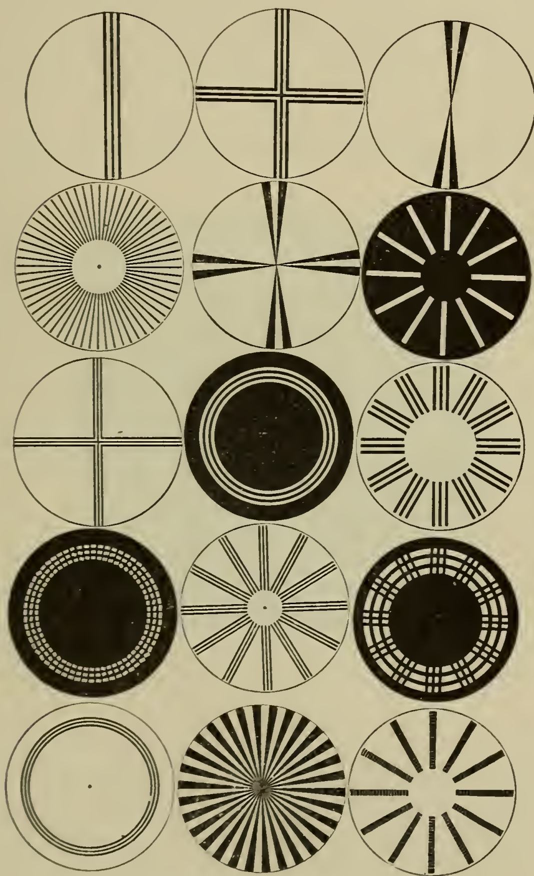

FIG. 113.—Astigmatic Charts of Dr. John Green.

which one to select. Ordinarily, the "clock-dial" will answer every purpose. (Fig. 114.) This is a white card * with peripheral Roman characters corresponding to the characters on the clock-face, hence its name. From these figures a series of three parallel and uniformly black lines, with interspaces of the same width as the lines, cross from XII to VI, III to IX, IIII to X, V to XI, VII to I, and VIII to II. This chart should be so calculated that

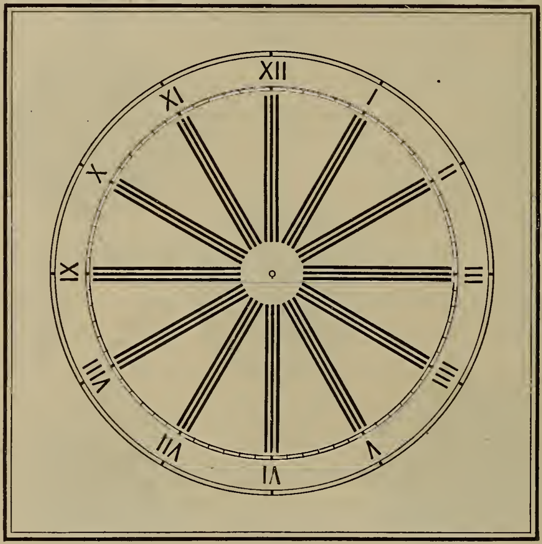

FIG. 114.

the lines and interspaces will form an angle of 5 minutes in width consistent with the distance at which the test is to be made: if at six meters, 8.7 mm.; if at four meters, 5.7 mm. In most charts the lines subtend an angle much greater than 5 minutes for the distance at which they are used, and in this way the true delicacy of the test for small errors or

* A black card with white lines is also used. (See Fig. 115.)

amounts of astigmatism is sacrificed. The purpose of the chart is to detect, by the patient's answer, whether astigmatism is present, and, if so, in which meridian.

The chart, illuminated by reflection from a steady artificial light, is placed on a horizontal line perpendicular to the patient's eyes; it should never be hung at an angle, and must always be perfectly flat. Each eye is to be tested separately. Looking at such a chart, if all the lines appear

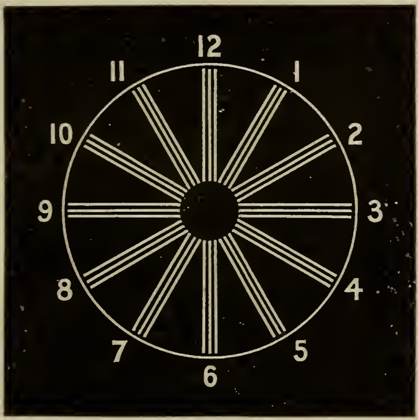

FIG. 115.

equally black, astigmatism of any considerable degree or amount may often be excluded; but if the patient selects one series of lines as darker than others, then the presence of astigmatism may be diagnosed. If the astigmatism is of a very high degree, the patient may see the three lines as one solid black line without interspaces.

RULE I.—The meridian of the eye which corresponds to the dark lines selected is the meridian of astigmatism.

Example.—If the horizontal lines (from III to IX) appear darker than all the others, then it is the horizontal meridian (0 or 180 degrees) of the eye which is astigmatic. Or if the lines from VI to XII are darkest, then the vertical meridian of the eye is astigmatic. In other words, the series of darkest lines indicates the meridian of greatest ametropia.

RULE 2.—The axis of the cylinder in the prescription will be opposite to the meridian of the dark lines.

Example.—A patient who requires a plus cylinder at axis 90 degrees sees the horizontal lines (from III to IX) as very dark, and the lines from VI to XII not so dark, and the axis of the cylinder in the prescription will be opposite to 180 degrees—*i. e.*, at 90 degrees.

According to the definition of "astigmatism with the rule" and "astigmatism against the rule," it follows that, with few exceptions, those patients who select a series of lines at 180 degrees, or within 45 degrees either side of 180 degrees, as darker than other lines, have hyperopic astigmatism, whereas those who select a series of lines at 90 degrees, or within 45 degrees either side of 90 degrees, have myopic astigmatism.

According to the definition of symmetric astigmatism, a patient's right eye selecting the lines at 90 or 180 as darker than those at right angles, will select the same series of dark lines in the left eye. If the series of dark lines with the right eye is from II to VIII, then the left eye selects the dark lines from X to IV, etc.

The clock-dial is the form of chart in common use, and as a test for astigmatism is not without considerable merit.

When the astigmatism is of small amount, it may not be recognized by means of the clock-dial until after the spheric correction has been placed before the eye or after a cycloplegic has been instilled.

6. The writer's **pointed line test,** as shown in figure 116, is a series of one-minute black squares, in three parallel lines at right angles to each other, on a cream-colored card; the squares and adjoining spaces making a five-minute angle for six meters. By means of a clockwork and battery, this dial may be revolved by pressing a button. The principle of the test is the same as the perforated disc.

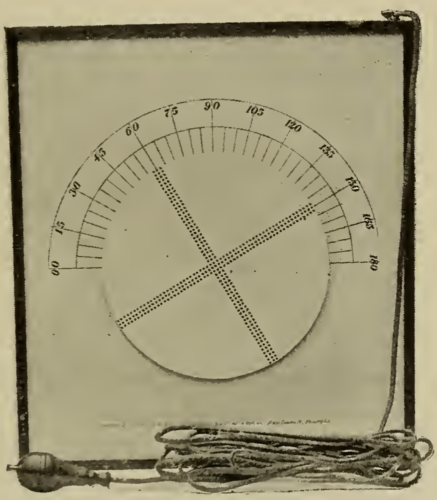

FIG. 116.

7. **The Perforated Disc** (Fig. 117).—This is a modification of the astigmatic chart. A piece of white cardboard or metal, about ten inches square, has small, round perforations made in it of certain definite size. Each perforation is separated from its neighbor by the distance of its diameter. These openings are arranged in series of one, two, or three parallel lines, exactly as in the pointed line test. This chart or disc is hung on the window-pane, or an illumination is placed behind it. The patient, looking at the disc,

signifies which series of perforations appear to coalesce and form lines. This test is not commonly known or used. It

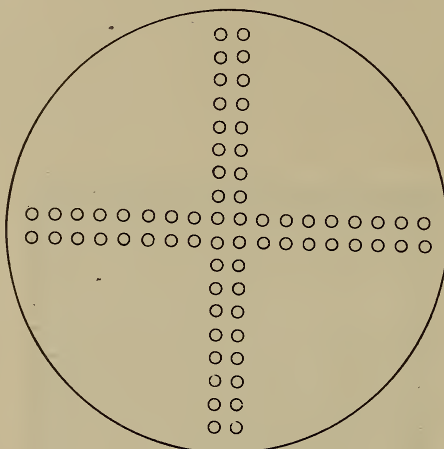

FIG. 117.

might be a valuable test if there was any convenient way of uniformly illuminating it from behind.

FIG. 118.

8. Pray's Letters (Fig. 118).—These letters are of the Old English type, and composed of strokes which run in different meridians. The patient, looking at these letters, selects that letter which appears darker than all the rest. The direction of the lines in the letter selected corresponds to the meridian of greatest ametropia. This test is very confusing to the patient, who sees first one letter and then another as darker than its fellows.

9. Scheiner's Test.—This is an old test for ametropia, good in theory, but really not sufficiently accurate for practical purposes. It is explained for the student's information, and not with the idea that he will ever take time to use it.

The test is made with a small piece of metal (Fig. 119) the size of the trial-lens, which contains two pin-point round openings at its center, separated by an interval of two or three millimeters. One of these openings is covered with a red glass, as suggested by Dr. Wm. Thomson. This disc is placed close to the eye, so that light may pass through both openings into the eye at one and the same time. The eye, if not presbyopic, should be under the influence of a

FIG. 119.

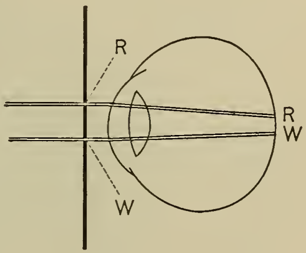

FIG. 120.

cycloplegic. The eye looks at a distant point of light. The principle of the test depends upon which part of the retina is stimulated by the rays entering the eye through these openings, all other rays being excluded. The student must remember that rays which fall upon the temporal side of the retina are referred to the nasal side; those which fall upon the nasal side of the retina are referred to the temporal side; those which fall upon the lower portion of the retina appear to come from above; and those which fall upon the upper portion of the retina appear to come from below.

Diagnosis of Hyperopia (Fig. 120).—The disc is placed with the red glass (R) above. The patient then sees a red and a white light (W). The red appears below the white. Gradually revolving the disc, the two lights move, and keep the relative positions and distance apart. The greater the distance between the two lights, the higher the refraction or amount of the hyperopia. That plus sphere placed in front of the disc which unites the two flames into one (pink) flame is the approximate amount of the hyperopia.

Diagnosis of Myopia (Fig. 121).—Placing the disc before the eye as before, with the red glass (R) above, the patient sees the red flame above the white (W). Gradually revolving the disc, these two lights keep their relative positions and distance. That minus sphere placed before the disc which makes the two lights appear as one (pink) light is the approximate amount of the myopia.

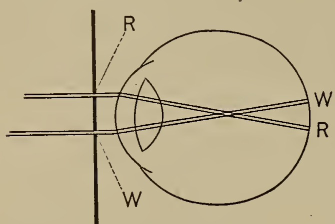

Fig. 121.

Diagnosis of Emmetropia.—This condition would give but one light (pink in color), and unchanged by rotating the disc.

Diagnosis of Simple Hyperopic Astigmatism.—One meridian appears the same as in emmetropia, and the meridian opposite to the emmetropic meridian would show a separation of the two lights, as in hyperopia. The plus cylinder placed before the disc which unites the two lights in the ametropic meridian represents the amount of the astigmatism.

Diagnosis of Simple Myopic Astigmatism.—The lights are red and white in one meridian, as in simple hyperopic astigmatism, but the red light is seen in the direction of the red glass, and when the disc is rotated to the opposite meridian, only one light appears, and of a pink color. The amount of the astigmatism is represented by the strength of minus cylinder which brings the two lights together in the ametropic meridian.

Diagnosis of Compound Hyperopic Astigmatism.—All meridians show two lights, the red light being in the direction of the clear opening in the disc, but one meridian will show a greater separation of the lights than in the meridian at right angles. To find the correction and the amount of the astigmatism, proceed as in simple hyperopia, correcting each meridian separately with a sphere.

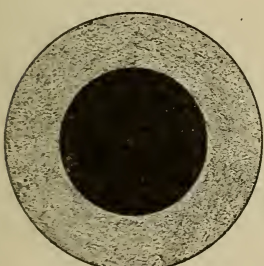

FIG. 122.

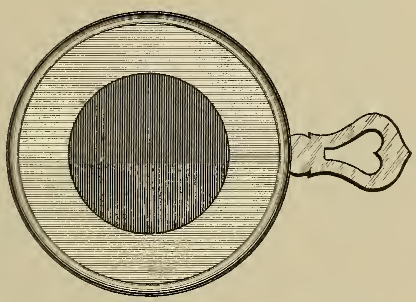

FIG. 123.

Diagnosis of Compound Myopic Astigmatism.—This is the same as in compound hyperopic astigmatism, with a reversal of the position of the lights, and the amount of the ametropia is obtained with minus spheres.

Diagnosis of Mixed Astigmatism.—One meridian appears as in simple hyperopic astigmatism, and the meridian opposite to it appears as in simple myopic astigmatism. The amount of the astigmatism is calculated as in these two conditions.

10. Chromo-aberration Test.—This is also known as the cobalt-blue glass test. Cobalt is a mineral, and is used as a coloring-matter by glass-blowers. Cobalt-blue glass comes in two forms: one in which the glass is colored throughout, and the other in which it is colored on only one surface, known as "flashed." To the eye, cobalt-blue glass appears dark blue, but contains a great deal of red. For purposes of testing ametropia, a dark shade of blue should be selected, or two or three pieces of a light shade may be cemented together so as to give the desired dark shade. This glass is cut round and fitted into a trial-cell. (See Figs. 122 and 123.)

The power of cobalt-blue glass to exclude all but blue

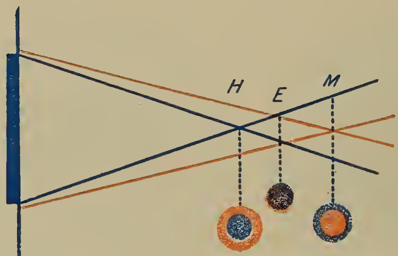

Fig. 124.

and red rays gives this test its principle. Blue rays being more refrangible than red, naturally focus sooner than red. Red rays will focus back of the blue. (See Fig. 124.)

There are several important details in the use of this test which *must* be carefully executed if definite results are to be obtained:

1. *The eye should be under the influence of a cycloplegic.*

2. By means of a light-screen, a small round area of steady white light should be looked at from a distance of four or six meters.

3. Each eye is to be tested separately.

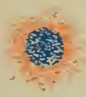

FIG. 125

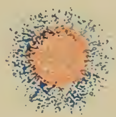

FIG. 126

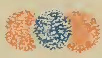

FIG. 127.

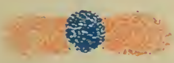

FIG. 128.

FIG. 129

FIG. 130.

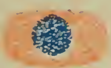

FIG. 131.

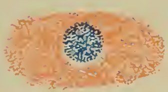

FIG. 132.

FIG. 133.

FIG. 134.

FIG. 135.

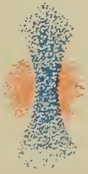

FIG. 136.

125. High hyperopia. 126. High myopia. 127. Low simple hyperopic astigmatism. 128. High simple hyperopic astigmatism. 129. Low simple myopic astigmatism. 130. High simple myopic astigmatism. 131. Low compound hyperopic astigmatism. 132. High compound hyperopic astigmatism. 133. Low compound myopic astigmatism. 134. High compound myopic astigmatism. 135. Low mixed astigmatism. 136. High mixed astigmatism.

4. The cobalt glass may be placed near the flame or, better still, close in front of the patient's eye; in every instance it must be perpendicular to the front of the eye, and never at an angle.

5. All other lights except the one in use should be excluded.

Diagnosis of Emmetropia.—Patient sees a small circle composed of two colors equally mixed; purple. (See *E* in Fig. 124.)

Diagnosis of Hyperopia (see *H* in Fig. 124).—The patient describes a red ring of light with a blue center.

Diagnosis of Myopia.—The patient describes a blue ring with a red center. (See *M* in Fig. 124.)

Diagnosis of Astigmatism.—If astigmatic, then he will describe one of the conditions as shown on page 147. If the test is made as suggested, it will have three points of recommendation:

1. The character of the refraction is quickly diagnosed.

2. It may lead to an early diagnosis of red-blindness, a condition often overlooked.

3. Likewise it will show a central scotoma for red in advanced toxic amblyopia, if the eye is made myopic with a plus sphere.

11. Thomson's Ametrometer (Fig. 137).—This instrument has two small gas-flames about five millimeters in diameter, one stationary and the other movable on a metal arm, which can be changed or revolved to any meridian. Each eye is tested separately at a distance of twenty feet, and preferably under a cycloplegic. The method of the test is to move one flame along the metal arm until the two lights appear to fuse. The scale, as marked on the arm, gives the approximate strength of lens necessary to correct the ametropia. By raising or lowering the arm any meridian may be tested. It is a most ingenious test, but not in common use.

12. **The Ophthalmometer** (see Figs. 138 and 139).—This name literally means an "eye measure," but as the instrument measures only the different radii of corneal curvature, a much better name would be keratometer, or measure of the corneal radii. The object of the ophthalmometer is

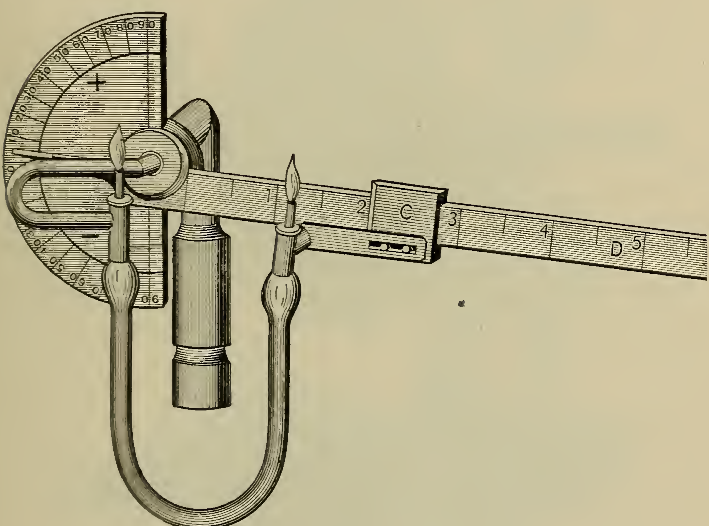

FIG. 137.

the measurement of corneal curves by means of catoptric images viewed through a telescope.

The ophthalmometer consists of a telescope which contains a Wollaston birefrangent prism placed between two biconvex lenses. Attached to the telescope is a graduated arc, upon which are placed two white enameled objects called mires (targets). (See Figs. 139, 140, 141.) The left mire is stationary, and is made up of two 3 cm. squares, separated by a black line 2 mm. wide ; the right mire is movable and graduated into steps, each 5 mm. wide ; a black line passes through the middle of these steps. For purposes of focusing, the telescope is mounted on a movable tripod. The patient is seated with his chin and forehead resting in a

FIG. 138.

frame. At the side of the frame, and attached to it, are two or four electric lights or Argand burners, which illuminate the mires. The surgeon, looking through the eye-piece of the telescope, focuses the center of the patient's cornea until he sees two images of each mire clearly ; then he selects the two central images for further study and ignores the peripheral images. The next step is to move the right-hand mire until these two images of the mires occupy the center or pole of the cornea, so that their inner edges just touch and the black line in each makes one continuous black line through both (see Fig. 140) ; and to do the

FIG. 139.

latter, the barrel of the telescope may have to be gradually revolved from left to right or right to left, but never more than 45 degrees either way. When this position is obtained, the axis or meridian is noted by the arrow, which points to the figure on the dial at the back of the arc, or, as in some old instruments, on the front of the dial. This position of the mires is spoken of as the primary position.

Revolving the telescope to the opposite meridian (meridian at right angles), which is called the secondary position, the observer notes any change which may have taken place in the relative positions of the mires. If they have not changed, but still maintain their edges in apposition, as in the primary position, then the cornea has a uniform curvature thoughout, and there is no astigmatism of the cornea present. If, however, when the secondary position is reached and the catoptric image of the mires with the steps has encroached upon the catoptric image of the stationary mire, then the astigmatism is calculated by the amount of this overlapping. (See Fig. 141.)

FIG. 140.

FIG. 141.

Each step representing one diopter of astigmatism, one-half a step of overlapping would represent half a diopter, etc. If, in making the change from the primary to the secondary position, the mires should separate, then the surgeon would know that his secondary position should have been his primary position, and he will have to make a corresponding change.

As already stated, lenticular astigmatism is not a condition to be ignored, as only too often it will increase, diminish, or even neutralize corneal astigmatism, so that in point of fact the ophthalmometric findings are more often useless than of real value in estimating the *total* refractive error. Cylinders should never be prescribed from the ophthalmometric findings until carefully confirmed by other and much more reliable tests. As a keratometer, the instrument can not be excelled, and, therefore, it has a place in testing the refraction in cases of aphakia. The ophthalmometer as a means of diagnosis is suggestive rather than positive.

13. Estimation of Curvature Ametropia (Astigmatism) with the Ophthalmoscope, Direct Method.—The presence of astigmatism is diagnosed by the direct method from the fact that the vessels or details of the fundus are not all seen clearly with one and the same glass in the ophthalmoscope; in other words, the vessels passing up and down on the disc are seen clearly with a different lens in the ophthalmoscope than is required to see the vessels passing laterally or at right angles. The amount of the astigmatism is the difference in the strength of the respective lenses used for this purpose; for instance, if the vertical vessels are seen best with a +4 S., and the horizontal vessels with a +2 S., then the amount of the astigmatism would be +2 D.

When using the ophthalmoscope for making refractive estimates in astigmatic eyes, the student should remember that the glass with which a vessel is seen distinctly in one meridian represents the amount of the refraction in the meridian at right angles to this vessel. In other words, each vessel in the eye-ground of an astigmatic eye is seen clearest through the meridian at right angles to its course. This is a puzzle to the beginner, but he must remember that cylinders refract opposite to their axes. In estimating the refraction with the ophthalmoscope, the observer looks first at the shape of the disc; if it appears oval, this would be an evidence of astigmatism; secondly, if the upper and lower edges of the disc are seen clearly with a different strength glass than that required to see the inner and outer margins, then this would be a further evidence of the presence of astigmatism; but the third and confirmatory test of the presence of astigmatism should be the different strength glasses required to see the vessels distinctly in the neighborhood of the macula. An eye having an oval nerve, whose edges can all be seen clearly with one and the same glass in the ophthalmoscope is not usually astigmatic.

Examples of estimated refraction by the direct method.

Simple Hyperopic Astigmatism.—Vertical vessels seen with a +1 S. and horizontal vessels seen without any lens would equal +1.00 cyl. axis 90 degrees.

Simple Myopic Astigmatism.—Vertical vessels seen without any lens and horizontal vessels seen with —3 S. would equal —3 cyl. axis 180 degrees.

Compound Hyperopic Astigmatism.—Vertical vessels seen with +4 S. and horizontal vessels seen with +3 S. would equal +3.00 S. ⊂⊃ +1.00 cyl. axis 90 degrees.

Compound Myopic Astigmatism.—Vertical vessels seen with —2 S. and horizontal vessels seen with —5 S. would equal —2.00 S. ⊂⊃ —3.00 cyl. axis 180 degrees.

Mixed Astigmatism.—Vertical vessels seen with +2 S. and horizontal vessels seen with —3 S. would equal —3.00 S. ⊂⊃ +5.00 cyl. axis 90 degrees.

14. Diagnosis of the Character of the Refraction by the Indirect Method (see Fig. 142 and p. 99).—There is nothing exact about this method, and the refractive error, to be recognized, must be considerable.

1. Gradually withdrawing the lens (objective) from in front of the eye, if the aerial image of the disc retains its uniform size in one meridian, it signifies emmetropia for that meridian; but if it grows smaller in one meridian, that meridian is hyperopic; or if larger, then that meridian is myopic.

2. If the image grows smaller, but more so in one meridian than the other, it signifies compound hyperopia. If the image grows larger, but more so in one meridian than the other, then the condition is one of compound myopia. The

image growing smaller in one meridian, while in the other it grows larger, indicates mixed astigmatism.

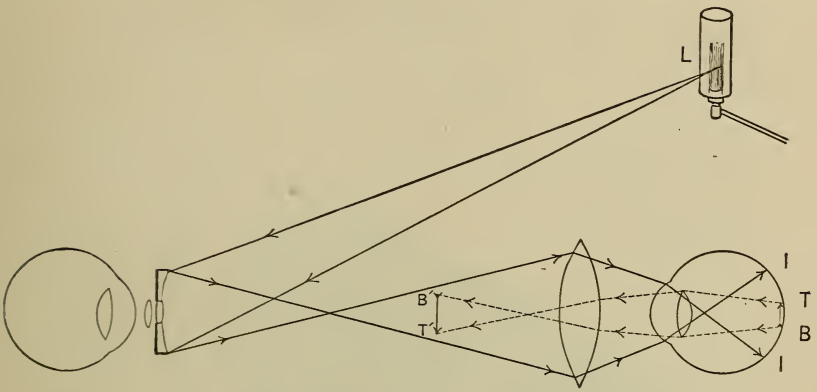

FIG. 142.—Companion picture to figure 89. Illustrating the indirect method. Rays from the lamp (L) are reflected convergently from the mirror of the ophthalmoscope, and, passing through the convex lens and into the eye, produce a large retinal illumination, extending from I to I. T B are rays from the edge of the disc, and, leaving the eye parallel, pass through the convex lens and form an inverted aerial image of the disc at T′ B′. The +4 S. in the ophthalmoscope magnifies the image T′ B′.

15. **The cylinder lens test** for astigmatism is described under Applied Refraction, page 251.

16. **Retinoscopy** is described in chapter VI.

CHAPTER VI.

RETINOSCOPY.

Retinoscopy, or the Shadow Test.—This may be de

FIG. 143.—The Author's Schematic Eye for Studying Retinoscopy.

fined as the method of estimating the refraction of an eye by reflecting into it rays of light from a plane or concave mirror, and observing the movement which the retinal illumination makes by rotating the mirror.

Suggestion.—Before attempting to practise retinoscopy upon the human eye, the beginner is advised to study the method upon one of the many schematic eyes to be found in the market.

The principle of retinoscopy is the finding of the point of reversal, or myopic far point; and when an eye is emmetropic or hyperopic, it must be given a myopic far point by means of a convex sphere. (Fig. 144.)

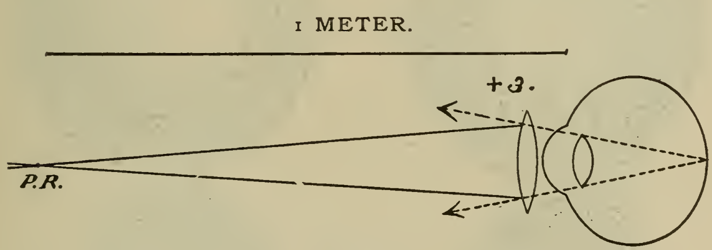

FIG. 144.

Advantages of Retinoscopy.—

1. The character of the refraction is quickly diagnosed.

2. No expensive apparatus is necessarily required.

3. The refraction is estimated without the verbal assistance of the patient.

4. The correction is quickly obtained.

5. The value of retinoscopy can never be overestimated in the young, in the feeble-minded, the illiterate; in cases of nystagmus, amblyopia, and aphakia.

Axiom.—With an eye otherwise normal except for its optic error, and under the influence of a reliable cycloplegic, there is no more exact objective method of obtaining its refraction than by retinoscopy.

The surgeon should wear any necessary correcting glasses and have a vision of more than $\frac{VI}{IX}$; otherwise he can never get satisfaction from this method. The surgeon should keep his eyes wide open and not hesitate to use his accommodation, as it does not have any effect on the result, as in estimating the refraction with the ophthalmoscope.

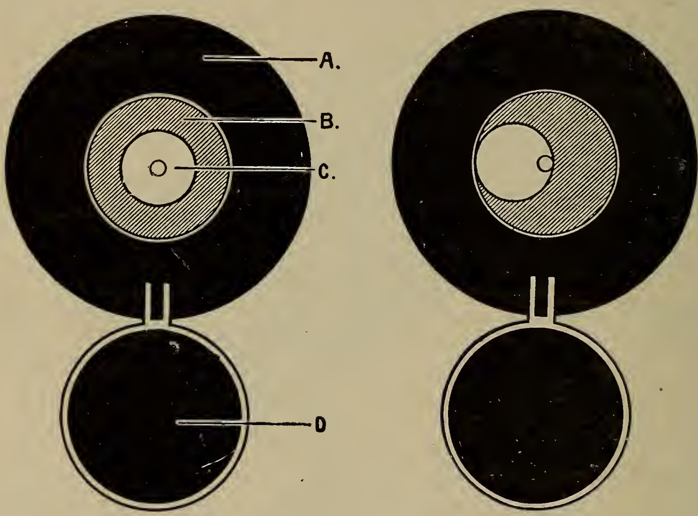

FIG. 145. FIG. 146.

Author's Mirror with Folding Handle.

FIG. 145.—Showing central light C, on small mirror B. This is the light the patient sees when looking into the mirror, and corresponds in size to the one-centimeter opening in screen. D is the folding cap handle to protect B when not in use. A is the metal disc.

FIG. 146.—Shows the light moved to one side as a result of tilting the mirror.

The patient *must have his accommodation under the influence of a reliable cycloplegic; this is imperative.* Each eye is tested separately, and if the patient has a squint, then one eye should be covered while its fellow is being refracted. The patient must be comfortably seated and told to look at the metal disc of the mirror or the observer's forehead above the mirror, and never into the mirror.

The Retinoscope, or Mirror.—The plane mirror is 2 cm. in diameter on a round 4 cm. metal disc, with a 2 mm. sight-hole at the center, made by removing the silvering, and not by cutting a hole through the glass. (See Figs. 145 and 146.)

The concave mirror recommended has a 25 cm. focus (ten inches) and is 3½ cm. in diameter on a metal disc of the same size as the plane mirror. The sight-hole is similar in size and made in the same way as that of the plane mirror.

The light should be steady, clear, and white, and secured to a movable bracket. For general use, the Argand burner is best.

The Light-screen, or Cover-chimney.—For the purpose of intercepting the heat this is made of thin asbestos, and the iris diaphragm attached to it regulates the amount of light desired. (See Fig. 147.)

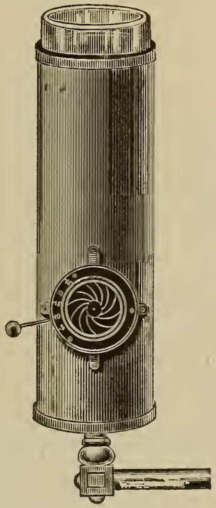

FIG. 147.—Author's Iris Diaphragm Chimney.

The room for retinoscopy should be darkened and all sources of light except the one in use should be excluded.

Position of Light and Plane Mirror.—These may be as close together as 6 inches or as far apart as 6 meters. It is a matter of choice with the surgeon himself where he prefers to have them. The writer recommends, however, having the rays of light come from the 10 mm. opening in the light-screen, at about 6 inches to the left and front of the surgeon, so that the rays pass in front of the left eye and fall upon the mirror held before the right eye. Some surgeons prefer having the light, with the 3 cm. opening in the screen, placed over the patient's head or to one side of it. (Fig. 148.) *The distance between the light and mirror will not alter the direction of the rays of light which come from the patient's eye.*

Position of the Light and the Concave Mirror (Figs. 148, 149, 150).—As the purpose of the concave mirror in retinoscopy is to focus rays of light before they enter the

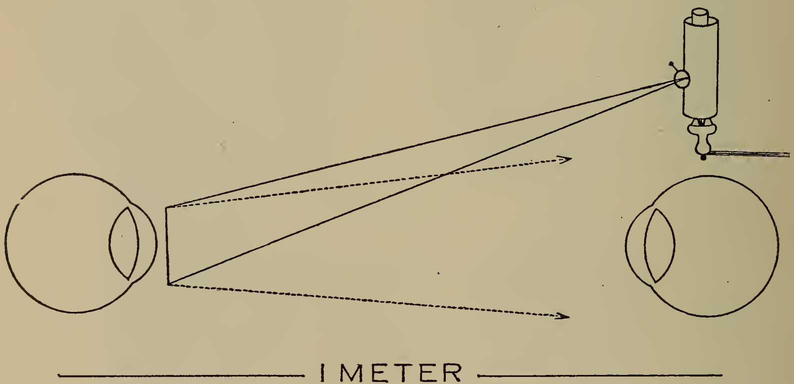

FIG. 148.—Light over Patient's Head, and the Observer with Mirror at One Meter Distance.

patient's eye, it is always necessary to have the light and mirror widely separated. Usually, the light with the 3 cm. opening in the screen is placed to one side or over the patient's head, and the surgeon with the mirror is seated about one meter from the patient. This will place the focus of the 25 cm. mirror about 33 cm. in front of the mirror.

Distance of Surgeon from Patient.—With the plane mirror he may approach within a few inches of the patient's eye to find the point of reversal, but with the concave mirror he *must* remain at a sufficient distance to have the focus of the mirror *in front* of the patient's eye.

How to Use the Mirror.—It should be held firmly in

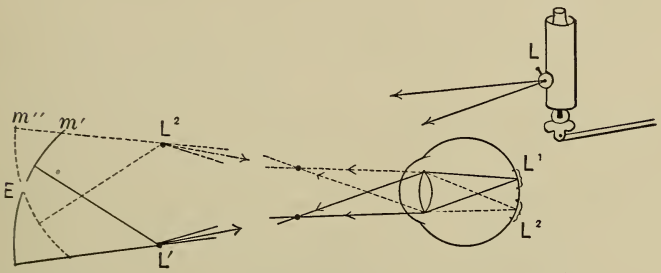

FIG. 149.—Illustrating High Myopia with a Concave Mirror.

Rays of light from the lamp (L) are reflected by the mirror (*m'*), and form a conjugate focus at L', and the rays from this focal point illuminate the retina at L¹. Corresponding effects result when reflection takes place from the mirror at *m''*. The eye (E) behind the mirror recognizes points of reversal between the eye and mirror, moving in the same direction to that in which the mirror is tilted.

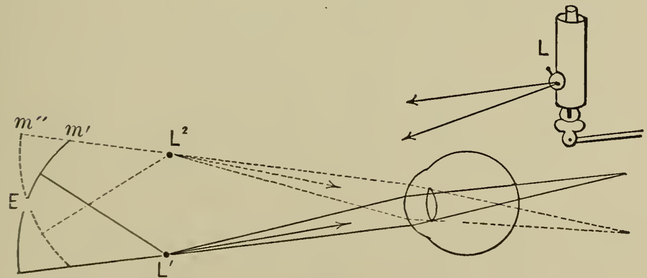

FIG. 150.—Illustrating Hyperopia with the Concave Mirror.

The eye (E) recognizes a virtual image behind the eye under examination, so that when the mirror (*m'*) is focusing the rays from the lamp (L) at L', the upper portion of the retina is illuminated, and vice versâ, when the mirror (*m''*) is focusing the rays at L_2, the lower portion of the retina is illuminated. The retinal illumination moves *opposite* to that of the mirror.

the right hand before the right eye, so that the sight-hole is opposite to the observer's pupil. The movements imparted to the mirror must be limited, though they may be quick or slow, but never at any time should the mirror be tilted more than 2 or 3 mm., otherwise the light will be lost from the eye.

What the Observer Sees, or the general appearance of the reflection from the eye.—**The reflex** from the pupil varies in different patients, and is subject to many changes as the refraction is altered by correcting glasses, by the turning of the patient's eyes, by increasing or diminishing the distance between patient and surgeon or the distance between the light and mirror, or the strength of the light. The amount of pigment in the eye-ground will change the general appearance of the reflex, being dim in some mulattoes, and very light in the blonde or albino. If the refractive error is a high one, the reflex will appear dull; or if a low error, it will appear very bright. If the media are not clear, the reflex will be altered accordingly. The bright pin-point catoptric images seen on the cornea and lens are not parts of the test, and should be avoided or ignored. The 1 mm. bright ring of light sometimes seen at the edge of the pupil should be avoided by the beginner in retinoscopy, as it is an indication of spheric aberration, which he will have to consider after mastering other details of the method.

Facial Illumination.—The rays of light reflected from the mirror illuminate a portion of the patient's face, and always move in the same direction as that in which the mirror is tilted, no matter whether the mirror is plane or concave.

Retinal Illumination.—This corresponds to the portion of the retina which receives the rays of light reflected from the mirror. The retinal illumination is also called "the image," "the light area," etc.

The Shadow.—This is the non-illuminated portion of the retina immediately surrounding the illumination. The illumination and shadow are, therefore, in contact; if the illumination changes its place upon the retina by a movement of the mirror, then the shadow will move also. By this change of illumination and shadow we speak of a movement of the shadow.

Where to Look and What to Look for.—Rotating the mirror through the various meridians of the eye, the observer makes a note of the (1) form, (2) direction, and (3) rate of movement of the retinal illumination as he watches for them through a four or five millimeter area at the apex of the cornea, as this is the portion of the refractive media in the normal eye that the patient will use when the effects of the cycloplegic pass away and the pupil regains its normal size.

Point of Reversal.—To find the point of reversal is the underlying principle of retinoscopy. For example, having determined with the plane mirror at a distance of one meter that the retinal illumination moves with the movement of the mirror and a +2.50 S. stops all apparent movement (no movement of the illumination being seen and the shadow having disappeared), the observer knows that his eye is at the point of reversal. Or with the concave mirror the retinal illumination will move opposite to the movement of the mirror and will stop with +2.50 S. before the eye. The point at which all movement of the retinal illumination appears to have ceased is the point of reversal.

The real movement of the retinal illumination depends upon the mirror—whether it is concave or plane. With the plane mirror the retinal illumination always moves with the mirror and the light on the face; whereas with the concave mirror (focusing rays before they enter the eye), the real movement of the retinal illumination is always opposite to that of the mirror. The student should not get the real and apparent movements confused, but pay close attention to the apparent movement.

Direction of the Apparent Movement of the Retinal Illumination.—With the plane mirror, the apparent movement of the retinal illumination will be with the mirror and with the light on the face as long as the observer is within the point of reversal; but just as soon as the observer is beyond the point of reversal, the retinal illumination will appear to move opposite to the movement of the mirror and opposite to the movement of the facial illumination.

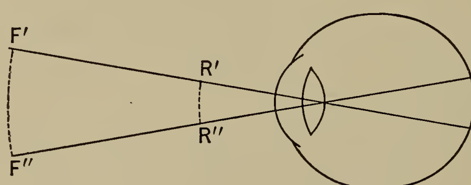

FIG. 151.

With the concave mirror the apparent movement of the retinal illumination will be with the movement of the mirror and the light on the face as long as the observer is beyond the point of reversal (Fig. 149); but just as soon as the observer's eye is within the point of reversal, the retinal illumination will appear to move against the movement of the mirror and against the light on the face. (See Fig. 150.)

Rate of Movement of the Retinal Illumination.—This is influenced by several factors, but practice will teach the observer that when the retinal illumination *appears* to move slowly, the refractive error is a high one, and when it moves fast, the refractive error is a low one.

Figure 151 represents a myopic eye with its far point

(point of reversal) at R′, and when rotating the mirror, this point moves to R″; but if the eye had its far point at F′, and the mirror was rotated to F″, then the illumination at R′, having to move through a smaller arc in the same time, appears to move slowly as compared with F′, which appeared to move fast. The same condition is shown in figure 152, in which the observer appears to see an erect virtual image back of the retina, and R′ appears to move slowly as compared with F′, which appears to move fast.

Form of Illumination.—A large, round illumination may signify emmetropia, hyperopia, or myopia, with or without astigmatism in combination. Astigmatism is recognized

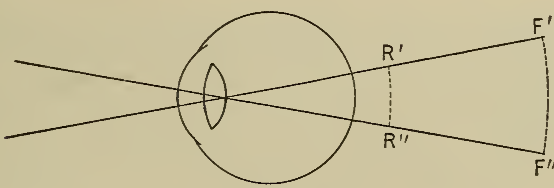

FIG. 152.

by the presence of a band of light, and this band of light may be seen before any correcting lens has been placed before the eye if the astigmatic error is high; or it will be recognized during the process of neutralization if the error is small—*i. e.*, if the astigmatism is of low degree. The presence of astigmatism is known, therefore, by the band of light or when the illumination appears to move faster in one meridian than in the meridian at a right angle. The astigmatism is in the meridian of slow movement.

The apparent difference between the plane and concave mirror in the direction of movement of the retinal illumination.—With the plane mirror the rays of light are reflected as if they came from a point just as far back of the mirror as the original source of light is in front of it. The surgeon's eye behind a plane mirror is, therefore, in the path of these rays, and sees that portion of the pupillary area illuminated to which these rays are directed. (See Fig. 153.)

With the concave mirror the reflected rays come to a focus, forming an inverted image of the flame, which becomes the immediate source of light *in front* of the observer's eye. When the concave mirror is tilted, the immediate source of light goes in the same direction, but with the result that the *opposite* portion of the pupillary area is illuminated. (See Fig. 143.) This shows the

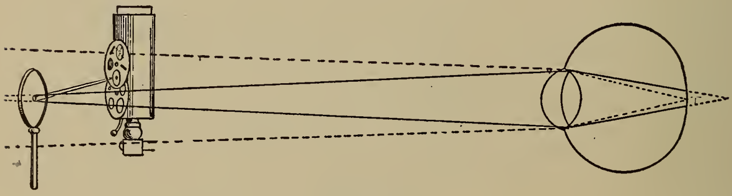

FIG. 153.

immediate source of light at L′ and mirror tilted downward; the rays proceeding from L′ diverge and illuminate the upper portion of the pupillary area. Tilting the mirror upward, the immediate source of light at L′ moves upward also (L^2), and the lower portion of the pupillary area becomes illuminated. (See also Fig. 149.)

Rule for Neutralizing Lenses with the Plane Mirror.—When the retinal illumination appears to move in the same direction as that of the mirror, the observer is within the point of reversal and a plus lens must be placed before the eye to stop all apparent movement. When the retinal illumination appears to move in the opposite direction to that in which the mirror is tilted, the observer is beyond the point of reversal, and a minus lens must be placed before the eye to stop all apparent movement.

Rule for Neutralizing Lenses with the Concave Mirror.—When the retinal illumination appears to move in the same direction as that in which the mirror is tilted, the observer is beyond the point of reversal, and a minus lens must be placed before the eye to stop all apparent movement. When the retinal illumination appears to move in the opposite direction to that in which the mirror is tilted, the observer is within the point of reversal, and a plus lens must be placed before the eye to stop all apparent movement.

Rule for neutralizing lenses, no matter whether the mirror is plane or concave.—When within the point of reversal, use a plus lens, and when beyond the point of reversal, use a minus lens.

Application of Retinoscopy in Emmetropia (Fig. 153).—Rays of light proceed parallel from an emmetropic eye under the influence of a cycloplegic, and if a +1 S. is placed in front of such an eye, the rays will converge and form a point of reversal at 1 meter distance, and the observer at this point will not be able to see any movement of the retinal illumination. The same result would have been obtained at ⅓ of a meter if a +3 S. had been used, or at 4 meters if a +0.25 S., or at ½ of a meter if a +2 S. had been used, etc.

In taking the patient from the dark-room to test his vision at 6 meters, an allowance must always be made for the distance from the patient's eye at which the point of reversal was found. If at ⅓ of a meter, 3 S. must be deducted from the lens used; if at ¼ of a meter, 4 S.; if at 6 meters, nothing, or 0.12.

Application of Retinoscopy in Hyperopia.—The same conditions hold good in hyperopia as in emmetropia. If a +4 S. gives a point of reversal at one meter, then 1 S. must be taken from the 4 S. to give the eye parallel rays of light, or infinity vision. If a +4 S. gave a point of reversal at 2 meters, then 0.50 S. would have to be deducted from the 4 S. for the infinity correction, which would be +3.50 S.

Application of Retinoscopy in Myopia.—Rays of light from a myopic eye come to a focus at some point inside of infinity, and if the surgeon so desires, he may approach such an eye from a distance of six meters, until he finds a point where the retinal illumination ceases to move (where it does not appear to move); and then, measuring this distance from the eye under examination, he can quickly calculate the amount of the myopia. This can not be done with the concave mirror if the myopia is more than 2 S. If the reversal point is at 4 meters, 3 meters, 2 meters, 1 meter, ½ of a meter, ⅓ of a meter, or ¼ of a meter, then the myopia would be 0.25 S., 0.33 S., 0.50 S., 1 S., 2 S., 3 S., 4 S., respectively.

If the surgeon will always refract the patient's eyes so that he gets the point of reversal at 1 meter distance, he will have the following rule to guide him—*i. e.*:

To add a —1 sphere to the dark-room correction, no matter what that may be. For example:

Dark-room,	0.00	+0.25 S.	+0.50 S.	+0.75 S.	+1.00 S.	+1.25 S.
Add, . . .	—1.00 S.	—1.00 S.	—1.00 S.	—1.00 S.	—1.00 S.	—1.00 S.
Infinity, . .	—1.00 D.	—0.75 D.	—0.50 D.	—0.25 D.	0.00	+0.25 D.

Application of Retinoscopy in Astigmatism.—If the surgeon has mastered retinoscopy in hyperopia and myopia, he should not have any difficulty in pursuing exactly the same course in cases of astigmatism. As already stated, the presence of astigmatism is diagnosed by the presence of a band or ribbon-like streak of bright illumination which extends across the pupillary area. (See Fig. 154.) This band of light may be seen before any neutralizing lens is placed in front of the eye, if the astigmatism is in excess of the spheric correction, as in the following formula :

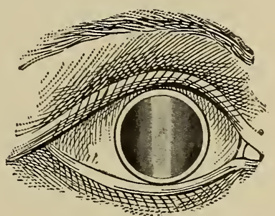

FIG. 154.—Band of Light. Astigmatism Axis 90 degrees.

+0.75 sph. ○ +4.50 cyl. axis 105 degrees.
—1.00 sph. ○ —5.00 cyl. axis 165 degrees.

Or the presence of astigmatism may *not* be recognized until *after* a sphere has been placed in front of the eye, as in one of the following formulas :

+4.50 sph. ○ +0.75 cyl. axis 75 degrees.
—5.00 sph. ○ —1.00 cyl. axis 180 degrees.

In refracting cases of astigmatism with the retinoscope, all the surgeon has to do is to refract the meridian of least ametropia first, and *then* the meridian of greatest ametropia. Taking the following formula :

+2.50 sph. ○ +1.00 cyl. axis 90 degrees ;

in the dark-room a +3.50 S. would make all movement cease in the vertical meridian, at one meter distant ; but when the mirror is tilted in the horizontal meridian, there would be seen a band of light extending across the pupil on axis 90 degrees. Then, substituting +4.50 S. for the 3.50 S., all movement will cease in the horizontal meridian, a +4.50 S. neutralizing the horizontal meridian. The difference between these two spheres is 1 D., which is the amount of the astigmatism. In neutralizing astigmatism the writer advises using spheres, and after each meridian has been refracted, to make the cylindric correction, and prove it, if so desired.

Axonometer.—To find the exact axis subtended by the band of light while studying the retinal illumination, when the meridian of least ametropia has been corrected, the writer has suggested a small instrument, which, for want of a better name, he has called an axonometer. This is a black metal disc, with a milled edge, 1 ½ mm. in thickness, of the diameter of the ordinary trial-lens, and mounted in a cell of the trial-set. It has a central round opening, 12

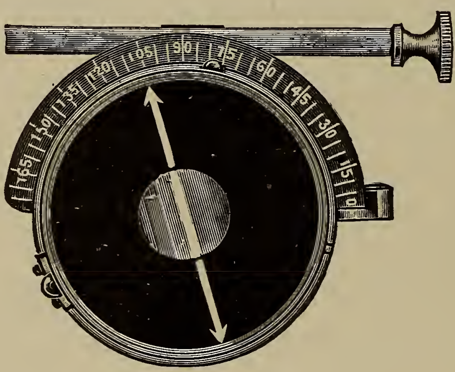

FIG. 155.

mm. in diameter—the diameter of the average cornea at its base. Two heavy white lines, one on each side, pass from the circumference across to the central opening, bisecting the disc. To use the axonometer, place it in the front opening of the trial-frame, and with the patient seated erect and frame accurately adjusted, so that the cornea of the eye to be refracted occupies the central opening. As soon as that lens is found which corrects the meridian of least ametropia, and the band of light appears distinct, turn the axonometer slowly until the two heavy white lines accurately coincide, or appear to make one continuous line with the band of light. (See Figs. 155, 219.)

The degree mark on the trial-frame to which the arrowhead at the end of the white line then points is the exact axis for the cylinder.

Application of Retinoscopy in Mixed Astigmatism.—Here the dark-room correction (after making deductions for the distance of the point of reversal) will show one meridian myopic and the other, at right angles to it, as hyperopic. If the astigmatism is more than one diopter in each meridian, the surgeon will diagnose in the dark-room the condition of mixed astigmatism by opposite movements in the meridians of minimum and maximum ametropia.

Application in Irregular Astigmatism.—This condition is either in the lens or cornea, usually in the latter. The reflex is more or less obscured by areas of darkness, which make it extremely difficult to study the refraction, and the observer will have to change his distance repeatedly to find clear spaces as close to the center of the pupil as possible, as it is this portion of the pupillary area that the patient will see through when the mydriatic effect passes away. The kaleidoscopic picture obtained by moving the mirror so as to describe a circle at the periphery of the pupillary space is quite diagnostic of the corneal condition. Whatever correction is obtained should be kept for reference in a postcycloplegic manifest refraction, as it will not always do to order the glasses while the eye has its pupil dilated. The patient may choose a slightly different correction in such cases, after the pupil regains its accustomed size.

Irregular Lenticular Astigmatism.—This is often more uniform than the corneal variety, and is characterized by faint striæ in the lens, pointing in toward the center. If the striæ are not very faint, they may be recognized with the ophthalmoscope, even before any cycloplegic has been used.

Scissor Movement (see Fig. 156).—This is a condition in which two bands of light are present, usually in the horizontal meridian or inclined a few degrees therefrom. Tilting the mirror in the vertical meridian, a band of light is seen to come from above and to meet another band, which comes from below; while these two bands are approaching, the dark space between them gradually disappears, until the two bands unite and form one band across the pupil in or approximating the horizontal meridian. This movement of the bands is likened to the action of the blades of a pair of scissors, and hence the name. To refract a case of this character, the observer must proceed slowly and endeavor to neutralize the horizontal meridian first, and then add minus cylinders with the axis corresponding to the axis of the two bands. The resulting prescription should also be a plus sphere with a minus cylinder, the cylinder of less strength than the sphere, as the condition is not one of mixed astigmatism, the patient preferring this combination, as a rule.

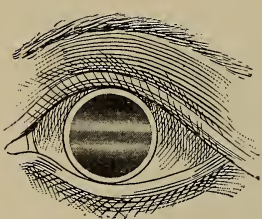

Fig. 156. — Scissor Movement.

Conic Cornea.—In this condition the observer is impressed at once with the bright central illumination, which usually moves opposite to the movement of the peripheral illumination. The best way to neutralize a case of this character is to proceed as in a case of irregular astigmatism. The observer should also be on the lookout for a band of light in this central illumination, as most of these cases are astigmatic.

Spheric Aberration.—This is of two kinds—positive and negative. (See Figs. 157 and 158.) In the positive form the peripheral refraction (A, A, that at the edge of the pupil) is stronger than the central (B, B); the reverse of this condition, negative aberration, is seen in conic cornea. These two varieties of refraction should not worry the observer, as most of the peripheral aberration is covered up by the iris when mydriasis passes away, and, therefore, is not of any great moment, except in conic cornea.

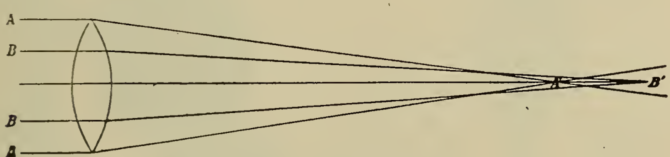

FIG. 157.—Positive Aberration.

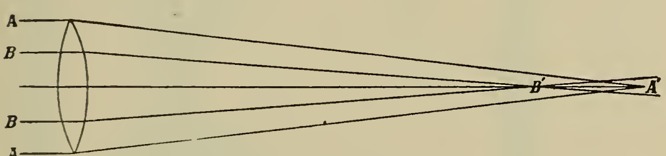

FIG. 158.—Negative Aberration.

The Reisner Retinoscope (Figs. 159 and 160).—This instrument combines the mirror with an axis finder. The metal disc, on which the mirror is secured by means of a coiled spring at one point only, has a milled edge like that of an ophthalmoscope. (See Fig. 159.) At the junction of the metal disc with the handle is a small push-button which has a short metal pointer which extends upward and beneath the mirror. Figure 160 is a back view of the instrument, and shows the degree-marks of half a circle and an index or pointer. When beginning the examination, this instrument may be used just the same as any other retinoscope, but as soon as the surgeon sees a band of light then he presses the push-button to see if the mirror rotates with its axis corresponding to the long measurement of the band of light. If this is not so, then the mirror must be turned by means of the milled edge, using the index-finger as in turning the disc of an ophthalmoscope. When the axis of rotation of the mirror corresponds with the long

FIG. 159.—(One-half size.)

FIG. 160. – (One-half size.)

axis of the band of light, then the pointer on the back of the instrument indicates the axis of the astigmatism, and now all the surgeon has to do as he makes the changes in the lenses is to press the button only. The handle of the retinoscope is now held perfectly still and the upper portion of the disc rests firmly against the observer's brow. The merits of this ingenious instrument are as follows: The handle is held perfectly still, the mirror alone does the moving; the sight-hole is always in front of the pupil; the axis of the astigmatism is carefully recorded.

FIG. 161.—(Two-thirds size.)

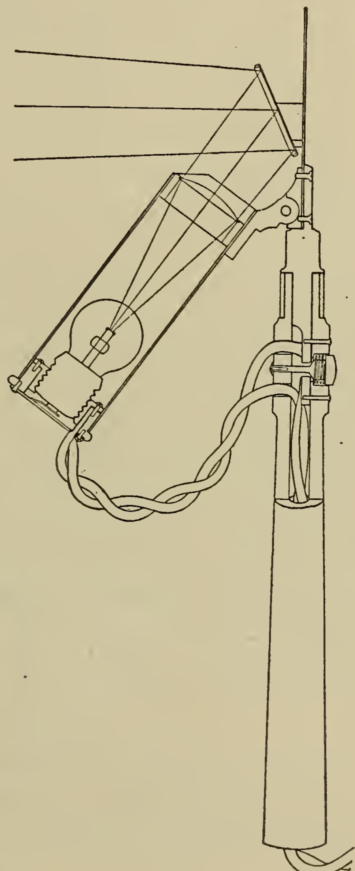

FIG. 162.—(Two-thirds size.)

The Luminous Retinoscope (Figs. 161 and 162).—*DeZeng Patent.*—The latest improvement in retinoscopes is the luminous instrument here described. This instrument is the author's plane mirror with the electric light attachment. (Fig. 161.) The filament is contained in a tube placed at an angle of 45 degrees with the handle and the mirror is correspondingly tilted at an angle of 22 degrees. The light from the filament passes divergently to a strong convex lens which renders the rays less divergent as they fall upon the mirror, and from the mirror the rays pass divergently to the patient's eye. (See Fig. 162.) This instrument has innumerable points of merit: It does away with any use of gas or lamp or cover chimney; the observer is not annoyed with the heat from the gas or lamp; the observer does not have to move the light or bracket when changing from one distance to another as when working with the gaslight close to the mirror; the electric wires (cords) carrying the current to the filament are of sufficient length to give the observer two meters of space in which to practise the method; the brilliancy of the illumination can be made most intense or diminished very materially with a convenient rheostat; the size of the divergent pencil may also be controlled by adjusting the condensing lens at the end of the tube. (See Appendix.)

CHAPTER VII.

MUSCLES.

Examination of the External Eye Muscles.

General Considerations.—When the retinal image of an object is situated exactly on the fovea, the eye is said to "fix" the object.

Normally, when both eyes "fix" the object, each eye has an image of the object on its fovea, and these foveal images or impressions are transmitted to the brain and fused as one image in the visual centers. This condition is spoken of as equipoise, or orthophoria, and the eyes are said to be in equilibrium, or to balance. Whenever one eye alone fixes an object, and the fellow-eye receives the image of the same object on a part of its retina distant from the fovea, then the brain takes note of two separate impressions, and this condition is spoken of as double vision (diplopia).

(*a*) The image of an object formed upon the retina above the fovea is projected downward—*i. e.*, objects situated below the horizontal line of vision are recognized by that portion of the retina above the fovea.

(*b*) The image of an object formed upon the retina below the fovea is projected upward—*i. e.*, objects situated above the horizontal line of vision are recognized by that portion of the retina below the fovea.

(*c*) The image of an object formed on the retina to the nasal side of the fovea is projected toward the temporal side—*i. e.*, objects to the temporal side have their images formed upon the nasal portion of the retina.

(*d*) The image of an object formed on the retina to the temporal side of the fovea is projected toward the nasal side —*i. e.*, objects to the nasal side have their images formed upon the temporal portion of the retina.

Homonymous Diplopia (Greek, ὁμώνυμος; from ὁμός, same, and ὄνυμα, name).—Figure 163 shows the right

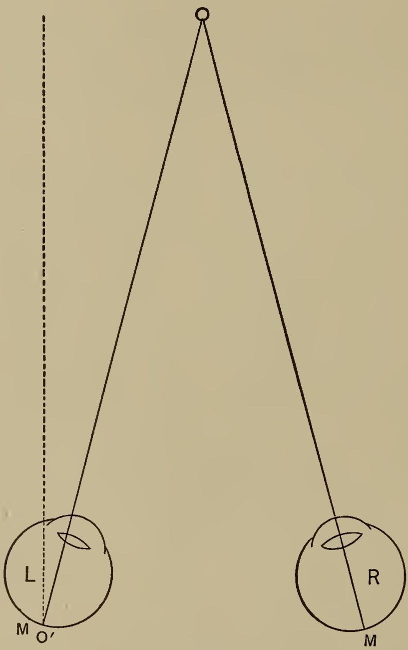

FIG. 163.

eye (R) fixing upon the object (O), but the left eye is turned inward, so that rays from O fall upon its retina to the nasal side of the fovea (M), and are projected outward to the temporal side; the result is that the left eye sees a false object to the left of the real object. This condition of the objects is spoken of as homonymous diplopia.

Heteronymous Diplopia (Greek, ἕτερος, other; and ὄνυμα, name).—Figure 164 shows the right eye fixing the object (O), but the left eye is turned outward, so that rays from O fall upon the retina to the temporal side of the fovea and are projected to the nasal side, with the result that the left eye sees a false object to the right of the real object. This condition of the objects is spoken of as heteronymous or crossed diplopia.

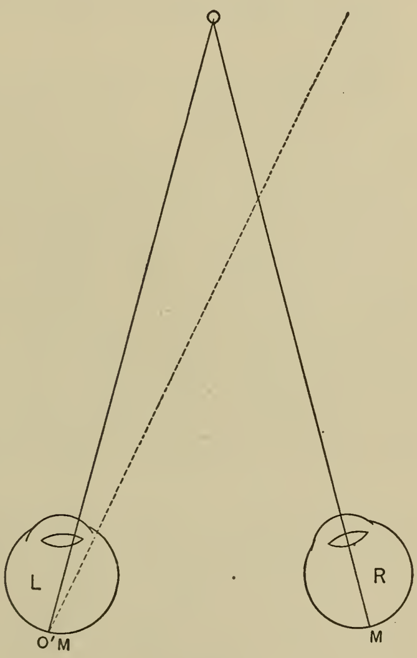

FIG. 164.

Hyperphoria (Greek, ὑπερ, over, above; φορεῖν, to tend).—In the consideration of vertical diplopia, — which is always a condition of crossed diplopia, never homonymous diplopia, — the eye which is deviated upward is spoken of as the hyperphoric eye, and necessarily its image must be lower than its fellow. For instance, if the left eye fixes an object and the right eye is turned upward, the rays of light from the object would fall upon the upper part of the retina of the right eye, and would be projected downward below the true object; and this position of the right eye is spoken of as right hyperphoria. Or if the right eye fixes an object and the left eye sees a false object below, then the position of the left eye is spoken of as left hyperphoria. Unfortunately, in hyperphoria (unless from paralysis) the position of the eyes does not tell whether the right superior rectus is too strong and the left inferior rectus too weak, or the left superior rectus too weak and the right inferior rectus too strong.

Muscle Phorometry.—Testing the power of the ocular muscles.

Abduction.—The power of the external recti muscles to turn the eyes outward. The patient is comfortably seated and told to look at a point of steady light at a distance of about 6 meters, slightly below the level of his eyes, never above the level. In this position prisms with their bases inward are placed in front of one or both eyes until the patient says he sees two lights very close together. The strength of the prism or prisms thus placed before the eyes which will just permit the eyes to see one object and if increased would produce diplopia, represents the power of the external recti muscles. This is spoken of as the power of abduction, and is abbreviated Abd. For example, if with 7 centrads, base in, before the eyes there are two lights, and with 6 centrads there is only one light, then 6 centrads would represent the amount of the abduction. In other words, in the case supposed, as long as there is less than 7 centrads before the eyes, base inward, the external recti muscles can overcome their effect, but as soon as a prism stronger than 6 centrads is used, then the external recti muscles can not counteract the effect, and diplopia is the result.

Adduction.—The power of the internal recti muscles to turn the eyes inward. The power of the internal recti is tested in the same way as the external, except that the prism is placed base outward. This is spoken of as adduction, and is abbreviated Add. For example, if with 19 centrads, base out, before the eyes two lights are seen, and with 18 centrads only one light, then 18 centrads represent the power of adduction. In other words, as long as there is a prism of 18 or less than 18 centrads before the eyes, base outward in this case, the internal recti muscles can overcome the effect; but as soon as a prism stronger than 18 centrads is used, then the internal recti muscles can not counteract the effect, and diplopia is the result. It must be remembered that the internal and external recti are antagonistic, and that the muscles of the two eyes are tested together. The relative power of adduction to abduction has been variously estimated, but most authorities are agreed that adduction is about three times that of abduction, or about 3 to 1—that is to say, in eyes with normal muscle balance, if adduction is represented by 18 centrads, then abduction should be 6; or if adduction is represented by 24 centrads, then abduction should be 8 centrads; or if adduction is 12 centrads, then abduction should be 4 centrads, etc.

Sursumduction.—This is the power of the eyes to fuse two images when one eye has a prism placed base up or down before it. For example, if a 3½ centrad prism is placed base up or down before either eye and diplopia results and persists, and then a 3 centrad is substituted and there is no diplopia, then the eyes have overcome the effect of the prism and the amount of the sursumduction is said to be 3 centrads. This test for sursumduction is made at the same distance as in testing the lateral muscles. In health the power of the superior and inferior recti muscles is, as a rule, the same—that is to say, they antagonize each other equally. The power of the superior recti is spoken of as *supraduction*, *sursumvergence;* and that of the inferior recti, as *infraduction*, *deorsumvergence.*

Muscular Imbalance.—Whenever there is any disturbance in the power, strength, or force of the ocular muscles, the condition is no longer one of equipoise, or equilibrium, or muscle balance, but is spoken of as muscular imbalance (heterophoria). From this statement it must not be supposed that the two eyes can not simultaneously "fix" an object, any more than it must be supposed that a hyperopic eye can not see or have $\frac{VI}{VI}$ vision without correcting glasses.

Just as in hyperopia distant vision may be made clear by the effort of accommodation, so in muscular imbalance the visual axes can be directed to one point of fixation by increased innervation. Muscular imbalance is subdivided into two classes—insufficiency and strabismus.

The following nomenclature of muscular anomalies, suggested by Stevens, of New York, is in common use:

Orthophoria, perfect muscle balance, equipoise, or binocular equilibrium.

Orthotropia, perfect binocular fixation.

Heterophoria, imperfect binocular balance, or imperfect binocular equilibrium.

Heterotropia, a squint or decided deviation or turning from parallelism.

Hyperphoria, a tendency of one eye to deviate upward.

Hypertropia, a deviation of one eye upward.

Esophoria, a tendency of the visual axes to deviate inward.

Esotropia, a deviation of the visual axes inward.

Exophoria, a tendency of the visual axes to deviate outward.

Exotropia, a deviation of the visual axes outward.

Hyperesophoria, a tendency of the visual axis of one eye to deviate upward and inward.

Hyperesotropia, a deviation of the visual axis of one eye upward and inward.

Hyperexophoria, a tendency of the visual axis of one eye to deviate upward and outward.

Hyperexotropia, a deviation of the visual axis of one eye upward and outward.

Insufficiency.—Also called latent deviation, heterophoria, or latent squint. This may be defined as the condition in which there is a tending or *tendency* of the visual axes to deviate from the *point of fixation*; this may be slight or transitory.

Causes of Insufficiency.—The chief cause of insufficiency is some form of ametropia. Another cause may be an anatomic defect of one or more of the ocular muscles themselves, or a weakness of the muscle or muscles individually, or as a result of some systemic weakness. The ocular muscles often sympathize with the economy.

Symptoms of Insufficiency, or Muscular Asthenopia.—Accommodative and muscular asthenopia are intimately associated, and the latter is so often the companion of the former that they produce symptoms which are identical in both and make it difficult to draw any sharp line of demarcation between the two. In muscular asthenopia, however, the patient complains that the eyes "become weak" or "tired" after any prolonged use, and that this is especially apt to occur by artificial light; that nearby objects (reading, writing, or sewing) grow dim; that the words "seem to jump," or the "letters run together," and in some cases occasionally, and in others more frequently, objects appear double for a moment. Sometimes one of the eyes feels as if it was turning outward or inward. There are innumerable reflex symptoms, dizziness, nausea, vomiting, fainting, and, in some instances, "all becomes dark for a minute." Such patients often become very anxious, fearing sudden blindness, etc.

Diagnosis or Tests for Insufficiency (Heterophoria).— Before taking up the individual tests for insufficiencies, it is well for the observer to study the movements or excursions of the eyes; and to do this the patient, with his head erect and steady in one position, fixes with his eyes the point of a pencil held in the hand of the observer at about thirteen inches distant. The pencil is moved from left to right and from right to left, and upward and downward; as this is done, the surgeon should watch closely to see that each eye has a normal mobility and the two eyes move together. From a central point of fixation the eyes should move inward about 45 degrees, outward 45 or 50 degrees, upward about 40 degrees, and downward about 60 degrees. The tropometer of Stevens will estimate the limit of motion of each eye separately, but if there is a defect in mobility, the surgeon may recognize it by comparing the distance of the corneal edge in each eye from a certain definite fixed point; for instance, whether the lid margins encroach equally upon the cornea or have equal intervals between cornea and lid edges.

The Cover Test.—The patient is told to look at the point of a pencil held in the hand of the surgeon on a level with the patient's eyes in the median line, and distant about eighteen inches, or at an object six meters distant. While the eyes fix the point of the pencil or distant object, the surgeon covers one eye with a small card, and a moment later quickly withdraws it and observes the position and movement of the eye which he has just uncovered; if it moved inward toward the nose to fix the point of the pencil, then there must have been an outward tendency of that eye when under cover; in other words, the external muscles must have been strong or the internal weak. If the eye thus released from the cover had moved outward toward the temple to fix the point of the pencil, then the external recti must have been weak or the internal strong. ' If the eye released from cover goes up to fix, then the fellow-eye deviates upward, and vice versâ. This test is not always reliable, and yet it may be a guide to further study.

The Fixation Test.—Instead of covering one eye, as in the previous test, the patient " fixes " the point of the pencil as it is slowly advanced in the median line toward the nose, up to within four inches, if necessary. During this advance of the pencil, if there is a weakness of the interni, the eye with the weaker internus is the one which will usually deviate outward.

To Determine Lateral Insufficiency.—The condition in which there is either a tendency for the visual axes to deviate outward (exophoria), or a tendency for the visual axes to deviate inward (esophoria). Proceed by producing vertical diplopia. Place a ten centrad prism base down before one eye,—for instance, the right eye,—and have the patient look at a point of light on a level with his eyes at a distance of six meters. He will see two lights, one above the other; the upper light must belong to the right eye, because the prism before the right eye bent the rays downward. If one light is directly above the other, then the condition is presumably one of equilibrium or equipoise.

If the upper light, however, is to the right, then the visual axes deviate inward (esophoria). The amount of the esophoria (insufficiency of the external recti) is represented by that prism placed base outward before the left eye which will bring one light directly above the other. If the upper light had been to the left, then there would have been a tendency of the visual axes outward (exophoria, insufficiency of the internal recti), and the amount of the exophoria is represented by the strength of prism placed base inward which will bring one light directly above the other.

To Determine Vertical Insufficiency (Hyperphoria).—Proceed by producing lateral diplopia. Place a ten centrad prism base inward before the right eye, and have the patient look at a point of light, as in testing for lateral insufficiency. (It is always well to have the point of light just in front of a large piece of black felt cloth tacked upon the wall.) If the two lights which the patient sees are on a horizontal line, then the condition is presumably one of equipoise. But if the right light is lower than the left, there is a tendency of the visual axis of the right eye to be higher than its fellow. As to which muscle is at fault, this test will not tell, and Stevens' tropometer will have to be used. The amount of the deviation is represented by the strength of prism placed base down before the right, or upward before the left eye which will bring the two lights into a horizontal line—*i. e.*, on a level.

To Determine Lateral Insufficiency at the Reading Distance.—Have the patient look at a black dot, with a black line two or three inches long running perpendicularly through it, at a distance of about thirteen inches. This is known as the line-and-dot test of von Graefe, and on a larger scale may also be used in the previous tests. A prism of seven or eight centrads is placed, with its base down, in front of the right eye. If the patient sees two dots exactly one above the other on one line, there is not supposed to be any insufficiency. If, however, there are two lines and two dots, and the upper dot is on the right, there is insufficiency of the externi (esophoria) for near. The amount of the insufficiency is represented by the strength of prism, placed base outward, before the left eye which will bring the two dots exactly on one line. If the upper dot is to the left, then there is insufficiency of the interni (exophoria) for near, and the amount of the insufficiency is represented by the strength of prism placed base inward over the left eye which will bring the two dots, one above the other, on one line.

Another method for testing lateral insufficiency at the reading distance of 13 inches is to have a card about 6 inches square, and on this card to draw a heavy black line about 3 inches long; this line is to be horizontal. At the middle of the horizontal line draw a heavy black line, one-half an inch long, extending vertically from the horizontal line; this short vertical line to be capped with an arrow-point. The horizontal line is divided off into equal

FIG. 165.—Scale for Testing Lateral Insufficiency at 13 inches.

spaces, each 3⅓ millimeters apart and numbered from 1 to 15 each side of the arrow; those to the left of the arrow are marked "esophoria," and those to the right of the arrow are marked "exophoria." (See Fig. 165.)

To use this method, a prism of 8 centrads is placed base down before the right eye; this doubles the scale vertically; the upper scale belongs to the right eye. The number and the word in the upper scale to which the arrow in the lower scale points, is the approximation in centrads of the amount of the esophoria or exophoria. For instance, if the lower arrow points to figure 9 in the upper scale to the right of the upper arrow, that is, the word "exophoria," then there is approximately 9 degrees of "exophoria" at this distance of 13 inches, the distance at which this scale is intended to be used.

These tests for insufficiencies should always be made before estimating the refraction, and also after the correcting lenses are carefully placed, with their optic centers, before the eyes.

To avoid confusion in making these tests, when a point of light is used as the fixing object, it is customary to place a piece of plane dark red glass before one eye, so that the

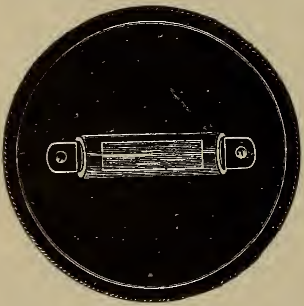

FIG. 166.—Maddox Rod.

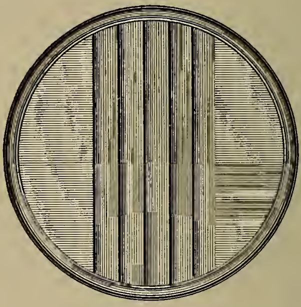

FIG. 167.

red light always corresponds to the eye with the red glass. Or a Maddox rod (Fig. 166), white or red, may be used for the same purpose. This may be a series of rods (see Fig. 167) placed in a metal cell of the trial-case, and the eye, looking through it at the light, will see the image of the flame distorted into a streak of broken light. A strong + cylinder from the trial-case will answer the same purpose. As the rod refracts rays of light opposite to its axis, the eye will see a streak of light in the reverse meridian to that in which its axis is placed. To expedite the determinations, the rotary prism of Crêtes or the revolving prisms of Risley may be employed. This latter apparatus (see Fig. 168) is composed of two superimposed prisms of 15 centrads each, and mounted in a milled-edged cell of the size of the trial-lens. By means of a milled-edged screw these prisms are made to revolve so that in the position of zero they neutralize each other, and when rotated over each other the prism strength gradually increases until the bases of the prisms come together and equal 30 centrads. The strength of the prism employed is indicated by an index on the periphery of the cell.

Fig. 168.

Stevens' Phorometer.—This is a very convenient apparatus, composed of two 4-degree prisms placed in a frame 3 ½ inches from the eyes, which with an attached lever can be rotated so as to test the strength of the vertical and lateral muscles. Indexes and letters at the periphery of the frame record the character and degree of the insufficiency. (See Fig. 169.)

Treatment of Insufficiencies.—As ametropia is the most common cause of insufficiency, the first consideration must be to select the proper correcting glasses. After this has been accomplished, if the insufficiency still persists and the patient is not comfortable, then the muscles should receive careful attention, and their condition be studied from every point of view. The patient's general health should be looked after, and if at all defective, must have remedies prescribed for its improvement. In some instances the patient may have to give up any close application of the eyes for a time and pursue an out-door life. Operative interference (tenotomy) must not be entertained until all known means for the relief of the muscular asthenopia have been exhausted.

The prescribing of prisms, as a fixed rule, for permanent use, which correct insufficiency, except in vertical errors, is often a serious mistake on the part of the surgeon, as in most instances they often do more harm than good by increasing the difficulty. Internally, sedatives will frequently

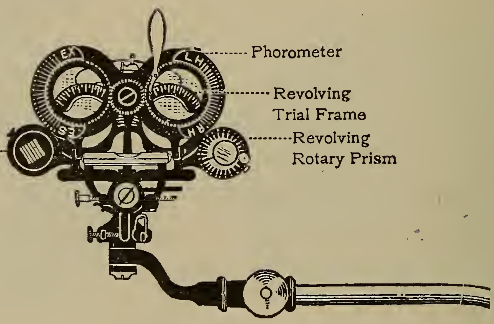

FIG. 169.

give great satisfaction and permanent relief. The writer is partial to the use of bromids with small doses of the iodid of potash three or four times a day. The *modus operandi* is not clear. The only guide that can be suggested is to use sedative treatment and rest of the eyes whenever there is a congestion of the choroid and retina and when the ophthalmoscope shows the nerve edges hazy, the retina woolly, etc. In another class of patients the internal use of nux vomica is the treatment *par excellence*, and it acts best in those cases where the nerve edges and the eye-ground in general appear clear and free from irritation.

To use nux vomica it must be given in the form of the tincture and increased, one drop at each dose, until the patient becomes quite tolerant of it, taking as high as thirty, forty, or even fifty drops three times a day, and then the dose is gradually diminished. Nux vomica does not seem to do well in cases in which the bromids are indicated as above, and vice versâ. (De Schweinitz.)

Treatment of Insufficiency of the Internal Recti.—Because the tests for heterophoria at 6 meters show an ability on the part of the patient to maintain equilibrium, it must not be supposed that there may not be an insufficiency. The normal ratio of adduction to abduction should be taken into consideration in every instance before coming to any such conclusion.

After the proper correcting glasses have been prescribed and the patient's general health looked after, attention, if necessary, should be directed to strengthening the weak muscles ; and to do this they must be given a certain amount of systematic exercise, known as ocular gymnastics. That success shall result from ocular gymnastics means perseverance on the part of the patient and the exercises systematically executed. There are two methods of procedure : in cases of exophoria—Dr. George M. Gould, "Med. News," Nov. 18, 1893—

1. Have the patient "fix" the point of a pencil, or the end of his finger held at arm's length, and slowly draw it toward the bridge of the nose. If diplopia results while doing this, the exercise should cease, and be repeated from the original distance. This is a very convenient exercise and should be practised several times a day and a number of times at each sitting.

2. **Prism Exercises.**—The patient is placed, standing, about a foot or two from a point of steady light, on a level or slightly below the level of the eyes, and told to look at

it, and at nothing else. In this position a pair of weak prisms, bases out, in a trial-frame are placed in front of his eyes.

Then he is told to walk slowly backward as he keeps his eyes fixed on the point of light. Should diplopia develop at any distance short of 20 feet, then he is to raise the prisms, go back to his original position, and start over again. Repeating this a number of times in the surgeon's office, it will be found, in most instances, that at the first practice a pair of 5 △ or 10 △ can be overcome at a distance of 20 feet. When the distance of 20 feet from the light is reached without developing diplopia, the patient is instructed to slowly count 20 or 30 (keeping the light single during this time), then raise the prisms (gazing at the light), and to slowly count 20 or 30 again. This exercise is repeated three or four times a day and a number of times at each practice. A prescription is given for such a pair of square prisms with a convenient frame to wear over the patient's glasses. These exercises should, as a rule, be conducted with the patient wearing his correction. Instead of the prism-frame, the patient may hold the square prisms with his hands; but these are tiresome to hold, and for general use the prism-frame, if not too heavy, is preferable. After a few days' practice at home, the patient returns, and stronger prisms which will permit the patient to maintain single vision are ordered. This practice with stronger and stronger prisms is repeated until the patient is able to overcome prisms greatly in excess of the normal ratio of adduction to abduction. It is often well to develop the power of the internal recti to three or four times the strength of the external recti; for when the exercises are stopped, some of the strength of adduction will rapidly disappear.

It has been incidentally mentioned that prisms should not be prescribed in combination with the ametropic correction for the treatment of insufficiency, and yet there is an occasional exception to this statement in cases which must have prompt, though temporary, relief. Occasionally, the relief may be permanent ; but this will not happen very often. When ordering prisms for such a case, it is best to prescribe them in the form of hook fronts, so that they may be thrown aside at any time. In hyperphoria the full prismatic correction (except in cases of presbyopia) is seldom ordered,—only about two-thirds of it, and this is divided between the two eyes—base down before one, and base up before the other.

Treatment of Insufficiency of the Externi (Esophoria).—As esophoria is a tendency of the visual axes to deviate inward, it will be found that patients with this form of insufficiency suffer very little, if at all, when using the eyes at near work ; their chief discomfort arises from using the eyes for distant vision. The " shopping headache," the " opera headache," the " train headache," may be due to this form of insufficiency, but it is not so apt to cause discomfort if the ametropic correction is worn constantly. In other words, if a hyperope does not wear his distance correction and accommodates at the same time that he endeavors to maintain equipoise (relative hyperopia), he may at times suffer severely. If the symptoms of muscular asthenopia persist after prescribing the ametropic correction, then prisms, bases out, may be prescribed as hook fronts to be worn over the constant correction when using the eyes for distance. It has been the writer's experience that esophoria of two, three, or four degrees seldom gives the possessor any discomfort whatever. Prism exercises for esophoria give very little benefit, and are often a waste of time ; yet they should be tried thoroughly if the case appears to demand it.

Treatment of the Insufficiency of the Superior and Inferior Recti.—Having prescribed the ametropic correction, an attempt should be made to strengthen the weak muscles by prism exercises—prism base down before one eye, and base up before the other eye. While this does not often give satisfactory results, yet it should be tried in each instance. If prism exercises do not correct the difficulty, then prisms which overcome most of the insufficiency should be prescribed for constant use. Failing in this second attempt with prisms or with a *full* prismatic correction, then tenotomy of the overacting muscle or muscles must have consideration.

Tenotomy.—As previously stated, *tenotomy should never be resorted to until every other known means of relief has been tried*, and even then no hard-and-fast rule can be given for *the amount* of the insufficiency in degrees which will prompt such a procedure. Some patients with as much as four or six degrees of esophoria may never suffer the least annoyance; and yet other patients with the same amount will estimate their sufferings as almost beyond endurance. And the same statement holds good in other forms of insufficiency, especially exophoria. The question of personal equation, the patient's nervous system, hysteric tendencies, etc., must all be considered before undertaking a tenotomy that may result in nothing but discouragement.

If an operation has been deemed best, then it is for the surgeon to decide whether he will divide the tendon of the strong muscle or advance the weak muscle, or both. Whatever operation or operations are performed, the amount of the deviation should be estimated immediately before, as well as during and after, the operation. When a simple tenotomy is performed, the eye is usually left open (unbandaged) so that visual fixation is maintained, and the muscle balance tested frequently to see that, by subsequent contraction, the insufficiency does not return. To avoid such a misfortune it may be necessary to use prism exercises during the healing process. The writer is not an advocate of partial tenotomies.

Strabismus (*στρέφω*, "to turn aside"); also called heterotropia, "cross-eye" or "squint," or manifest squint. This is a condition of the eyes in which the amount of the insufficiency is so great that it can not (always) be overcome by muscular effort; and, in fact, inspection often shows the manifest condition. Or strabismus may be defined as the condition in which the visual axis of one eye is deviated from the point of fixation. The eye which has the image of the object on its fovea is spoken of as the fixing eye, while the other eye is termed the squinting or deviating eye. The squinting eye does not always have normal visual acuity; and, in fact, correcting lenses will not always produce such a result.

Varieties of Strabismus. — Convergent, divergent, vertical, monolateral, alternating, periodic, concomitant, and paralytic.

Convergent squint (con, "together," and vergere, "to incline or approach"); also called internal squint (strabismus convergens), esotropia. This is the condition in which the visual axis of one eye is deviated inward, the other fixing the object; or one eye fixing an object, the visual axis of the other eye crosses that of the fixing eye closer than the object. (See Fig. 163.) This is the most common form of squint. Both eyes have some form of hyperopia, as a rule, the squinting eye usually being the most ametropic. The diplopia as a result of this condition is homonymous.

Divergent squint (di, "apart," and vergere, "to incline"); also called external squint (strabismus divergens), exotropia. (See Fig. 164.) This is the condition in which the direction of the visual axis of one eye is directed outward, the other eye fixing the object; or one eye fixing an object, the visual axis of the other eye can cross it only by being projected backward. The diverging eye is usually myopic.

Monolateral (one-sided) **squint**; also called constant. It may be either convergent or divergent, but the squint is a constant condition of one eye.

Alternating Squint.—This is the condition in which at different times the right eye fixes and the left eye squints, or the left eye fixes and the right eye squints. The vision in one eye may be as good as that of its fellow.

Periodic squint; also called intermittent. This is the condition in which the visual axis of one eye *occasionally* deviates. It may eventually become constant, and is often the first indication of a beginning convergent or divergent squint.

Vertical Squint.—This is the condition in which the visual axis of one eye is deviated upward. Also called hypertropia.

Concomitant Squint.—This is the condition in which the squinting eye has freedom of movement and will follow its fellow, and yet one eye deviates (inward or outward) because of an inability to "fix."

Paralytic Squint.—This is the opposite condition from concomitant, in which there is a restriction in the movement of one eye in a certain direction, due to a palsy of one or more of the muscles.

Causes of Squint.—These are many and various. The chief causes, however, are: (1) Ametropia, which may produce a change in the normal relationship between accommodation and convergence; (2) anatomic anomalies; (3) mechanic anomalies; and (4) amblyopia.

1. **Ametropia** produces a change in the normal relationship between accommodation and convergence. While it is possible for accommodation to take place without convergence, or convergence without accommodation, yet there is an affinity between the two processes which, if materially interfered with, will produce diplopia and eventually squint. In speaking of relative hyperopia, it was shown that the accommodative effort was accompanied by contraction of the internal recti muscles (convergence); so that in hyperopia of, say, four diopters, accommodating for infinity convergence would be stimulated to a proportionate degree at the same time; and if accommodating for a near point, the hyperope must accommodate and converge just that much more. The result is that a person with a hyperopia of any considerable amount frequently squints inward in the effort to maintain binocular vision. If, now, one eye is more hyperopic than the other, the difficulty of adjusting convergence to accommodation is increased. Say that the right eye has 3 diopters and the left 4 diopters of hyperopia; then the two eyes each exert 6 diopters to fix at 13 inches; the left eye still has 1 diopter of its hyperopia remaining, and with the result that the retinal image of that eye is not clear, and accommodation is still further taxed, stimulating at the same time the internal rectus, so that the left eye deviates inward and ultimately remains convergent. This act of convergence explains the presence of convergent squint in hyperopia, and also shows why the squinting eye usually has the higher refractive error. It must not be supposed that all hyperopic eyes have a squint, as some of these can

accommodate without converging in a proportionate degree, and this is especially so when the amount of the hyperopia is the same in both eyes.

Myopic eyes, in contradistinction to hyperopic eyes, can not accommodate beyond their far points, but must converge. If the myopia is 8 diopters, then these eyes would have to converge 8 meter angles to fix an object at that distance (5 inches) without any accommodative effort. It must also be borne in mind that myopic eyes are long eyes, and that to converge 8 meter angles means a great effort on the part of the internal recti muscles, and this force can not be continued for any length of time without discomfort; the result is, convergence is relaxed, and, one eye remaining fixed, the other is turned outward. This is much more likely to happen if one eye is more myopic than the other. This explains the presence of divergent squint in cases of myopia. But it must not be supposed that all myopic eyes necessarily have squint, as some of them have roomy orbits, strong internal recti muscles, and a short interpupillary distance.

2. **Anatomic Anomalies.**—This applies especially to the breadth of the face (skull) and the size of the eye and orbit. The broad face, which naturally gives a long interpupillary distance, predisposes to greater convergence than the narrow face. The long, myopic eye would not have the freedom of movement that the short eye possesses in the same-sized orbit.

3. **Mechanic Anomalies.**—This refers especially to the length and strength of the extraocular muscles. Short and strong internal recti would predispose to convergent squint, whereas strong external recti would develop divergent squint.

4. **Amblyopia.**—Statistics show that from thirty to seventy per cent. of all squinting eyes are amblyopic. The cause of the amblyopia may be that the eye was born defective in its seeing quality—*i. e.*, the cones at the fovea, the optic nerve, or the visual centers in the brain may be at fault. Or if born perfect and having its visual axis deviated by one of the many causes above mentioned, it may become amblyopic from not being used (amblyopia exanopsia). This consideration of cause and effect is most important from a prognostic point of view.

Among other causes of squint must be mentioned opacities of the media, as nebula of the cornea, or any want of transparency in the cornea at or near the visual axis, or polar or nuclear cataract. Temporary or intermittent squint may result from vitreous opacities, or from the remnant of a hyaloid artery passing in front of the fovea. Parents occasionally delude themselves with the idea that the child's squint is the result of whooping-cough, measles, teething, sucking the thumb, or imitating a companion, etc., and are slow to believe that there can be any refractive error, forgetting that the supposed causes they mention may be but coincidences.

To Estimate the Amount of the Strabismus or Squint.—This is not always easy at the beginning of the examination, for the reason that the squinting eye has long since learned to ignore the false object; and if the angle of the strabismus is large, the surgeon will have to reduce it in part with a prism, so that the patient can see the false object; and if this is a point of light, a piece of dark red glass will have to be placed in front of the fixing eye. The strength of the prism required to bring the two lights together will be the prismatic estimate of the deviation. Or the amount of the squint may be roughly determined with the strabismometer. (See Fig. 170.) This is a piece of bone or ivory hollowed on one side so as to fit the curve of the eyeball. Its edge is graduated in millimeters. This device is held gently against the lower lid of the squinting eye, so that the zero (o) mark corresponds to the center of the pupil as the eye fixes a distant object, the fellow-eye being under cover. When the cover is removed, the squinting eye again deviates, and the amount of the deviation is again noted by the position of the center of the pupil of the squinting eye over the millimeter line on the instrument. Each millimeter of deviation is supposed to represent 5 degrees of deviation. This device is not reliable, and is not in common use.

Fig. 170.

A more reliable estimate is obtained by measuring the deviation on the arc of the perimeter. (See Fig. 171.) To do this, the patient is seated with the squinting eye opposite to the fixation point (R) and instructed to look at a distant object (R) across the room, so that the object, the fixation point, and the squinting eye (R) are in line; this line represents the direction which the eye would take normally. The observer, taking a lighted candle, places it at the fixation point and gradually moves it outward along the inner surface of the arc until his own eye, *directly back of the flame*, sees an image of the flame at the center of the pupil of the squinting eye. The degree mark on the arc from which the flame was pictured represents the amount of the deviation or angle of the strabismus; this angle being formed by the visual axis with the direction of the normal visual line. The degree mark on the arc is in front of the

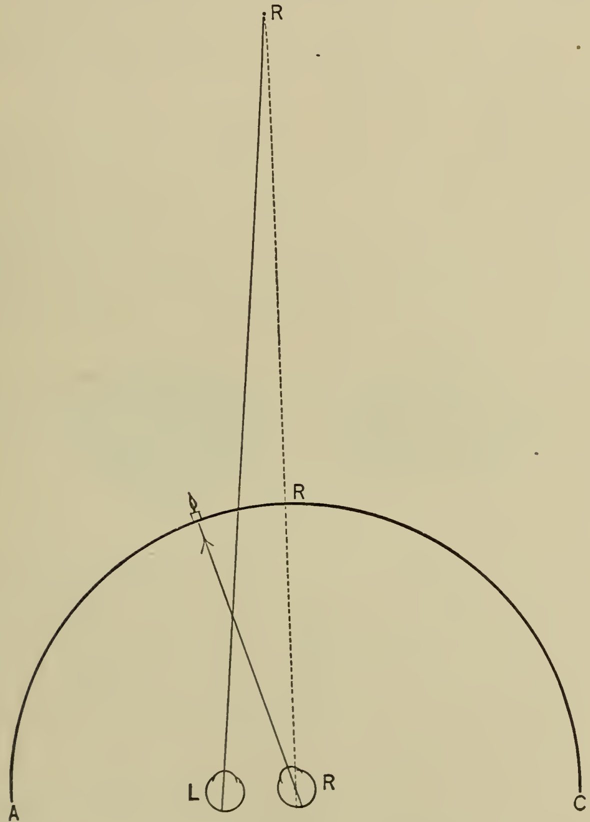

FIG. 171.

optic axis and not the visual axis, but for purposes of approximation they are considered as the same.

Treatment of Strabismus.—As ametropia is the chief factor in the cause of squint, this cause must be promptly removed by the use of correcting glasses. The correction of the ametropia means four essentials :

1. In young subjects the eyes must be put at rest, and kept at rest for two, three, or four weeks, with a reliable cycloplegic and dark glasses. Preference is given to atropin in each instance, the writer considering it folly to use homatropin in such cases.

2. During the use of the cycloplegic, the lenses which correct the ametropia are selected with care and the greatest precision, by every known means to this end ; and just here is the place of all places to use the retinoscope, as most cases of strabismus appear in children, and, too, the squinting eye often being amblyopic, can not assist in the selection of the glass.

3. The correcting glasses are ordered in the form of spectacles, and are to be worn from the time of rising until going to bed. The strength of the glasses should be as near the full correction as it is possible to give.

4. The "drops" are continued for a day or two after the glasses have been obtained, and in this way, while the drops are still in the eyes, and as their effect slowly wears away, the eyes gradually become accustomed to the new or natural order of accommodation and convergence. After the cycloplegic has entirely disappeared, the patient should be carefully restricted in the use of the eyes for near-work for several days or weeks.

As hyperopia and astigmatism in combination are generally congenital conditions, it therefore follows that convergent squint appears quite early in life, as soon as the child begins to concentrate its vision on near objects. The squint, at first periodic or intermittent, finally becomes constant. Such eyes should be refracted at once, and before amblyopia exanopsia can be established. It is interesting to note that the eyes in many young children begin to fix or lose their squint as soon as cycloplegia is established. The prognosis is favorable for good vision with glasses when this occurs. It will also be observed in other subjects that while the drops are in the eyes and glasses worn constantly, the squint disappears entirely ; but as soon as the cycloplegia passes away and near vision is attempted, the squint returns, and vision falls back in the squinting eye to almost the same point that it had before the cycloplegia. This occurs in cases where the amblyopia is becoming established, or where there is a strong muscle deviating the eye. If the squint is due to amblyopia exanopsia, then the vision may be improved in one of two ways, as

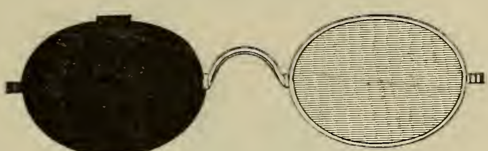

FIG. 172.

suggested by Dr. G. M. Gould, "Amblyopiatrics," "Med. News," Dec. 31, 1892. One way is to use drops in the fixing eye, and thus compel the squinting eye to do the seeing ; or the other way is to cover the fixing eye with a blank over the glass (see Fig. 172), and have the patient practise in this way for one or two hours each day, using the squinting eye alone.

Worth's Amblyoscope or "Fusion Tubes."—To cultivate or develop binocular vision Worth has given us an instrument which he calls an amblyoscope. (See Fig. 173.) This instrument consists of two halves joined by a hinge. Each half consists of a short tube joined to a longer one at an angle of 120 degrees; at the junction of the tubes is an oval mirror. A translucent glass object slide is placed at the distal end of each tube. At the hinged ends are lenses whose focal length equals the distance of the reflected image of the object slide; in front of these lenses are grooves into which additional lenses of the trial case may be placed to correct the refractive error of the patient. The two halves of the instrument are united by an arc, having a long slot at one end and an adjusting screw at the other. The object slides can be brought together to suit a convergence of 60 degrees, or a divergence of the visual axes of 30 degrees. When the adjusting screw is used an additional movement of 10 degrees is obtained.

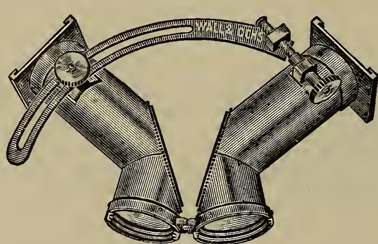

FIG. 173.—Worth's Amblyoscope. (Reduced size.)

At the far end of each tube there is also a square slot into each of which may be placed half a pictured object; for instance, a picture of the right side of a man, showing his arm and leg extended, may be placed in the left tube, and in the right tube is placed a picture of the same size, of the left side of the man with his leg and arm similarly extended. When the patient looks into the tubes, the surgeon (or the patient) may adjust the tubes until the two half pictures unite and form one complete picture. Or the picture in one tube may be a picture frame, and in the other tube is a picture of an animal or an object, the idea being to have the patient so fuse the two pictures that the object is placed in the frame. There are many different pictures accompanying the instrument so as to give variety to the daily exercises and thus maintain the patient's interest. This instrument is certainly a valuable one and in many instances accomplishes its purpose.

Cases that are cured by correcting the ametropia must wear their glasses constantly. Glasses in such cases can seldom be abandoned. In young children the squint returns almost at the instant the glasses are removed. The earliest age at which glasses can be prescribed is three years or thereabouts, as it would be unreasonable in *most* cases to expect a child to appreciate the glasses as anything but a toy before this age.

The younger the patient when glasses are prescribed, the more favorable the prognosis and less likelihood of a tenotomy. The older the patient when glasses are ordered, the less the likelihood that glasses will cure the squint and the greater probability of a tenotomy being necessary. This is explained from the fact that the squint having persisted for a long time, the muscle which held the eye in the deviated position has grown strong and the opposing muscle weak.

The correction of squint by glasses applies particularly to cases of the concomitant (convergent or divergent) form. Vertical squint is seldom cured by correcting glasses alone. Prisms will occasionally substitute for an operation.

Monocular and alternating squint are greatly relieved by the correction of the ametropia, and may or may not be cured with glasses alone.

Periodic or intermittent squint, if due to permanent opacities in the media, can not, as a rule, be cured by any form of treatment.

Paralytic squint is not a part of the subject-matter of this work. Cases of concomitant squint are generally amenable to operative treatment, whereas cases of paralytic squint are not.

It may be stated as a good rule to follow that *no case should ever be operated upon until the glasses which correct the ametropia have been worn constantly for several weeks after all apparent improvement has ceased.* If cases for operation can be selected, the best age is about puberty, when the muscles have reached a fair state of development. If the squint is due to an anatomically short muscle, then there need not be any great delay in operating after glasses have been ordered.

Whenever a tenotomy has been performed, the eyes should again be carefully refracted, as it is a well-established fact that tenotomy often relieves a tension that will materially change the radius of corneal curvature; and hence the amount of the astigmatism and the cylinder axis will be altered.

Tenotomy.—For convergent squint, if of moderate degree, division of the tendon of the internus of the converging eye may be sufficient; but if the squint is considerable, the tendons of both interni may have to be divided. Occasionally, it is necessary to divide the internus and advance the externus.

For divergent squint, if of moderate degree, division of the tendon of the externus of the diverging eye may be sufficient; but if the squint is considerable, the tendons of both externi may have to be divided. Occasionally, it is necessary to divide the externus and advance the internus.

For vertical squint, tenotomy of the stronger superior or stronger inferior rectus, or both, may be necessary.

It is good practice in every instance, before "rushing" into an operation for squint, to take the field of vision and search carefully for a central scotoma, which, if present, should put the surgeon on his guard against operative interference with the hope of obtaining any result other than cosmetic ; and even then there is grave danger that the case will soon lapse into the former state of deviation, or possibly deviate in the opposite direction.

CHAPTER VIII.

CYCLOPLEGICS.—CYCLOPLEGIA.—ASTHENOPIA.—EXAMINATION OF THE EYES.

A cycloplegic (from the Greek, κυκλος, "a circle,"—*i. e.*, the ciliary ring,—and πληγή, "a stroke") is a drug which will *temporarily* paralyze the action of the ciliary muscle.

A mydriatic (from the Greek, μυδριασις, "enlargement of the pupil") is a drug which will *temporarily* dilate the pupil.

Atropin will dilate the pupil and also cause a paralysis of the ciliary muscle. Cocain will cause a dilatation of the pupil, but will not paralyze the action of the ciliary muscle. A cycloplegic is also a mydriatic, but a mydriatic is not necessarily a cycloplegic.

The Uses of a Cycloplegic.—(1) To temporarily suspend the action of the ciliary muscle, or to put the eye in such a state of rest that all accommodative effort is for a time suspended while the static refraction is being estimated. (2) The retina and choroid are given an opportunity to recover from irritation and congestion incident to eye-strain ("eye-stretching"). There are many different cycloplegics employed for estimating the static refraction, and each has particular qualifications for individual cases. Cycloplegics may be classed as of three kinds: (1) those the effect of which passes away slowly; (2) those the effect of which passes away moderately fast; and (3) those the effect of which is very brief.

The first effect of a cycloplegic is its mydriatic quality, after which the accommodative effort is suspended. The paralysis is not permanent. The following table, from Jackson, shows the length of time paralysis persists and the time it takes for the ciliary muscle to fully recover :

Atropin,	effect	begins to	diminish in	4 days;	complete	recovery,	15	days.
Daturin,	"	"	"	3 "	"	"	10	"
Hyoscyamin,	"	"	"	3 "	"	"	8	"
Duboisin,	"	"	"	2 "	"	"	8	"
Scopolamin,	"	"	"	12 hours.	"	"	6	"
Homatropin,	"	"	"	12 "	"	"	2	"

If a solution of one of the above-mentioned cycloplegics be instilled into the conjunctival sac of a healthy eye, it will be carried by the blood- and lymph-vessels at the sclerocorneal junction into the ciliary muscle and iris, where it acts directly upon the nerves and ganglia of these structures, and the aqueous humor also receives some portion of the drug. If cautiously used, the action will be limited to one eye, showing that the drug does not pass through the cardiac circulation ; otherwise, the pupil and ciliary muscle of the fellow-eye would be similarly affected.

Some conjunctivas are very sensitive to any of these drugs, and develop an inflammation so severe in individual instances as to resemble ivy poisoning of the lids. Duboisin especially, and hyoscyamin, by absorption, may develop hallucinations and even a loss of coordination.

Any cycloplegic, in fact, when carelessly used, may produce very unpleasant symptoms, such as dizziness, dry throat, flushed face and body (mistaken for scarlatina), rapid pulse, a slight rise of temperature, and delirium. To avoid such an annoyance, which is apt to reflect discredit upon the physician and upon the profession in general, the patient should always be given definite instructions how to use the drug in each instance. Stopping the use of the drug and applying cold compresses will relieve the conjunctivitis, and if constitutional symptoms manifest themselves, a dose of paregoric, cooling drinks, a darkened room, and stopping the use of the drug will soon restore the patient.

FORM OF PRESCRIPTION.

Name, MR. BROWN.
℞. Atropin. sulphatis, ... gr. j
Aquæ dest., ... f℥ ij.
M. Ft. sol. *Label*, poison drops ! !
SIG.—One drop in each eye three times a day, as directed.
℞. Dropper. DR. ———
Date, Tuesday, March 14, 1899.

The reason for labeling this prescription "poison drops" is not to frighten the patient, but to caution him against leaving the medicine where children may get hold of it, and at the same time to let him understand that it is to be used and handled with care.

Mr. Brown is told to have one drop put in each eye three times a day, after meals, and to report at the office on Thursday (the prescription is given on Tuesday in this case). The reason for using the drug for this length of time is to insure complete paralysis, and also to give the eyes a physiologic rest. In having these "drops" put in the eyes, the patient should tip his head backward and turn his eyes downward, and as the upper lid is drawn up, one drop (from the dropper) is *placed* (not dropped) on the sclera at the upper and outer part. After the drops are placed in the eyes, as far away from the puncta lachrymalia as possible, the patient holds the canaliculi closed by gently pressing with the ends of the index fingers on the sides of the nose at the inner canthi for a minute or two. If more than one drop enters the eye, it will run over on to the cheek, and should be wiped off. With children, these instructions are not so easy of execution, and the writer has seen a few such clinical subjects flushed and delirious from gross carelessness on the part of parents in dropping the medicine into the inner canthi, where it soon passed into the nose, or else the drug is allowed to flow over the cheek and into the child's open mouth. Ordinarily, there need *never* be any discomfort from the use of these drugs beyond a slight dryness of the fauces.

Caution.—Cycloplegics should never be used when there is the least suspicion of glaucoma in one or both eyes. Cycloplegics should not be used in the eyes of nursing women; such patients are peculiarly susceptible to the action of these drugs, and the mammary secretion may thereby be diminished in amount. After the age of forty-five or fifty years, or in the condition known as presbyopia, it is seldom necessary to use a cycloplegic. If a cycloplegic is necessary in presbyopia, one of the weaker drugs is generally employed.

In the selection of a cycloplegic the surgeon must be guided by the patient's occupation, age, the character of the eyes, and the refraction. From the foregoing table it will be seen that atropin and daturin are slow in passing from the eye, making their employment on this account very objectionable in many instances. The accommodation returns sooner after the use of hyoscyamin and duboisin than from atropin, but not so promptly as from scopolamin and homatropin. The effect of the latter is very brief. A patient who might lose his business position if he remained away from work for more than a week could not afford to have atropin or daturin used in his eyes, whereas a school child might accept atropin as a luxury. The man of business, the cashier in a bank, the storekeeper, and others must, in many instances, have their eyes refracted in at least two days; and this latter time means, of course, the use of homatropin. The nearer the age to forty years, the less need for one of the stronger cycloplegics, as the power of accommodation has markedly diminished at this period of life, so that hyoscyamin or scopolamin will answer every purpose. After thirty-five years homatropin can, as a rule, be relied upon as a cycloplegic.

In hyperopic eyes of young subjects it is useless to employ homatropin, as the active ciliary muscle requires a strongly acting cycloplegic to stay the accommodative power. In myopic eyes one of the stronger cycloplegics may be used to advantage, for the following reasons: Myopic eyes have large pupils, as a rule, and do not mind the mydriasis; myopic eyes are often in a state of irritation, and the drug gives them a much-needed rest; the myope's distant vision is not disturbed by the cycloplegic, as in the case of the hyperope.

Whenever a cycloplegic is prescribed, the patient should be ordered a pair of smoked-glass spectacles to wear during the mydriasis. Of the two forms of smoked glasses,—coquilles and plane,—the latter should always be preferred, as they are without any refractive quality, whereas coquilles have some form of refraction that may act very injuriously. Another reason for ordering the plane glass is that the patient will often wish to wear them with his prescription glasses, which he could not do so well if they were coquilles. Dark glasses are of four shades of "London smoked"—A B, C, and D, A being the lightest shade and D the darkest. The prescription would be:

For Mr. Brown:

℞. One pair plane London smoked "D."

Sig.—For temporary use. Dr. ———

March 14, 1899.

The cycloplegics above mentioned for purposes of refraction are ordered in the following strengths:

Atropin. sulphatis, ...	gr. j to aq. dest., . .	f ʒ ij.
Duboisin. sulphatis, ...	gr. ss " " " . .	f ʒ ij.
Hyoscyamin. sulphatis, ...	gr. ss " " " . .	f ʒ iss.
Daturin. sulphatis, ...	gr. ss " " " . .	f ʒ ij.
Scopolamin. hydrochlor., ...	gr. j " " " . .	f ℥ j.

All these, except scopolamin, are ordered to be used three times a day, preferably after meals; but scopolamin being a very powerful drug, the surgeon should place it in the patient's eyes himself in the office, and not give a prescription for it. Only two drops are necessary, and are instilled a half-hour apart, the static refraction being estimated one hour after using the second drop.

How to Use Homatropin.—This drug is expensive, and it is never necessary to prescribe more than one grain for any one patient. Personally, the writer has found the following most satisfactory, though the strength of the homatropin may be increased if desired:

For Miss Robinson:
℞. Homatropin hydrobromate, ... gr. j
Aq. dest., ... ♏ xl.
M. Ft. sol. *Label*, poison drops!!
Sig.—One drop in each eye, as directed.
℞. Dropper. Dr. ———
March 14, 1899.

One drop of this solution instilled into a healthy eye will produce mydriasis in a few minutes, but its action on the ciliary muscle is so trifling that the near point will be but slightly changed. It is thus shown that this drug is a decided mydriatic, and only becomes a cycloplegic under definite usage.

To produce cycloplegia with homatropin, the patient is given the above prescription and told to use it as follows:

To place one drop in each eye at bedtime the first night. This one drop dilates the pupil and establishes a change in the circulation of the blood-supply to the iris and ciliary body—a very important matter for the patient's comfort, and at the same time preventing a tendency to spasm of the ciliary muscle. The next morning one drop is to be placed in the eye every hour, from the time of rising until leaving home to go to the surgeon's office. At the office one drop is placed in each eye about every five minutes, until six drops have been used; then, after waiting half an hour (for the cycloplegic effect, which will last for one hour), the refraction is carefully estimated. After a short interval the cycloplegic effect will begin to rapidly disappear, so that the patient will be able to read within forty-eight hours' time with his correcting glasses.

Occasionally, a busy patient will insist upon having his eyes refracted during his first visit, and can not take time to use the drops in the manner above suggested. The surgeon must, therefore, start and use the drops in his office. This is *forcing* the ciliary muscle into a state of paralysis that does not always give ultimately satisfactory results. "Forcing" homatropin into an eye in this way will always produce a "bloot-shot" eye (hyperemia of the conjunctiva, etc.) that does not improve a patient's appearance; and it often produces severe neuralgic headache that may result in nausea or vomiting in occasional instances. Furthermore, it is possible, with a drug like homatropin, if not properly used, to have some of the sphincter-fibers become paralyzed while others may remain free to act. In this way a spasm of the ciliary muscle may be produced that will give a false astigmatism. Personally, the writer is not partial to this method of forcing the ciliary muscle into repose.

To somewhat obviate the "blood-shot" condition of the eye, and also to assist the action of the "forcing" process, one drop of a two or four per cent. solution of cocain may be instilled while the homatropin is being used. This also diminishes the danger of spasm. But cocain is objectionable in that it will, in some cases, "haze" the cornea. The retinoscope will show this, and the patient will state that, while he can see the letters on the test-card, yet they have a "mist" over them. Instead of using the homatropin alone, a small amount of cocain may be added to the solution for the purpose mentioned. Or, homatropin may be combined with cocain and chlorid of sodium in the form of a disc, and one of these, placed in the conjunctival sac, is allowed to dissolve, and in this way paralyze the accommodation. Or, homatropin may be used in a solution of distilled castor oil. It is *claimed* that when the drug is used in this form, it remains in contact with the tissues and acts more energetically.

Homatropin as a cycloplegic should be held in reserve for individual cases, and not used as a routine practice. It is a good, reliable paralyzer of the accommodation in many eyes at the age of thirty-five, or thereabouts ; but in a young hyperopic eye it is a waste of time to attempt successful paralysis with it, and the danger of producing a false astigmatism should certainly deprecate its use in these cases. Another very serious objection to its use is that before the eyes can become accustomed to the prescription glasses, the ciliary muscle recovers and begins to accommodate, with the result that the patient says he can see better at a distance without his glasses than he can with them, and has no small amount of mistrust of the surgeon's ability, as he will have to wear his glasses a long time before his ciliary muscle will relax its accustomed accommodative efforts. This is not nearly so likely to occur if one of the slowly acting cycloplegics is used.

The method of refracting with one of the slowly acting cycloplegics, and then endeavoring to counteract the effect with a solution of eserin, is not recommended. Temporarily, eserin may overcome the cycloplegic ; but as its action is only transitory, the paralysis reasserts itself and will not disappear until the specified time.

Refracting one eye at a time with a cycloplegic while the patient pursues his occupation with the other eye is not a method to be considered. This means a great amount of discomfort, headaches, eye-strain, and even diplopia at times, during so prolonged a treatment.

If a hyperopic patient must occasionally use his eyes for near work while he has drops in them, a pair of +3 or +4 spheres may be given for temporary use.

Cycloplegia.

Cycloplegia is a paralysis or paresis of the ciliary muscle. This condition may be monocular or binocular ; it may be partial or complete. Mydriasis may or may not accompany the cycloplegia, though the two conditions usually occur together ; and when they both exist, the paresis is spoken of as ophthalmoplegia interna. The ciliary muscle and sphincter of the iris are controlled by branches from the third nerve ; but these branches are from independent centers ; the fibers going to the ciliary muscle arise beneath the floor of the third ventricle, in front of the fibers which go to control the sphincter of the iris.

Causes.—Temporary paralysis of the ciliary muscle and iris, as already stated, will result from the external or internal administration of a cycloplegic. It is interesting, in many cases, to find the cause and relieve the patient's anxiety when the paresis is due to one of the cycloplegics. Aside from the use of eye-drops, the question of external medication (liniments, ointments, and plasters) should be inquired into, as also whether rectal or vaginal suppositories containing a cycloplegic have been used.

Other causes of this form of paralysis are tonsillitis, quinsy, diphtheria, Bright's disease, rheumatism, gout, exhausting diseases, blows upon the eye, etc. Other and more serious causes, as controlling a guarded prognosis, are intracranial hemorrhage, meningitis, syphilis, brain tumor, etc. In some instances the cause can not be definitely ascertained.

Symptoms and Diagnosis.—Photophobia, dilatation of the pupil, and loss of accommodative power consistent with the optic condition of the eye.

A myopic eye retains its vision at the far point only; an emmetropic eye or a hyperopic eye wearing correcting glasses has good distant vision and absence of a near point; an uncorrected hyperopic eye has poor distant and near vision.

Prognosis.—This depends upon the cause.

Treatment.—This must be symptomatic and expectant, with a removal of the exciting cause, if possible. As many cases of cycloplegia are the result of, or follow, an attack of diphtheria, or a disease which has reduced the system below par, tonics, fresh air, etc., must be ordered. When brought on by syphilis, mercury and iodid of potash must be prescribed. Dark glasses for the photophobia should always be ordered, and lenses for near-work may be worn as a temporary expedient. The use of eserin locally will occasionally do good work, but is *not* advised for constant use or for every case. Faradism may be used if the cycloplegia is very persistent, but the best results may be expected from systemic treatment. The use of strychnin or nux vomica are recommended in certain instances.

Cramp of the Ciliary Muscle.

Cramp of the ciliary muscle is the opposite condition to that of cycloplegia, just described. Ciliary cramp may occur in one or both eyes, usually in both; it may occur in any form of ametropia or in emmetropia. Ciliary cramp is of two kinds—clonic and tonic.

Clonic cramp is an occasional and temporary condition which comes on while the eyes are in use, and passes away soon after the eyes have had an opportunity to rest, and may not occur again for several days.

Tonic cramp, also called "spasm" of the accommodation, is a permanent condition as compared with the clonic form, and occurs whenever the eyes are used for distant or near vision. The patient can not use his eyes for any length of time, or with any considerable concentration, without suffering as a consequence.

Causes.—Clonic cramp may occur as one of the early symptoms of presbyopia. Ametropia is a very common cause, and especially in cases of low amounts of hyperopia or myopia. Emmetropia, or eyes made emmetropic with glasses, may develop clonic or even tonic cramp if the eyes are used to excess or in a bad light. Such cases have been called "hyperesthesia of the retina." Tonic cramp may develop from the same causes which bring on the clonic form, and is usually seen among young hyperopic children, or the "pseudo-myope" already described. It also occurs occasionally in hysteric patients or those recovering from some severe or long illness. The writer has seen this form of cramp precede or antedate by several weeks a collapse of the nervous system—*i. e.*, nervous prostration.

Symptoms.—Naturally, ciliary cramp means ocular pains and headaches. Opera headache, "train headache," "shopper's headache," "bargain-counter headache," etc., are some of the many names given to cramp of the ciliary muscle, and are, no doubt, the result of accommodative effort in a bright light or watching moving objects, these symptoms being a part of the history of accommodative asthenopia (already described) and accompanying insufficiency of the muscles. Symptoms of myopia are very evident during the cramp. In the tonic cramp the ocular pains and headache may be so excruciating in individual cases as to make the family physician and patient dread cerebral disease until the immediate cause is found out.

Treatment.—As the cause is usually one of ametropia, this must be corrected by the careful selection of glasses while the eyes are undergoing a *prolonged* rest with a cycloplegic and dark glasses. Later on the patient must be cautioned against any overuse of the eyes. The general health should have any necessary attention. Sedatives, alteratives, and tonics have their place in individual cases. Reflex causes must be looked for and, as far as possible, removed. Insufficiencies should always be carefully searched for, and frequently prism exercises to develop the strength of the weak muscles may give marvelous results. Unfortunately, there are occasional instances of tonic cramp that persist in spite of any treatment, and such cases obtain relief only when presbyopia definitely asserts itself.

Asthenopia (from the Greek, ἀ priv.; σθένος, "strength"; ὤψ, "eye") means a weakness or fatigue of the eye, applying especially to the retina, the ciliary muscle, the extra-ocular muscles, or a general weakness of any one or two or all of these structures in one and the same eye. Asthenopia is a disease, and is often spoken of as "weak sight," "eye-strain," or "eye-stretching."

Varieties.—For purposes of study, differential diagnosis, and treatment, asthenopia, or eye-strain, has been divided into the following varieties: Retinal, muscular, accommodative, and asthenopia due to a combination of any two or all three varieties.

Retinal Asthenopia.—This is the rarest form of asthenopia, and usually occurs in females. It is brought about by overuse of the eyes in too dim or too bright a light, and may result from a too prolonged use of the eyes at any kind of work or in any kind of light. It may result from exposure to the sun's rays, to electric lights, or to lightning, or by reflection from bright objects, such as snow, etc. Retinal asthenopia may occur as a *symptom* of hysteria, or in a patient whose nervous system is peculiarly susceptible to vibrations, sounds, and lights; in a patient whose nervous system is an uncertain quantity. Such patients are very unsatisfactory to treat or even to examine; they often imagine that the reflected light from the ophthalmoscope or retinoscope is "very hot," etc.

Symptoms.—The chief symptom is a dread of light (photophobia), or photophobia and lacrimation together.

Treatment.—The first thing to do is to remove the cause, if this can be found; otherwise the treatment should be very conservative. Ametropia must be corrected and the eyes be given some regular work; in other words, it is not good practice to restrict all use of the eyes. The treatment with "tinted glasses," made so much of by the charlatan to "gull" the innocent public, should not be ordered, as the patient grows accustomed to them and they eventually become an absolute necessity on all occasions. Careful attention to the general health is certainly indicated; tonics, out-door sports, etc., should be prescribed in individual cases. The shade of the trees is to be recommended in preference to the seashore and bright reflection from the sand and water.

Muscular Asthenopia.—This is due to weakness or fatigue of one or more of the extra-ocular muscles, most frequently the interni (exophoria). Muscular asthenopia of the exophoric kind is the result, as a rule, of a want of power to maintain convergence. The symptoms are in keeping with a cramp followed by a relaxation of converging power. Ocular pains, eyeballs tender to the touch (perchance the internal recti themselves become sore to the touch or feel sore on movement of the eyes), and in some cases the conjunctiva and subconjunctival tissues overlying the muscles become hyperemic during or after the use of the eyes, simulating rheumatism of these structures. In other cases dim vision and diplopia will be occasional manifestations. Patients with muscular asthenopia occasionally find that they can continue at near work by using one eye, but this does not occur very often.

Treatment.—This resolves itself into the correction of the ametropia, exercise of the weak muscles, etc. (See chapter on Muscles.)

Accommodative Asthenopia.—This is by far the most common form of asthenopia, and is due to fatigue of the ciliary muscle; it is, therefore, to be expected in hyperopic eyes. It is caused in various ways: from overuse of the eyes in too bright or too dim a light, or from using the eyes for too long a time in any kind of a light. The best pair of eyes, if overtaxed, may suffer from accommodative asthenopia, even when wearing the ametropic correction. Or accommodative asthenopia may result from a weakness of the ciliary muscle as a part of the general condition of the whole body, and this may come on after or during some long illness, such as typhoid fever. Accommodative asthenopia is often present in the early months of presbyopia.

Symptoms.—The principal symptom is headache—frontal, frontotemporal, or fronto-occipital; or this pain or discomfort may extend into the neck or between the shoulders. The headache develops during the use of the eyes, and grows worse if the effort is prolonged, and usually ceases after the eyes are rested. See chapter on Hyperopia and Myopia.

Treatment.—When glasses are necessary, they should be ordered by the static refraction. The general health of the patient should receive careful attention. An out-of-door life will often be necessary, and in certain cases the time for using the eyes at any near-work will have to be very much restricted.

Accommodative with Muscular Asthenopia.—This variety of asthenopia embraces the two forms just mentioned, and its description and treatment are included in both.

Reflexes Due to Eye-strain.—Among the symptoms of the various forms of asthenopia described on the previous pages, the writer has avoided any decided reference to reflex symptoms, preferring to speak of these reflexes in a general way under one heading. Many patients who suffer from headaches, ocular pains, etc., during the use of their eyes, also very frequently suffer from constipation, indigestion, heartburn, nausea, or even vomiting. Other patients may have nervous attacks, a fear of some impending calamity, or they are irritable or despondent; they may suffer from insomnia, or, if they sleep, it is not a restful sleep. Others may have epileptic attacks, nervous twitchings, etc. To just what extent eye-strain is responsible for these and many other reflexes the writer is not prepared to say, though every ophthalmologist has certainly seen *some* cases of accommodative and muscular asthenopia with gastric symptoms, or nervous symptoms, or epileptic attacks, or irritable tempers, or insomnia, or enuresis, etc., in which these reflex symptoms entirely disappeared after the eye-strain was properly treated.

Examination of the Eyes.

A systematic method should be pursued in the examination of the eyes, and the results recorded in a book or on a card prepared for that purpose. The student should be a careful observer, and also be able to question the patient intelligently for short and definite answers. The following is an excellent method of making records, but there is no arbitrary rule, and in this respect each surgeon may follow his own desires :

Date,..

Name,..

Residence,..

Occupation,.......................................

Age,.................... *Sex,*.................... *Diagnosis,*....................

	Accommodation.	Astigmatism.	Muscles.
O. D. V., ...	p. p.		
O. S. V., ...	p. p.		

History,..

S. P. (*status præsens,* "present condition"). *Inspection,*..........................

Ophthalmometer, O. D.......................... O. S. ....

Ophthalmoscopic examination, O. D.......................... O. S. ....

Manifest refraction. Fields. Color sense. ℞.

The above record is filled out as the examination proceeds, but it is not always advisable to follow the examination in the order given ; on the contrary, it is better, after getting the patient's name and address, to ask certain other questions which may appear in keeping with an individual case.

1. **Occupation.**—This is a very important question, as bearing directly upon the amount and character of work done by the eyes ; for example, writing, reading, sewing, music, engraving, weaving, drafting, surveying, painting, typewriting, typesetting, sorting colors, etc.

2. **Age.**—This is of the utmost importance in comparing the range of accommodation (near point) with the emmetropic condition. Knowing the patient's age and near point will often give a diagnosis of the character of the refraction.

3. **The name** tells the sex, but the question really is whether the patient is married, single, widow, or widower. If a young married woman, whether she is nursing a young child.

4. **History.**—Under this heading the questions should bear directly upon the eyes. "In what way do the eyes cause trouble ?" The usual answer to this question is "*headache*." To get a complete history of the headache, and be able to differentiate it from headache due to other causes, the succeeding questions seem appropriate :

What part of the head aches ? Is it frontal, occipital, temporal, interocular, vertex, or all over the head ?

When does the headache come on—during or after the use of the eyes ? Does it cease *after* resting the eyes ? Is the headache worse when using the eyes by artificial light ? Is the headache constant ? Is it periodic ? Is it worse at a certain hour of the day ? Is the headache present when first waking in the morning ? Does the head ache during or after attending a place of public amusement or when shopping? If a female, is the headache only monthly?

The ophthalmologist must not think because a patient has a headache that it is surely and always due to the eyes, and that glasses are going to cure it. It is for the ophthalmologist to find out just what part the eyes take in causing the patient's discomfort, and not always expect to cure with glasses headaches that have no direct relation to the eyes.

One of the most common causes of headache which may be mistaken for ocular headache is the "brow ache" due to malaria, but a history of previous malarial attacks, chills and fever, a residence in a malarious district, and the fact that it is periodic in character, should certainly give a clear differential diagnosis.

Other patients may not consult the ophthalmologist on account of headache, but for a pain in or back of the eyes, or back part of the head, or between the shoulders, which comes on after any effort of vision. Others may complain of a feeling of sand in the eyes, or a burning in the lids, or a smarting or itching in the lid margins, or excessive lacrimation, or a feeling of drowsiness as soon as the eyes are used for any length of time, or a feeling as if the eyelids would stick to the eyeballs.

The patient's seeing qualities may develop the history of poor distant vision and good near vision, or vice versâ; this should be inquired into very carefully, and it may be well to ask about other members of the family, if they have the same condition. Or a history of the vision gradually failing or of a sudden loss of sight may be obtained, and presbyopic symptoms should be referred to, if the patient is over forty years of age.

If the patient wears glasses, it is well to inquire whether they were ordered by an ophthalmologist or if they are the patient's own selection. In the former instance a record should be made of the character and strength of the lenses, and whether the lenses were ordered with or without "drops" in the eyes; and if "drops" were used, if the effect lasted for two days or longer (slowly or quickly acting cycloplegic). Ask how long the glasses have been worn, and if the same symptoms are present that existed when the lenses were previously ordered.

Having made a note of the patient's history, it is next in order to study the present condition (*status præsens*):

1. Breadth of face, its symmetry or asymmetry; interpupillary distance.

2. The eyelids, whether swollen, discolored, or having red margins.

3. The eyelashes (cilia), whether regular, irregular, or absent. If there are chalazia, styes (hordeola), inflammation, moist or dry secretion at the roots of the cilia (blepharitis).

4. Inspect the inner surface of the lids and ocular conjunctiva for inflammation or growths.

5. Inspect the lacrimal apparatus in all its parts.

6. Inspect the cornea for its polish, transparency, and regularity.

7. Depth of the anterior chamber.

8. Iris, its color and mobility.

9. Pupil, its size, shape, and position.

10. Color of reflex from the pupillary area.

11. Palpate to measure the intraocular tension.

12. Use the cover test at 13 inches for any muscular anomaly.

Following this record of the history and present condition, the distant vision and near point are taken for each eye, one or more tests for astigmatism are made, the muscles are tested for distance (six meters), and the ophthalmometric measure of corneal curvature may be recorded. Finally, and most important of all, the ophthalmoscopic examination is made, and the cornea, aqueous, lens capsule, lens, vitreous, nerve (shape, size, color, cupping, and vessels), conus, macular region, etc., and periphery of the eye-ground are studied.

Lastly, fields and color sense, dynamic or manifest refraction.

CHAPTER IX.

HOW TO REFRACT.

General Considerations.—Before placing lenses in front of an eye, the surgeon should be acquainted with at least five important facts :

1. **The Patient's Age.**—This tells at once, from the table on page 70 (which the surgeon should commit to memory), what the near point will be if the eyes are emmetropic or standard.

2. **The Near Point.**—This will usually indicate hyperopia if beyond, and myopia if closer than, the emmetropic near point for the age.

3. **The Distant Vision in Each Eye.**—If very defective, or if less than $\frac{VI}{VI}$ and near point closer than the age calls for, myopia is indicated. Good distant vision and near point removed indicate hyperopia.

4. **The distant vision, if recorded with question marks,** usually indicates astigmatism.

5. **The Results of Testing with the Astigmatic Chart.**—Darkest lines from XII to VI, or I to VII, or XI to V, indicate astigmatism (myopic) with the rule; or darkest lines from IX to III, or VIII to II, or X to IV, indicate astigmatism (hyperopic) with the rule.

It is well to remember that about four patients out of five have hyperopia, or one patient in five has myopia, and the minus sphere selected almost invariably requires a cylinder in combination. Remember, also, that astigmatism is usually with the rule and symmetric, and that plus cylinders are generally selected at axis 90 or within 45 degrees either side of 90, and minus cylinders are generally selected at axis 180 or within 45 degrees either side of 180.

The Placing of Trial-lenses.—1. These should always be placed as close as possible to the eyes without interfering with the lashes; and to accomplish this, the trial-frame should be easy of adjustment.

2. The center of the trial-lens must be opposite to the center of the pupil.

3. If the distant vision is very defective,—$\frac{VI}{XV}$, $\frac{VI}{XX}$, $\frac{VI}{XXX}$, $\frac{VI}{XL}$, or $\frac{VI}{LX}$,—a strong lens of 2 or 3 D. will often be required; whereas, if the vision is $\frac{VI}{VIISS}$ or $\frac{VI}{X}$, a weaker lens would be called for.

4. When a spheric lens placed before an eye improves the vision, it should not be changed for another unless the vision is made better by having its strength increased or diminished by placing in front of it another sphere (plus or minus) of less strength. For instance, if a +2 sph. has been placed before the eye and the vision is improved from $\frac{VI}{LX}$ to $\frac{VI}{VIISS}$; this +2 sph. should not be changed until a +0.50 or —0.50 sph. has been held in front of it and the patient states whether he can read more with it or less without it. When a vision of $\frac{VI}{VI}$ is approximated, then its accuracy must be determined by placing first a +0.25 and then a —0.25 in front of the correction, so as to learn from the patient which one, if either, of these lenses improves the vision. Or if the correcting lenses selected are weak ones, then 0.12, plus and minus, may be used in place of the 0.25.

5. Spheric lenses should always be tried before using cylinders, and the vision brought as low as possible with

a sphere before combining a cylinder, and, in fact, after the vision has been improved as much as possible with a sphere, the pointed line-test for astigmatism may be brought into use, as very often low errors of astigmatism are not recognized until this point in the refraction has been reached. Advocates of the ophthalmometer place the cylinder before the patient's eye and then add the spheric correction. The writer is not partial to this method or way of refracting.

6. When a patient miscalls one or more letters in a certain line, the surgeon must not hurry on until these are corrected by the patient with a suitable glass, and in this way the refraction is gradually worked out until the vision is brought to the greatest acuity possible. It is never wise to stop with a vision of $\frac{VI}{VI}$, as we are often able to get a visual acuity of $\frac{VI}{V}$, or occasionally $\frac{VI}{IV}$.

7. **Cylinders.**—When a plus cylinder is employed, it is placed with its axis at 90, and then slowly revolved (if necessary) to an axis where the patient says he can see better. A minus cylinder is placed at axis 180, and revolved in the same manner. The rule (4) for changing spheres also applies to cylinders—*i. e.*, to increase or decrease the strength of the cylinder by placing in front of it a plus or minus cylinder of less strength at the *same* axis.

8. **Axis of the Cylinder.**—When a patient is not sure about an *exact* axis, though he is sure that the cylinder improves the vision, then the surgeon may employ a sphere of the strength of the sphere *and* cylinder combined, and use a cylinder of the same strength as before, but with opposite sign and at about the opposite axis. For example, with +2.25 sph. ⊂ +0.75 cyl., the patient is not sure if the vision is best with the axis at 35, 40, or 45, the surgeon must then use a +3.00 sph. ⊂ —0.75 cyl., when the

exact axis (at right angles) will usually be selected without any hesitancy or doubt.

9. **Proving the Correction.**—All tests at the trial-case, when a cycloplegic is used, should be confirmed with the retinoscope.

10. **Crossed Cylinders.**—This is a trial-lens that has one meridian minus and the opposite meridian plus. They are made of any strength, but for general use the 0.25 cylinders are employed—*i. e.*, —0.25 sph. ⊂ +0.50 cyl. The purpose of the crossed cylinders is to increase the refraction in one and diminish it in the opposite meridian. For example: if +2.00 sph. ⊂ +1.00 cyl. axis 90 gives a vision of $\frac{\text{VI}}{\text{VIIss}}$, and the crossed cylinder lens is placed in front of this combination with —0.25 at axis 180, and the +0.25 at axis 90, and the vision comes down to $\frac{\text{VI}}{\text{VI}}$, it shows that the vertical meridian was 0.25 too strong, and the horizontal 0.25 too weak, and the result would be +1.75 sph. ⊂ +1.50 cyl. axis 90 degrees. Or, if —3.00 sph. has brought the vision to $\frac{\text{VI}}{\text{IX}}$, and the crossed cylinder lens is placed before it and rotated to axis 15 for the minus cylinder and axis 105 for the plus cylinder, and the vision comes to $\frac{\text{VI}}{\text{VI}}$, the result would be —2.75 sph. ⊂ —0.50 cyl. axis 15.

Methods of Estimating Refraction.—To determine the refraction of an eye it may or may not (as in presbyopia) be necessary to employ a cycloplegic. When the refraction is estimated without a cycloplegic, it is spoken of as manifest or dynamic (Gr., δύναμίς, "power") refraction. When a cycloplegic is used, the refractive estimate is spoken of as static (Gr. στατίκος, from, ἱςτάναι, "to stand at rest"). In one instance the ciliary muscle is permitted to act, and in the other it is at rest. A third method is to obtain the static refraction and then to estimate the strength of the glasses to be prescribed *after* the effect of the cycloplegic has passed out of the eyes; this is spoken of as post-cycloplegic refraction. Eyes for refraction are divided into two general classes, according to the age of the patient. In those under forty-five years of age a cycloplegic is usually employed, but after this age a cycloplegic is often dispensed with. (See Presbyopia.)

Fogging Method.—This method simulates the static or cycloplegic method, as the ciliary muscle is in great part (if not entirely) placed artificially at rest by having in front of the eye under examination *a plus sphere of sufficient strength to more than overcome any ciliary muscle power that the eye might otherwise use when looking at a distance of six meters.* The "fogging" method is so called because distant vision is made obscure or "foggy." The eye under examination with this strong plus sphere in front of it is, to all intents and purposes,—for the time being, at least,—myopic. This fact should be carefully borne in mind, as the method to pursue in estimating the refractive error is to proceed the same as in any regular case of myopic refraction. Therefore, this method is only of service in estimating the refraction of eyes that have some form of hyperopia or simple myopic astigmatism, and is not of service in myopia or compound myopia.

How to Proceed in Hyperopia.—Having estimated with the ophthalmoscope that the eye is hyperopic about 2.50 D., then place a plus 4 D. sphere before the eye and have the patient look at the card of test letters at a distance of six meters. This has the immediate effect of making distant vision very "foggy," but by waiting a few seconds this foggy vision will clear slightly and the ciliary muscle will relax a part, if not all of its effort to accommodate. Then proceed as if refracting a myopic eye by placing a

— 0.50 sphere in front of the +4 D. sphere, and gradually increase the strength of the minus sphere until the patient reads $\frac{VI}{VI}$. If the minus sphere is 1.25 D., then the amount of the hyperopia will be + 2.75 D., which is the difference between the +4 D. and the — 1.25 D.

How to Proceed in Simple Hyperopic Astigmatism.— Having estimated with the ophthalmoscope or retinoscope or ophthalmometer or any of the various ways that the eye has hyperopic astigmatism of about 2.50 D., proceed as in hyperopia by making the eye myopic by the addition of a +4 D. sphere. Have the patient look first at the card of test letters and then at an astigmatic clock-dial next to the letters. Proceed by adding minus spheres as in the previous case, and as soon as the patient recognizes one series of lines on the clock-dial as much darker than those at right angles to these dark lines, then place minus cylinders in position with their axes at right angles to the darkest lines, and as soon as the lines are uniformly black on the dial then have the patient look at the test letters again and increase the strength of the minus sphere if necessary until the eye can read $\frac{VI}{VI}$ or $\frac{VI}{V}$. Presuming that — 2 sphere and — 2 cylinder at axis 180 degrees were used, then the difference between these and the + 4 sphere would give + 2 cylinder, axis 90, as the amount of the hyperopic astigmatism.

How to Proceed in Compound Hyperopic Astigmatism.—If the meridian of highest refraction is 4 D., then place a +5 D. sphere before the eye, wait a few seconds, then begin by adding minus spheres until a series of lines on the clock-dial show up very black, then add minus cylinders until all the lines become uniformly black, then turn to the test letters and increase the strength of the minus sphere as necessary until the vision is brought to normal.

With + 5 D. sphere before the eye and if —1 sphere and —3 cylinder at axis 165 were employed, then the compound hyperopia would be + 1 sphere with + 3 cylinder at axis 75.

How to Proceed in Mixed Astigmatism.—Estimating the refraction approximately as + 2 ⊂⊃ —3, cylinder; place + 5 D. sphere in position as before, then find the meridian of darkest lines on the clock-dial, add minus cylinder with the axis at right angles to the darkest lines, then when all lines are equally black, diminish the strength of the plus sphere until vision comes to the normal, if it is possible to get it to this point. The result may be + 5 sph. ⊂⊃ — 2.50 sph. ⊂⊃ — 3.50 cyl. × 180, which would equal + 2.50 ⊂⊃ — 3.50 cyl. × 180°.

Advantages of the Fogging Method.—It is one of the best approximate ways of estimating the refraction if for any reason a cycloplegic can not be employed, as in cases of glaucoma, nursing mothers, or of an individual who may have an idiosyncrasy for a cycloplegic. The fogging method also has the advantage, like the cycloplegic method, of uncovering or bringing out most if not all the latent hyperopia.

Manifest or Dynamic Method.—This method is the very reverse of the "fogging" method, in that the refraction is estimated without first making the eye artificially myopic, or placing the ciliary muscle at rest. It is, therefore, a method that is liable to give all sorts of erroneous results if the subject is hyperopic and less than forty years of age.

To estimate the refraction by the manifest method, the patient is told to look first at the test letters and then at the clock-dial at 6 meters distant; the astigmatism is corrected and then plus or minus spheres added as necessary to bring the vision to the normal. The rule is to employ the strongest plus lenses or the weakest minus lenses which will give normal vision.

Advantages of the Manifest Method.—This is the method by which the eyes of patients past forty-five years of age are refracted; a fairly good method in cases of compound myopia in young subjects if drops can not be employed.

Objections to the Manifest Method.—It is not a method to be used as a rule in young subjects. If a young subject must be refracted without drops, then the fogging method should be followed.

The habit of prescribing glasses from the manifest or "fogging" method without any knowledge of the ophthalmoscopic findings is not a method that merits the attention of the conscientious physician. Such work is very unsatisfactory, often leading to gross errors, ultimate dissatisfaction on the part of the patient, or injury to the eyes.

Postcycloplegic Refraction.—The ordering of glasses after the static refraction has been recorded and the effect of the cycloplegic has left the eyes. For instance: While the ciliary muscle is paralyzed with atropin the static refraction is found to be $+1.50$ sph. ⊃ $+2.00$ cyl. axis 90 degrees, which gives a vision of $\frac{VI}{V}$. The atropin is then stopped and the patient told to report in fifteen days, when the ciliary muscle will have regained its original strength and gone back to its old habit of accommodating for distance. The static refraction is placed before the eyes, and the strength of the sphere is gradually reduced until the vision just equals $\frac{VI}{V}$, as it was when the "drops" were in the eyes. Whatever this correction with the glasses may be, is ordered. Occasionally the strength of the cylinder as well as its axis is also changed.

Objections to the Postcycloplegic Method.—The patient is annoyed by the long delay to which he is subjected before getting his glasses. But the principal fault lies in the fact that the eye is not placed in the emmetropic condition; it is allowed to retain more or less of its accommodative power for distance. This, however, can not always be avoided.

Static Refraction.—By this method the glasses are prescribed while the ciliary muscle is under the effect of the cycloplegic. In hyperopia allowance must be made in the strength of the sphere for the distance at which the test is made. At 6 meters 0.25 is deducted from the sphere without any change in the cylinder. The only possible objection to this method is in cases of hyperopia, in which, after the effect of the cycloplegic passes away, the ciliary muscle may endeavor to accommodate for distance with the glasses in position, and with the result that the patient can not see clearly except near at hand. To avoid any such contingency the surgeon will have to make a deduction in the strength of the plus sphere to meet such cases. The rule for ordering glasses by the static refraction in hyperopia is to deduct 0.25 from the sphere and have the glasses worn at once and constantly while the effect of the "drops" is gradually leaving the eyes. In this way the eyes grow accustomed (slowly) to seeing at a distance without exerting the ciliary muscle; the eyes are thus placed in an emmetropic condition. If this effect of the cycloplegic passes away before the patient can obtain the glasses, it will be necessary to use the drops for a day or so after the glasses are received. Unfortunately, however, some hyperopic eyes, in young subjects especially, with vigorous ciliary muscles, will develop a spasm of the accommodation for distant vision which will make the glasses very annoying on account of distant objects looking "dim." Such patients should be advised of this fact at the time the glasses are ordered, and if dim distant vision does develop, that it will be transitory, and to persist in wearing the glasses. There are two ways of relieving this "dim" vision if it should occur:

1. To prescribe a weak solution of atropin ($\frac{1}{20}$ of a grain to 1 fluidounce), 1 drop in each eye once or twice a day, the idea being to slightly relax the accommodation; this *is* accomplished, but, unfortunately, the mydriatic effect is a disturbing element which the patient will not submit to long enough, as a rule, to obtain relief.

2. The better way is to make a compromise in the strength of the sphere. An eye which has been in the habit of accommodating 3, 4, 5, or 6 diopters for distance, does not often give up this habit very gracefully, even if assisted by a slowly acting cycloplegic, so that when the static refraction calls for more than 3 diopters, the surgeon is frequently compelled to make a deduction of more than 0.25. *There is no hard and fast rule as to just how much shall be deducted*, and very few surgeons agree on this point. Glasses may be ordered as follows, the surgeon being guided in great part by the patient's age and occupation; also as to whether there is esophoria or exophoria. It will be found that cases of esophoria will accept almost a full correction, whereas cases of exophoria will require a very liberal deduction in the strength of the glass, the patient being allowed to use his relative hyperopia:

Static refraction at 6 meters:

+1.00 sph. or less	deduct 0.12 or 0.25.
From +1.00 sph. up to 3.00 sph.	" 0.25 or 0.50 or 0.75.
" +3.00 sph. up to 6.00 sph.	" 0.50 or 0.75 or 1.00 or 1.50.
" +6.00 sph. up to 8.00 and above	" 1. or 1.50 or 2.00 up to 3.00.

It is true that glasses ordered in this way do not leave the eyes in an emmetropic condition, and that, later on, when asthenopic symptoms redevelop, the strength of the glasses will have to be increased. But this method has two advantages : first, it gives the patient his glasses without any long delay, and the eyes have an opportunity to become accustomed to them while the effect of the "drops" is passing away ; and, second, the patient accepts a much stronger glass in this way than by the postcycloplegic method, which is a decided advantage.

The ordering of lenses in low errors for distant vision depends entirely upon the condition of the patient's eyes and symptoms. It is not unusual to find the most distressing asthenopia, headaches, blepharitis, etc., disappear as if by magic when corrections are ordered for small defects, especially if there is astigmatism. In other instances slight ametropic errors may not produce any unpleasant symptoms, and such a patient need not wear the correction for distance.

The Ordering of Glasses in Myopia. — There is no fixed rule for prescribing glasses in myopia. Each case is a law unto itself, and should receive the most careful consideration from every point of view. But as the student must have some idea as to how to proceed, the writer would suggest the following subdivisions :

1. Myopic eyes which can with safety use one pair of glasses for distant and near vision.

2. Myopic eyes which require two pairs of glasses—one for distant vision, and another pair for near-work, reading, writing, etc.

3. Myopic eyes which should have the near correction only.

Class I comprises those cases in which there is an active ciliary muscle, and the ophthalmoscope shows but little, if any, change in the eye-ground indicative of stretching (children, or in beginning myopia). Glasses carefully selected by the static refraction may be ordered in such instances for constant use, but with the distinct understanding that if any discomfort arises at any time they will be subject to change.

Class 2.—Adults who have not previously worn their myopic glasses. In these cases the power of the ciliary muscle is weak, deficient in sphincter fibers, and, if forced into activity, the patient would be very uncomfortable, the eye would stretch, and the myopia increase, the tissues in these eyes yielding more readily than in class 1. The glasses selected by the static refraction may be prescribed for distance, but a second pair, 1, 2, or 3 diopters weaker, must be ordered for the reading, writing, or working distance, that the accommodative effort may in part be kept in abeyance. Class 1, if not carefully watched, may pass into class 2 and class 2 may pass into class 3.

Class 3.—These cases require unusually strong lenses, and it is to these especially that the term "sick," or "stretched" eye particularly belongs. The ophthalmoscope may show vitreous opacities, areas of retinochoroiditis, macular choroiditis, a broad myopic conus, and even posterior staphyloma. The eyes are prominent, occupying much of the orbital space. Eyes of such length are limited in their power of comfortable rotation, and hence it is common for one eye to diverge, the patient stating that he uses only one eye for near vision. The diverging eye is usually more or less amblyopic, due to want of use or pathologic changes, or to both. Such eyes have lost almost or quite all the power of accommodation. These eyes must be placed in such a condition that the desire to converge and accommodate is at a minimum. The prescribing of glasses for these long eyes must be limited to the one pair for near-work, and yet the patient may, by bringing the glasses closer to the eyes, improve the distant vision for the time being—a sort of artificial accommodation. To appreciate what is meant by this statement it is necessary to reconsider the optics of a myopic eye. A myopic eye of 20 D. has a far point of 5 cm., and the minus lens required to make such an eye receive parallel rays of light at a focus upon its retina should be of such strength that the rays passing through it would have a divergence as if they came from this far point (5 cm.). Such a lens would be a —20 D. This means, of course, that the —20 D. would have to be placed with its surface against the surface of the cornea, which is an impossibility. The usual distance for a lens in front of the eye is 1 or 1 ½ cm., so that this distance must be subtracted from the distance of the far point. In this instance 1 cm. from 5 cm. would leave 4 cm., and this would represent 25 D. As just stated, the glasses for this class of patients are limited to the one pair for near-work, and therefore it would be necessary to reduce the strength of these lenses 4 diopters and thus prevent, as far as possible, any accommodative effort. The patient using this —21 D. for near, can, if he wishes, improve his distant vision at any time by pressing the lenses closer to his eyes. The strength of concave lenses increases as they are brought closer to the eyes, and diminishes as they are removed from the eyes.

Caution.—The great danger in any refraction at the trial-case, but especially in myopia, is an overcorrection, and this is very likely to occur if the surgeon is not extraordinarily careful in having his lenses placed as close to the eyes as possible while making the test.

Prophylaxis.—The prescribing of glasses for myopic eyes is only a part of the general treatment to which these "sick" eyes are entitled. If the treatment stops at this point, then the glasses may be an injury instead of a blessing. Myopia once established may pass through the various classes already described, and eventuate in greatly reduced vision or total blindness if certain limitation of their use is not insisted upon.

1. **Light.**—A good, clear, and steady light is always essential; it should come from the left side, never from in front.

2. **Time.**—The length of time that myopic eyes may be used should be restricted as much as possible, consistent with their condition; that is to say, they should never be used after they become the least fatigued, and any use of the eyes should be counteracted by life in the open air.

3. **Attitudes.**—The head should have as little inclination as possible in reading, writing, or close work, as so faulty a position invites a congestion of the intraocular tissues. At school or at home the book should be inclined, and its distance from the eyes be regulated by the size of the patient.

4. **Print.**—The use of small print or minute objects must be forbidden. English or Gothic type should be substituted for Greek, German, and other characters. Fine needle-work, embroidery, etc., must be abolished. If necessary, music notes must be given up entirely.

5. **Health.**—The health of the patient must be looked after, and all irregularities corrected—constipation, etc.

These are a few of the major considerations to which the patient's attention must be drawn, the surgeon being limited in his remarks to the exigencies of the individual case.

In conclusion it may be well to know how myopia is produced, since it has been stated that the condition is rarely seen in young children. It is well known that astigmatism (hyperopic) is a congenital defect, and with this in mind it is very easy to appreciate the succeeding steps which lead to the compound myopic condition, showing at the same time the reason why *simple* myopia is so rare an anomaly.

Take a child six years of age who has a compound hyperopia of say +0.50 sph. ⊂ +0.75 cyl. axis 90 degrees ; this child enters upon its course of study without any correcting glasses, and is subjected in its pursuit for knowledge to a faulty school desk and chair, possibly facing a window. The print is defective in many ways. The artificial light for home study in the evening may be of poor quality, and so placed that but few of its rays fall upon the child's book. With these and other hindrances the eyes are strained (stretched). The tissues are very yielding in their growing state, so that at the age of ten years the refraction may show +0.75 cyl. axis 90. The +0.50 sph. (the axial ametropia) has disappeared by an elongation of the optic axis. The vertical meridian is now emmetropic. The same conditions exist for the next three years, during which the number of studies is multiplied and the hours for study are prolonged and the child reaches the age of puberty; the refraction is now found to be —0.50 sph. ⊂ +0.75 cyl. axis 90 degrees, mixed astigmatism. In two years more the refraction is found to be —0.25 sph. ⊂ —0.75 cyl. axis 180—*i. e.*, compound myopic astigmatism. From this time forward these eyes progressively stretch and are subject to the stretching process unless the progress is stayed with glasses and prophylactic treatment.

In the brief detail of this one case the student will fully appreciate another important fact—that the vertical meridian of the cornea, as a rule, maintains throughout the shortest radius of curvature. This is abundantly demonstrated by statistics.

The following summary of refractive errors and direction of meridians of shortest radius of curvature in 2500 pairs of eyes,—1300 in private and 1200 in hospital work,—prepared by Dr. Risley and the writer, shows the correctness of the above statements: *

	Private.		Hospital.	
Monocular astigmatism,	70	5.0%	94	7.8%
Binocular astigmatism,	1151	88.5	828	69.0
Total cases,	1221		922	
Binocular symmetric astigmatism,	694	60.2%	613	74.4%
Binocular asymmetric astigmatism,	310	26.8	158	19.8
Heteronymous astigmatism,	123	10.6	40	5.2
Homonymous astigmatism,	24	2.1	17	1.2
Total binocular astigmatism,	1151		828	
Symmetric astigmatism:				
(*a*) According to rule (homologous),	543	78.2%	559	97.7%
(*b*) Against rule (heterologous),	151	21.8	54	2.3
Total symmetric astigmatism,	694		613	
Asymmetric astigmatism:				
(*a*) According to rule,	223	71.8%	126	79.1%
(*b*) Against rule,	87	28.2	32	20.9
Total asymmetric astigmatism,	310		158	

Direction of the Meridian of Shortest Radius in all Cases of Symmetric Astigmatism.

Meridian at 90°,	57.0+%
Meridian inclined 15° or less on each side,	19.7+
Meridian inclined from 15° to 30° on each side,	4.0—
Meridian inclined from 30° to 45° on each side,	1.0
Meridian at 180°,	12.0
Meridian inclined 15° or less on each side,	4.0—
Meridian inclined from 15° to 30° on each side,	2.0
Meridian inclined from 30° to 45° on each side,	0.5

* This report was read in the Section on Ophthalmology at the forty-sixth annual meeting of the American Medical Association, at Baltimore, Md., May 7 to 10, 1895.

CHAPTER X.

APPLIED REFRACTION.

In estimating the refraction of any eye the surgeon will do good work if he will make it a rule never to be satisfied until each eye has a vision of $\frac{VI}{VI}$ or more, and if this visual acuity is not attained, to understand the reason why: whether it is his fault or the fault of the eye itself. It is most essential in every instance to have the good-will of the patient.

The following cases are detailed so as to demonstrate each form of ametropia in all its phases:

Case I.—**Simple Hyperopia.**—This is a common form of ametropia, occurring about 20 times in 100 cases:

January 3, 1899. John Smith. Age, twenty. Single. Stenographer.

O. D. $\frac{VI}{IV}$. p. p. = type 0.50 D. at $12\frac{1}{2}$ cm.

O. S. $\frac{VI}{IV}$. p. p. = type 0.50 D. at $12\frac{1}{2}$ cm.

Add. = 22 degrees; abd. = 6 degrees.

History.—Frontotemporal headaches almost constantly, but much worse when using eyes at near-work. Had severe headaches when a school-boy. Never liked to study; preferred out-of-door sports.

S. P.—Face symmetric, but narrow. Blepharitis marginalis. Irises blue. Pupils round, 3 mm. in diam. Eyes fix under cover.

Ophthalmometer.—Negative.

Ophthalmoscope.—Both eyes the same. Media clear.

Disc small and round, with physiologic cup. All vessels near the disc are seen clearly with + 2 S. Eye-ground flannel-red and accommodation very active.

Manifest or dynamic refraction :

O. D. +1.25 S. $= \frac{VI}{IV}$.

O. S. +1.25 S. $= \frac{VI}{IV}$.

℞. Atropin and dark glasses for refraction.

January 5, 1899. Patient seated at 6 meters from test-card and small point of light. O. D. V. $= \frac{VI}{XXX} =$ O. S. V. $\frac{VI}{XXX}$. Cobalt-blue glass shows (each eye separately) blue center and red halo. (See Fig. 125.)

Retinoscope, with +3 S., developed point of reversal at 1 meter for each eye.

With trial-lenses, O. D. and O. S. each select +2 S., which gives a vision of $\frac{VI}{IV}$, and they positively refuse to see $\frac{VI}{IV}$ clearly with an addition of +0.25 S. In other words, this +2 S. is the *strongest* lens which each eye will accept and maintain clear distant vision. *The rule for refraction in hyperopia is to employ the strongest lens which the eye will accept without blurring the distant vision.*

To prove that the ciliary muscle is at rest, and that the glass selected is correct, add a +4 S. to the distance correction, and the rays of light emerging from the eye must focus at the principal focus of the added +4 S., at 10 inches (25 cm.); and if the patient can read fine print at this distance, the ciliary muscle is at rest and the glass correct. If a +3 S. had been added instead of a +4 S., then the principal focus would be at 13 inches; if +5 S., then at 8 inches, etc.

The question is, What glasses shall be ordered? The writer would give the following prescription, and instruct the patient to stop the drops and wear the glasses constantly:

For Mr. Smith.
℞. O. D. + 1.75 sph.
O. S. + 1.75 sph.
Sig.—For constant use.
January 7, 1899.

January 8th: Glasses from the optician neutralize; are centered and accurately adjusted.

January 21st: Add. = 18 degrees. Abd. = 6 degrees. Near point in each eye = 10 cm. No headache or discomfort of any kind.

Considerations.—The static refraction as represented by + 2.00 sph. means that rays of light which pass through this lens and focus at the fovea diverge from six meters' distance, which heretofore we have considered for purposes of calculation as parallel; but when glasses are ordered, allowance must always be made for this small amount of divergence, and so 0.25 is deducted from the + 2 sph., that the eye may have parallel rays focusing on its retina when looking *beyond* a distance of six meters. To have been mathematically exact, + 0.12 should have been deducted in place of + 0.25.

The *purpose* in all cases of refraction is to place the eye in an emmetropic condition, though this is not always advisable in every instance. The hyperopic eye naturally accommodates for distance, and the emmetropic eye does not; then the hyperopic eye is made emmetropic when a spheric lens permits parallel rays to focus upon its fovea without any assistance whatever from the ciliary muscle.

Advantages of Atropin in This and Similar Cases.—The glasses are ordered while the ciliary muscle is at rest. The accommodation returns gradually. The eye becomes accustomed to seeing at a distance without the assistance of the ciliary muscle. Atropin produces a physiologic rest, which the overacting ciliary muscle, disturbed choroid, and irritated retina require. None of these good results can be expected in a case of this kind from the use of a "quick" cycloplegic like homatropin.

SUMMARY.—Age of patient, twenty years. Amplitude of accommodation is 10 D. for this age.

Near point is $12\frac{1}{2}$ cm., which shows only 8 D.

Facultative hyperopia (Hf.) equals difference between 10 and 8 D., which is 2 D.

Manifest hyperopia (Hm.) equals 1.25 D.

Total hyperopia, or static refraction (Ht.), equals 2 D.

Latent hyperopia (Hl.) equals the difference between the manifest and total, 2 D. and 1.25 D., making 0.75 D.

The far point, or conjugate focus, is negative or virtual, and lies back of the retina, where the emergent rays (diverging) from the eye would meet if projected backward; this point corresponds to the principal focus of the lens which corrects the hyperopia—*i. e.*, in this instance, +2 D., and the negative far point is therefore at 20 inches.

The +1.75 makes the eye practically emmetropic; the near point, after the effect of the atropin passes away, is 10 cm., which is the emmetropic near point for the patient's age. The plus sphere selected represents a shortening of the eye of $\frac{2}{3}$ mm., as measured on the optic axis.

CASE II.—**Simple Myopia.**—With the one exception of emmetropia, it will be found that myopia, plain and simple, without astigmatism, is one of the *rarest* conditions of the eye which the surgeon will meet in careful refractive work. About one and one-half per cent. of all patients, by careful refraction, are found to have simple myopia. Therefore the condition is not common.

January 3, 1899. Miss Rare. Age, twenty-five years. Single.

O. D. V. $= \frac{VI}{LX}$. p. p. = type 0.25 D. at 9 cm.; p. r. at 40 cm.

O. S. V. $= \frac{VI}{LX}$. p. p. = type 0.25 D. at 9 cm.; p. r. at 40 cm.

Add. 16 degrees. Abd. 6 degrees. Exophoria, 3 degrees at 13 inches.

History.—Does not suffer much from headache, but eyes ache after any prolonged use at near-work. Never able to see well at a distance. Always stood high in her class at school, though she had to have a front seat to see the figures and writing on the blackboard. Has excellent vision for near-work and does fine embroidery. Has been accused of passing friends on the street without speaking to them. If she drops a pin on the floor, has to get on her knees to find it. Parents do not wear glasses. Grandfather had "elegant" sight, had "second sight," and never wore glasses. Patient has postponed getting glasses because parents objected.

S. P.—Face symmetric. Interpupillary distance, 65 mm. Irises dark. Pupils large, round, 5 mm. Eyes out under cover.

Ophthalmometer.—Negative.

Ophthalmoscope shows each eye the same. Media clear. Disc large and round. Shallow physiologic cup. Narrow myopic conus at temporal side of disc. Choroidal vessels seen throughout periphery of eye-ground and extending almost to nerve margin. All vessels near nerve-head seen with —3. S.

Manifest Refraction.—Each eye —3.00 sph. gives vision of $\frac{VI}{VI}$.

Cobalt-blue glass gives red center and dark blue halo. (See Fig. 126.)

R. Atropin and dark glasses for refraction.

January 5, 1899: Patient seated at 6 meters from test-card. O. D. and O. S. vision equals $\frac{VI}{LX}$. Retinoscope with —1.50 S. develops point of reversal at 1 meter for each eye. It will be noticed that the vision in hyperopia with and without drops is decidedly different, whereas in myopia there is little, if any, change. With trial-lenses each eye selects separately —2.50 sph., which gives a vision of $\frac{VI}{VI}$. If a —2.25 sph. is substituted, the vision falls to $\frac{VI}{VIISS}$. If a —2.75 is employed, the vision remains $\frac{VI}{VI}$, but the letters look small, black, and "far away." The rule for refraction in myopia is to employ the *weakest* lens through which the eye can still maintain clear, distant vision.

What Glass to Order.—The writer would give the following prescription and instruct the patient to stop the drops and wear the glasses constantly:

January 7, 1899. For Miss Rare.
℞. O. D. —2.50 sph.
O. S. —2.50 sph.
Sig.—For constant use.

January 9th: Glasses neutralize; are centered and accurately adjusted. Add. 18 degrees. Abd. 10 degrees. Patient is delighted with glasses.

January 21st: Near point, 12 cm.

Considerations.—As a rule, concave lenses are ordered without any deductions for the slight amount of divergence of the rays of light for the distance (6 meters) at which the estimate is made. To be exact, —0.25 should be added to the —2.50 sph. in this case; but the surgeon must avoid the danger of *over*correcting the myopic eye, and, to be on the safe side, the glass is usually ordered as the patient selects and the retinoscope confirms it. These lenses make the eyes, to all intents and purposes, emmetropic.

Advantages of Atropin.—The choroid and retina are given a physiologic rest that they could not obtain in any other way. The patient will not select too strong a glass, as was the case in this very instance when manifested. Myopic eyes usually have large pupils, and do not suffer, therefore, from mydriasis to the same extent as hyperopic eyes. The far point remains unchanged. The power of convergence is somewhat relieved by the glasses, which at the near working distance are of the nature of prisms, bases in.

SUMMARY.—Age of patient is twenty-five years. Amplitude of accommodation at this age is 8.5 D. Near point, 9 cm. = 11 D., and far point 40 cm. = 2.50 D. Difference between near point and far point in diopters = 8.50 D., which is the amplitude of accommodation for the patient's age.

Difference between the near point in diopters (11 D.) and the amplitude (8.50 D.) is 2.50 D., which is the amount of the distant correction needed. With glasses on, the near point, after the effect of the atropin passes away, is 12 cm., which represents the emmetropic near point for the age. This myopia of 2.50 D. represents an eye nearly 1 mm. longer than the standard eye, as measured on the optic axis.

CASE III.—**Simple Hyperopic Astigmatism.**—Not an uncommon condition. About 5.5 per cent. of all eyes have this form of refraction.

April 3, 1899. MISS ROBINSON. Age, twenty-four years. Single. Dressmaker.

O. D. V. $= \frac{VI}{IX}$???. p. p. = type 0.50 at $13\frac{1}{2}$ cm.

O. S. V. $= \frac{VI}{IX}$???. p. p. = type 0.50 at $13\frac{1}{2}$ cm.

Add., 23 degrees. Abd., 5 degrees. At 6 meters, esophoria 4 degrees; at 13 inches 10 degrees of exophoria.

Astigmatic clock-dial shows darkest lines from X to IV with O. D.

Astigmatic clock-dial shows darkest lines from VIII to II with O. S.

History.—Headache every day; seldom entirely free from ocular discomfort. Distress begins in the forehead and extends to the back of the head and into the neck. After a hard day's sewing, has to go to bed and bind the head with a handkerchief. Once a week has a "sick headache," when she has to give up work entirely and take headache powders. Sick headache often ceases after emesis.

S. P.—Face symmetric. Blepharitis well marked, with many cilia missing. Edges of lids thickened. Irises light blue in color. Pupils apparently oval in vertical meridian. Corneal reflex shows axis inclined from vertical in each eye.

Ophthalmometer.—O. D., 1.50; axis, 75, with the rule; O. S., 1.50; axis 105 degrees, with the rule.

Ophthalmoscope.—O. D., vertically oval nerve axis, 75 degrees. Accommodation very active. Underlying conus down and out. Vessels at 75 best seen with +1.50; and at axis 165, without any lens. O. S., same general conditions as in O. D. Vertically oval nerve axis, 105. Vessels at 105 degrees seen with +1.50, and at axis 15 without any lens.

Manifest Refraction.—

O. D., +1.25 cyl. axis 65 degrees $= \frac{VI}{VI}$???.
O. S., same cylinder with axis 125 degrees.
℞. Hyoscyamin and dark glasses for refraction.

April 5th: Six meters from test-card and point of light.

O. D. V. $= \frac{VI}{XX}$???.
O. S. V. $= \frac{VI}{XX}$???.

Clock-dial shows the same as at first examination. Cobalt-blue glass before O. D. gives blue center and red on each side at axis 165 degrees. O. S. the same at axis 15 degrees. (See Fig. 128.)

Stenopeic Slit.—O. D., axis 75 with +0.25 S., V. = $\frac{VI}{VI}$; and at axis 165 with +1.50 S., V. = $\frac{VI}{VI}$. O. S., axis 105 with +0.25 S., V. = $\frac{VI}{VI}$; and at axis 15 with +1.50 S., V. = $\frac{VI}{VI}$.

Retinoscope at 1 meter shows: O. D., at axis 75 degrees +1.25 S., and axis 165 degrees, +2.25 S. O. S., at axis 105 degrees, +1.25 S., and at axis 15 degrees, +2.25 S.

At Trial-case.—

O. D. +0.25 sph. ⊃ +1.00 cyl. axis 75 degrees, V. = $\frac{VI}{VI}$ +
O. S. +0.25 sph. ⊃ +1.00 cyl. axis 105 degrees, V. = $\frac{VI}{VI}$ +.

April 6th: Same result as April 5th. Add., 20 degrees. Abd., 6 degrees. Esophoria, 2 degrees at 6 meters.

For Miss Robinson.
℞. O. D. +1.00 cyl. axis 75 degrees.
O. S. +1.00 cyl. axis 105 degrees.
Sig.—For constant use.

April 7th: Glasses neutralize; are centered and accurately adjusted.

April 16th: Perfectly comfortable. Free from headache since the first day she used the "drops." Add., 20 degrees. Abd., 6 degrees. Esophoria at 6 meters, 2 degrees; and at 13 inches, 0°. Near point, 12 cm.

Considerations.—Apparently, the static refraction in this case would indicate compound hyperopic astigmatism; but when 0.25 is deducted to produce parallel rays, then the prescription becomes one for simple hyperopic astigmatism.

General Rule for Prescribing Cylinders.—Order the cylinder just as found, without any change in its axis or strength.

The vision in each eye at the different visits, before lenses were placed in front of the eyes, was always uncertain, the patient miscalling certain letters, and hence it is that the vision is recorded with as many question marks as there are mistakes in the line of letters—*i. e.*, $\frac{VI}{IX}$? ? ?.

In taking the vision at the first visit, the patient could read part of $\frac{VI}{VIISS}$ if not closely watched. In other words, if she was permitted to tilt her head to one side and narrow the palpebral fissure by squinting the lids together, and making, as it were, a stenopeic slit out of her eyelids, the vision was improved. But when told to open the eye wide, she could read only part of $\frac{VI}{IX}$. This is explained by the fact that when the lids were drawn together, the vertical meridian was partly excluded, and then, by accommodating, the vision was improved through the horizontal meridian. Astigmatic eyes often take advantage of this condition when the nature of the astigmatism is suitable, but only at the expense of frowning and straining the accommodation.

It will also be noticed that the stenopeic slit was not used as a test at the first visit. This is also explained for the same reason that the patient would draw his lids together and therefore annul the virtue of this test. The stenopeic slit is to be used in these cases only when the ciliary muscle is at rest.

Summary.—When the hyoscyamin has passed out of the eyes and the glasses are in position, the near point becomes 12 cm., which is quite consistent with the patient's age. Before using drops, the near point with the eyes wide open was only 13½ cm., representing about 2.50 D.; and this, subtracted from the amplitude for twenty-four years of age, would leave 1 D. for distance uncorrected.

As every 6 D. cylinder represents 1 mm. of lengthening or shortening of the radius of curvature of the cornea, then this patient, taking a +1 cyl. at axis 75 in the right eye, has the 165 degree meridian $\frac{1}{6}$ of a mm. too long as compared with the 75 meridian, which is supposed to have the normal radius of 7.8 mm.

The same is true of the meridians of the left eye.

CASE IV.—**Simple Myopic Astigmatism.**—Not a common condition. About 1.5 per cent. of all eyes have this form of refraction.

April 10. MISS JENKS. Age, eighteen years. Single.

O. D. V. $= \frac{VI}{X}$???. p. p. 9 cm. p. r. 50. cm.

O. S. V. $= \frac{VI}{X}$???. p. p. 9 cm. p. r. 50. cm.

Add., 20 degrees. Abd., 5 degrees. Esophoria at 6 meters = 3 degrees; and 1 degree at 13 inches.

Pointed Line Test.—Each eye selects the series of points from XII to VI as coalescing and appearing as dark lines.

Cobalt-blue Glass.—O. D. and O. S. each show blue above and below the red. (See Figs. 129 and 130.)

Stenopeic Slit.—Axis 90 degrees V. $= \frac{VI}{XXX}$; axis 180 V. $= \frac{VI}{VI}$.

History.—Never had good distant vision. Has occasional headaches. Comes to find out if glasses will improve vision.

S. P.—Face symmetric. Irises dark in color. Pupils apparently round, 5 mm. in diameter. Eyes out under cover.

Ophthalmometer.—Each eye 2 D., axis 90.

Ophthalmoscope.—O. D., media clear. Disc large and round, with underlying conus out. No physiologic cupping. Choroidal circulation everywhere recognized, characteristic of a stretching eyeball. Horizontal vessels seen with —2; vertical vessels seen without any correcting lens. O. S., same general conditions as in O. D.

Manifest Refraction.—

O. D., —2.50 cyl. axis 180 = $\frac{VI}{VI}$.

O. S., —2.50 cyl. axis 180 = $\frac{VI}{VI}$.

℞. Atropin and dark glasses for refraction.

April 12th: Six meters from test-card and point of light. Retinoscopy at one meter. Vertical meridian —1.00 S. Horizontal meridian +1.25 S.

Stenopeic slit at axis 180 with +0.25 = $\frac{VI}{VI}$; at axis 90 = —2.50, $\frac{VI}{VI}$.

Cobalt-blue glass and *pointed line test* show same results as at first visit:

O. D. V. = $\frac{VI}{XV}$???.

O. S. V. = $\frac{VI}{XV}$???.

At Trial-case.—

O. D., +0.25 sph. ⊂ —2.25 cyl. axis 180 degrees = $\frac{VI}{VI}$.

O. S., +0.25 sph. ⊂ —2.25 cyl. axis 180 degrees = $\frac{VI}{VI}$.

April 13th: Same results as yesterday. Add. = 20; Abd. = 6. Esophoria, 2 degrees.

For Miss Jenks.

℞. O. D., —2.25 cyl. axis 180

O. S., —2.25 cyl. axis 180.

April 14th: Glasses neutralize. Centered and properly adjusted.

April 28th: Comfortable. Enjoys good distant vision. Near point, each eye, 9 cm.

Considerations.—Apparently, the static refraction would indicate mixed astigmatism, but when +0.25 is deducted to produce parallel rays, the prescription resolves itself into one for simple myopic astigmatism.

The general rule for ordering cylinders is the same in myopia as in hyperopia—*i. e.*, no change in the strength or in the axis of the cylinder.

A cycloplegic is always necessary in such cases, as is shown by the different lenses obtained by the manifest and stenopeic slit.

The vision was always uncertain before lenses were placed before the eyes, as is indicated by the question marks.

At the first visit the vision was taken with the eyes wide open. If allowed to narrow the palpebral fissure by squinting the eyelids together and making a stenopeic slit out of them, the patient could read a part of $\frac{VI}{VIISS}$. When the lids were thus drawn together, the myopic vertical meridian was excluded in part and the horizontal meridian was utilized. The stenopeic slit was of some assistance before drops were used, as the accommodation could not be exerted, as in the case of the hyperope.

SUMMARY.—After recovery from the cycloplegic, small type was clear at 9 cm., which was in keeping with the patient's age. The near point before "drops" were used was also 9 cm., but not constant, nor was the type clear. The —2.00 cyl. at axis 180 represents ⅓ of a mm. of shortening in the vertical radius of curvature as compared with the normal radius of 7.8 mm. in the horizontal.

The astigmatism is regular, symmetric, with the rule.

CASE V.—**Compound Hyperopic Astigmatism.**—The most common form of all refraction. It is a combination of simple hyperopia with simple hyperopic astigmatism. About 44 per cent. of all eyes have this form of refraction.

April 12th. MR. COMMON. Age, twenty-eight. Married. Bookkeeper.

O. D. V. = $\frac{VI}{X}$??. p. p. = type 0.75 D. = 18 cm.

O. S. V. = $\frac{VI}{X}$??. p. p. = type 0.75 D. = 18 cm.

Add., 23 degrees. Abd., 7 degrees. Esophoria, 2 degrees; at 13 inches, 0.

Astigmatic Clock-dial.—O. D. and O. S. each selects darkest series of lines from IX to III.

Placido's disc shows each corneal image as a horizontal oval. Scheiner's test shows two lights, separated in all meridians: the vertical have the least separation and the horizontal the most.

Ophthalmometer.=2.25 D. with axis 90 in each eye.

History.—Family physician has tried in vain to stop the headaches, which he said were from biliousness. Headache develops as soon as the patient commences to use his eyes, and gets worse toward noon; and from that time on, during the rest of the day, he is cross and irritable, and feels dizzy. Unable to read in the evenings às he did a few years ago. Is wearing a pair of "rest" glasses, which he received from an optician; they were of some benefit for a very short time.

S. P.—Lid margins red and excoriated. Many fine scales (looking like dandruff) adhering to the cilia. Irises gray in color. Pupils round, 3 mm. Eyes in, under cover.

Ophthalmoscope.—O. D. and O. S. each medium clear. Disc small, vertically oval. Shallow physiologic cup. Venous pulsation on disc. Narrow conus to temporal side. Nerve-head prominent and edges somewhat hazy. No pathologic conditions recognized. Vertical vessels best seen with +2.00 and horizontal with +0.50.

℞. Duboisin and dark glasses for refraction.

April 14th: Six meters from test-card and point of light.

O. D. V. = $\frac{\text{VI}}{\text{LX}}$???.

O. S. V. = $\frac{\text{VI}}{\text{LX}}$???.

Retinoscopy develops point of reversal at one meter in each eye; vertical meridian with +1.75 S., and horizontal meridian with +3.50 S.

Stenopeic slit axis 90 degrees with $+1.00 = \frac{VI}{VI}$; at axis 180 degrees with $+2.50 = \frac{VI}{VI}$.

Cobalt-blue glass, blue center and red all round, more conspicuous on the right and left sides. (See Figs. 131 and 132.)

At Trial-case.—

O. D., $+0.75$ sph. ⊃ $+1.75$ cyl. axis $90 = \frac{VI}{VI}$.

O. S., $+0.75$ sph. ⊃ $+1.75$ cyl. axis $90 = \frac{VI}{VI}$.

April 15th: Same results as April 14th. Add., 22. Abd. 7. Esophoria, 1 degree.

For Mr. Common:

℞. O. D., $+0.50$ sph. ⊃ $+1.75$ cyl. axis 90 degrees.
O. S., $+0.50$ sph. ⊃ $+1.75$ cyl. axis 90 "

Sig.—For constant use.

April 17th: Glasses neutralize; are centered and adjusted.

April 24th: Has been perfectly free from headaches ever since getting glasses. Never realized what a blessing glasses could be. Near point with each eye is now 14 cm.

Considerations.—The prescription for glasses was the same as the static refraction, with the exception of the reduction in the strength of the sphere. No change in the cylinder. A cycloplegic as a means of obtaining a prompt, correct, and satisfactory result in such cases can not be dispensed with.

The decided change in the vision before and with the cycloplegic is quite diagnostic of compound hyperopic astigmatism. When the cylinder and sphere are of any considerable strength, the patient can often overcome (facultative hyperopia) the spheric but not the cylindric correction.

Summary.—After recovery from the cycloplegic the small type becomes clear at about 13 cm., which is the near point consistent with the patient's age. The far point before using drops was really two points, both negative—that of the vertical meridian being about 2 meters, and the horizontal meridian about $\frac{1}{2}$ of a meter back of the retina.

The form of the astigmatism is regular, symmetric, and with the rule.

CASE VI.—**Compound Myopic Astigmatism.**—A combination of simple myopia with simple myopic astigmatism. This is the usual form of refraction in myopic eyes. About 8 per cent. of all eyes have compound myopia. The writer's experience is such that he never refracts a case of myopia without searching carefully for a cylinder in combination with the sphere. (See page 123.)

April 12th. MRS. USUAL. Age, thirty years. Married. Housewife.

O. D. V., $\frac{VI}{L}$???, type 0.50 = 10 to 33 cm.

O. S. V., $\frac{VI}{L}$???, type 0.50 = 10 to 33 cm.

Add., 16 degrees. Abd., 6 degrees. Exophoria at 6 meters, 2 degrees.

History.—Suffers from ocular pains, as if knife-points were sticking into the eyes, which come on as soon as near-work is attempted or continued. Says that she constantly sees fine dust particles floating before her vision. Has been wearing glasses from an optician (—3 sph.). Has all the symptoms of near-sightedness. Family history of father and two sisters wearing glasses for "near sight."

S. P.—Face symmetric. Eyeballs prominent. Irises dark in color. Pupils small (for a myope) and round, 3 mm. Eyes markedly out under cover.

Ophthalmoscope.—O. D., many fine floating vitreous opacities. Nerve large and round, with broad underlying conus down and out. Choroidal vessels seen throughout eye-ground. Vessels at about axis 120 degrees best seen with —2, and vessels at axis 30 degrees best seen with —3. O. S., same general conditions as in O. D., except the principal meridians are about 60 degrees and 150 degrees.

Indirect method shows a vertically oval nerve, with the conus to the nasal side of the aerial image (as the eye-ground and nerve-head have undergone vertical and lateral inversion). Withdrawing the lens, the nerve grows larger in all meridians, but more so in the vertical.

Cobalt-blue glass shows O. D. red center, blue all around, more pronounced on the sides in the 120 meridian. O. S. shows red center, blue all around, more pronounced on the sides in meridian of 60 degrees. (See Figs. 133 and 134.)

Stenopeic slit before O. D. at axis 120 V. $= \frac{VI}{LX}$; at axis 30 V. $= \frac{VI}{XX}$??. O. S., the same with axis 60 degrees and 150 degrees.

Astigmatic Chart.—O. D. selects the lines from V to XI as darkest. O. S. selects the lines from VII to I as darkest.

Ophthalmometer.—O. D., 1 D., axis 35 degrees. O. S., 1 D., axis 145 degrees.

Manifest.—

O. D., —2.50 sph. ⊂—0.75, cyl. axis 35 $= \frac{VI}{VII}$????.

O. S., —2.50 sph. ⊂—0.75 cyl. axis 145 $= \frac{VI}{VII}$????.

℞. Atropin and dark glasses for rest and refraction.

April 13th: At six meters from test-card and point of light:

O. D. V. $= \frac{VI}{LX}$+. O. S. V. $= \frac{VI}{LX}$+.

O. D., —2.00, sph. ⊂ —1.00 cyl. axis 30 $= \frac{VI}{VI}$.

O. S., —2.00 sph. ⊂ —1.00 cyl. axis 150 $= \frac{VI}{VI}$.

Retinoscope confirms this trial-case result. Retinoscope also shows a general cloudiness of the media (vitreous), which, of course, will account in part for the vision not being $\frac{VI}{V}$ in each eye with correcting glasses.

April 14th: Same result as on the 13th.

For Mrs. Usual.

℞. O. D., —2.00 sph. ⊃ —1.00 cyl. axis 30 degrees.
O. S., —2.00 sph. ⊃ —1.00 cyl. axis 150 "

Sig.—For distance, as directed.

April 15th:

℞. Tonics. Rest of eyes. Attention to general health.

April 17th: Glasses neutralize; are centered and adjusted.

April 29th: Add., 16. Abd., 6. Exophoria, 2.

Vision in each eye $\frac{VI}{VI}$, read slowly.

Considerations.—The static refraction was ordered just as found, and no deduction whatever was made in the sphere. The rule is to prescribe in the same way as in simple myopia. But all cases of myopia can not and must not be prescribed for by rule. Each case of myopia is a law unto itself. See description under General Considerations, page 238, also pages 227, 228, and 229.

Summary.—The near point is now 14 cm., which is perfectly consistent with the patient's age. Fourteen centimeters represents an accommodative power of 7 D., and this was the difference between the near and far points before the drops were used. The astigmatism is regular, symmetric, and with the rule. Vision is not brought up to normal on account of the changes in the vitreous and disturbed eye-ground, due, no doubt, to the want of a proper correction—the cylinder. The choroid and retina are both in a stretching condition.

Case VII.—**Mixed Astigmatism.**—Not an uncommon condition. About 6½ per cent. of all eyes have this form of refraction. This is a combination of the simple hyperopic and simple myopic astigmatisms, with their axes opposite or at right angles to each other, as a rule.

April 8th. MR. CROOK. Age, twenty-one years. Single. Clerk.

O. D. V. = $\frac{VI}{XL}$. p. p. = 12 cm. with type 0.75 D.

O. S. V. = $\frac{VI}{XL}$. p. p. = 12 cm. with type 0.75 D.

Add., 20. Abd., 10.

History of poor sight all his life, but thinks it was better as a boy. Has frequent frontotemporal headaches, which are worse after using eyes at any prolonged near-work. Father has good sight, but his mother and her family have all been near-sighted; has one aunt that developed cataracts. Has been to several "stores," but could not get fitted with glasses that would improve his vision.

S. P.—Face broad and symmetric. Long interpupillary distance. Irises dark in color. Pupils large, 5 mm.; round. Eyes out under cover.

Ophthalmoscope.—O. D., media clear. Disc vertically oval, axis 105. Macular region shows changes. Vessels at 105 best seen with +2, and at right angles with —2. O. S., same conditions found, except that the meridians are at 75 degrees and 165 degrees.

Ophthalmometer.—O. D., 4 D. axis 100. O. S., 4 D. axis 75.

Cobalt-blue Glass.—O. D. violet center, blue above and below in meridian of 105 and red at the sides in meridian of 15. O. S., pink center, blue above and below in meridian of 75, and red on sides at axis 165. (See Figs. 135 and 136.)

Stenopeic Slit.—O. D. axis 15 with +2 sph., V. = $\frac{VI}{X}$; at axis 105 with —2 sph., V. = $\frac{VI}{IX}$. O. S. axis 165 with +2 sph., V. = $\frac{VI}{IX}$; at axis 75 with —2 sph., V. = $\frac{VI}{X}$.

Indirect Method.—Each eye shows a lengthening of the vertical meridian as the condensing lens is withdrawn from the eye, and at the same time the horizontal meridian grows narrower. As the lens is advanced toward the eye the vertical meridian grows shorter and the horizontal meridian grows broader.

The astigmatic chart does not show any difference in the shading of the lines; they all appear about the same. Retinoscope at 1 meter distance shows myopia in the vertical meridian and hyperopia in the horizontal.

℞. Atropin and dark glasses for refraction.

April 10th: At six meters from test-card and point of light. O. D. and O. S. V. $= \frac{VI}{LX}$.

Cobalt-blue glass shows the same as at first visit.

Retinoscope at the distance of one meter shows point of reversal in O. D. at axis 105 degrees with —1.50 D., and axis 15 with +3 D. O. S., axis 75 with —1.50 D., and axis 165 with +3 D.

Stenopeic Slit.—O. D., axis 15 with +2 sph., V. $= \frac{VI}{IX}$; axis 105 with —2.50. sph., V. $= \frac{VI}{IX}$. O. S., axis 165 with +2 sph., V. $= \frac{VI}{IX}$; at axis 75 with —2.50 sph., V. $= \frac{VI}{IX}$.

At Trial-case.—O. D., —2.50 cyl. axis 15 degrees $\bigcirc$ +2 cyl. axis 105 degrees, V. $= \frac{VI}{VIISS}$. O. S., —2.50 cyl. axis 165 $\bigcirc$ +2 cyl. axis 75, V. $= \frac{VI}{VIISS}$.

Or,

O. D., —2.50 sph. $\bigcirc$ +4.50 cyl. axis 105, V. $= \frac{VI}{VIISS}$.

O. S., —2.50 sph. $\bigcirc$ +4.50 cyl. axis 75, V. $= \frac{VI}{VIISS}$.

Or,

O. D. +2 sph. $\bigcirc$ —4.50 cyl. axis 15 degrees, V. $= \frac{VI}{VIISS}$ +.

O. S. +2 sph. $\bigcirc$ —4.50 cyl. axis 165, V. $= \frac{VI}{VIISS}$ +.

April 11th: Same results as April 10th. Add., 20. Abd., 8.

For Mr. Crook.

℞. O. D. +2 sph. ⊃ —4.50 cyl. axis 15 degrees.
O. S. +2 sph. ⊃ —4.50 cyl. axis 165 "
Sig.—For constant use.

April 12th: Glasses neutralize; are centered and adjusted.

April 26th: Near point 10 cm., which is consistent with age of patient.

Considerations. — The ophthalmoscope, retinoscope, cobalt-blue glass, indirect method, and stenopeic slit were direct guides to the character of the refractive error. Emphasis is placed upon these different methods, as so many beginners in ophthalmology have a fear or dread of the result in refracting cases of mixed astigmatism.

The *stenopeic slit* shows a difference of 4.50 in the two principal meridians; bearing this fact in mind, if a —4.50 cylinder at axis 15 be placed before the right eye, then all meridians would be made equally hyperopic 2 D. Combining +2 sph. with the —4.50 cylinder at axis 15 in the right eye or at axis 165 in the left, the refraction would be corrected.

Or, if a +4.50 cylinder at axis 105 be placed before the right eye, then all meridians would be made myopic 2.50 D. Combining a —2.50 sph. with this +4.50 cylinder at axis 105 in the right eye or at axis 75 in the left eye, the refraction would be corrected.

For a further consideration of combination of lenses see page 51.

The rule for ordering cylinders is the same in mixed astigmatism as in other cylindric corrections—without change.

Summary.—The character of the astigmatism is regular, symmetric, and with the rule. The near point returns to the normal for the age. Eyes with such high errors do not, as a rule, obtain a visual acuity of $\frac{VI}{VI}$, for the reason that changes have taken place in the eye-ground, especially at the macula.

Case VIII.—**Irregular Astigmatism.**—

April 2d. Mary Smiles. Age, ten years. Scholar.

O. D. V. $= \frac{VI}{XXX}$ slowly. No p. p. obtained.

O. S. V. $= \frac{VI}{LX}$. No p. p. obtained.

History of poor sight ever since an attack of measles when two years of age, at which time was kept in a dark room for six weeks. Eyes were never strong afterward; always very sensitive to light. Child was sent home from school with a note from the teacher: "Mary is near-sighted and should see a doctor."

S. P.—Eyelids appear normal. Excessive epiphora. Corneas nebulated, especially O. S., which has a decided leucoma at the pole. Anterior chambers of normal depth. Pupils 3 mm., round. Corneal reflex very irregular.

Ophthalmoscope.—No view obtained of the eye-ground through the small pupils on account of corneal opacities. Homatropin mydriasis shows O. D. cornea faintly nebulated in scattered areas; rest of media clear. Nerve small and round. Vessels at axis 35 degrees best seen with +2 D. O. S., there is a 3 mm. area of opacity at the pole of the cornea; no clear view of the eye-ground. Indirect method shows a small nerve and refraction hyperopic.

℞. Atropin and dark glasses for refraction.

April 22d: Retinoscope at 1 meter shows band of light at axis 35, indicating hyperopia. Other meridians very irregular. O. S., nothing definite made out.

Placido's disc shows irregular, distorted circles.

With Pin-hole Disc.—O. D. V. = $\frac{VI}{XX}$. O. S. V. = $\frac{VI}{LX}$.

With Stenopeic Slit.—Axis 45 degrees before O. D. and with +2.25 S., V. = $\frac{VI}{XV}$??. O. S., can not improve vision with any glass.

At Trial-case.—O. D., +2.00 cyl. axis 145 = $\frac{VI}{XV}$??. O. S., no glass accepted.

April 23d: At trial-case O. D., +1.75 cyl. axis 35 = $\frac{VI}{XV}$.

For Mary Smiles.

℞. O. D., —0.25 sph. ⊃ +1.75 cyl. axis 35 degrees.
O. S., plane glass.
Sig.—Constant use.

Considerations.—This case shows the advantage of the stenopeic slit and the use of the pin-hole disc. The near point could not be obtained on account of the poor visual qualities and the child's inability to appreciate what was wanted.

Case IX.—**Tonic Cramp or Spasm of the Accommodation.**—

Mrs. L. Age, twenty-four years.

O. D. V. = $\frac{VI}{XL}$??. p. p. = 9 cm. (?) Add., 24 degrees. Abd., 6 degrees. Esophoria, 4 degrees.

O. S. V. = $\frac{VI}{XL}$??. p. p. = 9 cm. (?) No vertical deviation.

History of having had glasses changed on three different occasions during the past year. Drops were used each time, and the three prescriptions were all different. Glasses were always satisfactory for the first week, but after this time she was always able to see better at a distance without them. Has pains in her eyes and all over the head whenever she attempts to use the eyes with or without any glasses. Headaches nearly set her "wild" if she tries to concentrate her vision on a distant or near object. Has not been able to read or write or sew for the past two years. Has been under the care of the gynecologist and neurologist, and they each pronounce her physical condition as normal. The neurologist suggests a diagnosis of "hysteria." Patient sleeps well and has a good appetite, but will suffer from nausea and vomiting if she uses her eyes for any length of time. Patient has been married five years. Has one living child. No miscarriages. Is apparently in the very best of health, and is provoked with her apparent good health as not being consistent with her suffering, and hence she does not receive any sympathy from her family or her friends.

S. P.—No external manifestations of any ocular irregularity.

Manifest Refraction.—

O. D., —0.50 S. $\supset$ +1.00 cyl. axis 90 degrees $= \frac{VI}{VI}$.
O. S., the same as O. D.

Ophthalmoscope.—O. D. and O. S., media clear. Discs vertically oval, eye-grounds "woolly." Accommodation very active. Shot silk retina. Refraction is compound hyperopic astigmatism.

Cobalt-blue glass shows a red center and broad blue halo. (Patient is certainly accommodating.)

℞. Atropin and dark glasses for refraction.

Static Refraction.—

O. D. +1.50 S. = +1.75 cyl. axis 90 degrees $= \frac{VI}{V}$.
O. S. +1.50 S. = +1.75 cyl. axis 90 degrees $= \frac{VI}{V}$.

Patient states that her "pains and headaches all disappeared after using the drops for the third time."

Refraction repeated on three different occasions, and the following prescription given:

For MRS. L.

℞. O. D., +1.25 S. ⊃ +1.75 cyl. axis 90 degrees.
O. S., +1.25 S. ⊃ +1.75 cyl. axis 90 degrees.

Glasses properly centered, and accurately adjusted.

After ten days patient returns with the statement that her pains and aches have recurred as before, and that she can see better at a distance without her glasses. With correction, each eye sees $\frac{VI}{XL}$, and with both eyes can see $\frac{VI}{XXX}$. Add., 20 degrees, and abd., 8 degrees. No vertical deviation. Has 3 of esophoria at 6 meters.

℞. Atropin $\frac{1}{20}$ of a grain to the ounce.
SIG.—To use one drop in each eye each morning and noon.

To wear a pair of dark glasses with her prescription glasses when exposed to any bright light. Not to attempt any near-work. This treatment was continued, off and on, for six months. Patient was always free from ocular pain and headache as long as the atropin was being used, but as soon as the ciliary muscle commenced to contract, then the pains would return with all their former severity. This patient eventually recovered by using her distant correction with a pair of plus 2 spheres as hook-fronts for any near-work.

CASE X.—**Exophoria.**—

MISS. V. B. D. Age, twenty-two years.

O. D. V. = $\frac{VI}{VI}$. p. p. = 0.50 D., type at 11 cm.
O. S. V. = $\frac{VI}{VI}$. p. p. = 0.50 D., type at 11 cm.
Add. and abd., 12 degrees. Exophoria = 4.

History of seeing double several times a day. Friends and members of her family have told her she was "squinting." Always returns home with a severe occipital headache after going shopping or to any place of amusement. Has headache when using her eyes, but it soon passes away after resting the eyes.

S. P.—Eyes markedly out under cover. Irises react promptly to light, accommodation, and convergence. Fixation test shows the right eye divergent.

Ophthalmoscope.—O. D. and O. S. No apparent changes, and refraction almost emmetropic; some small amount of hyperopia and astigmatism.

℞. Atropin and dark glasses for rest and careful refraction.

Static refraction, after several repetitions, O. D. and O. S., +0.50 S. ⁀ +0.37 cyl. axis 90 degrees $= \frac{VI}{V}$. And this is ordered, less 0.25.

With this correction carefully centered, add. = 14 degrees and abd. = 12 degrees, with 3 of exophoria at 6 meters and 12 degrees of exophoria at 13 inches. This patient was given prism exercises for more than two months, and, finally, after the adduction reached 30 degrees and abduction was 10 degrees and 3 degrees of esophoria were obtained, the prism exercises were stopped, and patient told to report promptly if any discomfort arose at any time. To wear her glasses constantly.

CASE XI.—**Anisometropia.**—

MR. ALBERT S. Age twenty-nine years. In general business.

O. D. V. $= \frac{VI}{XXX}$. p. p. type 0.50 D. = 25 cm.

O. S. V. $= \frac{VI}{XL}$. p. p. type 0.75 D. = 30 cm.

Add., 10 degrees. Abd., 6 degrees. Left Hy., 2 degrees.

History.—Has had three pairs of glasses ordered, with "drops," during the past eighteen months. Has never had any but the very slightest relief from ocular pains and frontal headaches, which have been almost constant for the past four years or more. On account of the ocular discomfort and headaches, the patient has given up all attempts to read for more than fifteen minutes at a time. Patient states that if he uses his eyes for more than this length of time they become bloodshot and very tender to the touch. General health of patient is excellent; has a good appetite and sleeps well. Does not use tobacco or liquor of any kind.

S. P.—Face symmetric. Nose very prominent. Interpupillary distance, 62 mm.

Ophthalmoscope.—O. D., nerve-head over capillary. Not swollen. Accommodation very active. Eye-ground "fluffy." Refraction is that of compound hyperopia. O. S., same general conditions, but the nerve is vertically oval and the refraction is compound hyperopic astigmatism.

℞. Atropin and dark glasses for refraction.

Static Refraction.—

O. D., +2.00 S. ⊂ + 1.00 cyl. axis 75 degrees $= \frac{VI}{VI}$	2△ of left hyperphoria.
O. S., +1.25 S. ⊂ +3.00 cyl. axis 105 degrees $= \frac{VI}{VI}$???	

℞. O. D., +1.75 S. ⊂ +1.00 cyl. axis 75 degrees ⊂ ¾△ base up.
O. S., +1.00 S. ⊂ +3.00 cyl. axis 105 degrees ⊂ ¾△ base down.
SIG.—For constant use.

This patient was not made comfortable until he was given five-grain doses of the bromid of potash three times a day for four weeks. Is now able to use his eyes without the least discomfort.

CHAPTER XI.

PRESBYOPIA.—APHAKIA.—ANISOMETROPIA. —SPECTACLES.

Presbyopia.—The word presbyopia (from the Greek, πρέσβυς, "old"; ὤψ, "eye") literally means old sight, and patients at the age of forty-five or more years are universally recognized as presbyopes, and the condition of their eyes as presbyopic. There is no exact age limit as to when presbyopia shall begin, the advent of presbyopia being controlled by the character of the ametropia and physical condition of the eyes themselves. Presbyopia may be described in several different ways, according to the cause—*i. e.*,

1. Old sight.

2. The condition of the eyes in which the punctum proximum has receded to such a distance that near vision (close work) is impossible without the aid of convex lenses.

3. The condition of the eye in which the lens fibers have become more or less sclerotic, and, as a consequence, the lens loses some of its inherent quality of becoming more convex during contraction of the ciliary muscle.

4. The condition of the eye in which the power of the ciliary muscle has become weakened.

5. The condition of the eye in which the power of accommodation is diminished at the same time that the lens fibers become sclerotic.

6. The condition of the eye in which two different refractions (not necessarily two pairs of glasses) are required, one for distance and one for near vision.

7. The condition of the eye in which one pair of glasses will not answer for distant and also for near vision.

8. Presbyopia may be described as the condition in which nature has instilled a slowly acting but permanent cycloplegic (the term cycloplegic is used here in a general sense).

Causes of Presbyopia.—1. *Age.*—It is a well-established fact that in childhood the center of the lens begins to harden, becomes sclerotic or sclerosed, to form a nucleus; and this process continuing, eventuates in complete sclerosis at sixty or seventy-five years. The term sclerosis must not be confounded with opacity.

2. *Disease.*—Ordinarily, presbyopia, as applied to the lens, should be recognized as a physiologic process, as a penalty for growing old, though it is a condition which may be hastened by disease. Any disease, therefore, which will cause the nutrition of the lens to suffer must eventually interfere with its ability to become more convex during accommodation. The most common ailments that tend to this result are rheumatism, gout, Bright's disease, diabetes, lithiasis, la grippe, etc. Any disease which will weaken the ciliary muscle will produce presbyopic symptoms.

Presbyopic Near Points.—The near point and power of accommodation in a healthy emmetropic eye, or a healthy eye made emmetropic by the addition of correcting lenses, is as follows for certain ages:

Age.	Near Point.	Power of Accommodation.	
40 years,	. . . . 22 cm.	4.50	diopters.
45 "	. . . . 28 "	3.50	"
50 "	. . . . 40 "	2.50	"
55 "	. . . . 55 "	1.75 or 2.00	"
60 "	. . . . 100 "	1.00	"
65 "	. . . . 133 "	0.75	"
70 "	. . . . 400 "	0.25	"
75 "	. . . . ∞ "	.00	"

Ordinarily, the average adult holds a newspaper or book at about 33 cm. (13 inches) from his eyes when reading; and if he is forty years of age and emmetropic, or is made emmetropic with glasses, he would be using 3 D. of his normal 4.50 of accommodation, which would leave a reserve power of 1.50 D.; and in this condition, other things being equal, he can maintain a reading distance with comfort. In fact, he could, by using all of his 4.50 D. of accommodation, see objects as close as 22 cm., but not for any great length of time, as the ciliary muscle would soon relax.

This same patient at forty-five or forty-six years of age will have lost 1.00 or 1.50 D. of his accommodation, and now has only about 3 or 3.50 left; and if he uses all of it at a working distance of 33 cm., the ciliary muscle soon yields. In fact, the ciliary muscle can not be held in such a state of tension without causing all sorts of pains and aches and reflex disturbances; and the ciliary effort relaxing suddenly, the near vision blurs, and the work or reading or sewing must be put at a greater distance to obtain relief, or else the effort must be abandoned.

Symptoms of Presbyopia.—The principal symptom is that which indicates a recession of the punctum proximum; the patient stating that there is an inability to maintain the former reading, writing, or sewing distance, and that all near-work must be held at a greater distance than formerly. Symptoms of accommodative strain may be present if the patient endeavors to force the accommodation to its maximum.

Diagnosis.—The age of the patient and the history of having to hold reading matter at an uncomfortable distance; or a history of good distant vision and an inability to retain clear near vision—small objects, to be seen, must be held far away or "at arm's length."

Correction of Presbyopia.—The presbyopic state represents a class of patients for whom glasses may be prescribed by the manifest refraction, although there are exceptional cases in which a quick cycloplegic will be necessary when an amount of astigmatism or cylinder axis is uncertain.

For a working, reading, writing, or sewing distance of 33 cm. (13 inches), the writer makes it a rule to *add to the distance correction* at forty-five years of age a +1 sphere; at fifty years of age, a +2 sphere; at fifty-five years of age, a +2.50 sphere; and for sixty or more years, a +3 sphere.

The following table for emmetropic eyes shows these additions for the different years, and also the near and far points *with* these additions as well as the range of accommodation or "play" between the near and far points. It will be observed that the range of 78 cm. at forty-five years rapidly diminishes in the succeeding years, until at sixty there is a play of only about 3 inches, and at seventy the range is practically gone.

Years.	Add.	Near Point.	Far Point.	Range.
45	+1.00	22 cm.	100 cm.	78 cm.
50	+2.00	22 "	50 "	28 "
55	+2.50	23 "	40 "	17 "
60	+3.00	25 "	33 "	8 "
65	+3.00	27 "	33 "	6 "
70	+3.00	30 "	33 "	3 "
75	+3.00	33 "	33 "	0 "

Because a patient is fifty years of age does not signify that he will be able to read at 33 cm. with a pair of +2 spheres, or because he is sixty years of age that he can use his eyes at 33 cm. comfortably with a pair of +3 spheres; on the contrary, this rule that the writer has given applies only to cases of emmetropia. It often happens that presbyopic patients state that they do not want glasses for distance; that they do not need them; that all they wish is a pair of glasses to use at near-work, reading, etc. When the vision is taken in such cases, it may be found to be $\frac{VI}{VI}$ or approximating $\frac{VI}{VI}$; but the young ophthalmologist must not be thrown off his guard by this record, as it has already been stated that a vision of $\frac{VI}{VI}$ does not by any manner of means prove the existence of emmetropia. Let the surgeon make it *a constant rule in every case of presbyopia to always carefully estimate the amount of the distance ametropia first, no matter how weak or what its form (sphere or cylinder); and to the result thus obtained, add the plus sphere which will be required for the working distance or point at which the patient wishes to see clearly.*

Illustrative Cases.—CASE I.—Accepts +0.50 sph. for distance. At forty-five years this case would require +1.50 sph. for reading at a distance of 33 cm.; at fifty years, +2.50 sph.; at fifty-five years, +3 sph.; and at sixty or more years, +3.50 sph. Only one pair of glasses is necessary.

CASE II.—Accepts +2 sph. for distance; at forty-five years these eyes would require +3 sph.; at fifty years they would require +4.50 sph.; and at sixty or more years they would require +5 sph. Two pairs of glasses would be indicated in this case.

CASE III.—Accepts —1.00 sph. for distance; at forty-five years this patient could read without any glasses, as —1 for distance would be neutralized by the +1 required for reading. At fifty years, however, the patient would require a +1 sphere for near, and at fifty-five a +1.50, and at sixty years a +2 sphere. Case II required two corrections, one for distance and one for near; and the same may be said about Case III; but in this latter instance there was a time at forty-five years when there was no necessity for glasses for the near-work, as the patient's eyes were in a suitable condition of refraction to read without them.

CASE IV.—Accepts —3 sph. for distance. At forty-five years would require —2 sph. for reading; at fifty years would require —1 sph. for reading; and at sixty years can read *without* any glasses. Such a patient says he has gotten his "second sight."

CASE V.—Accepts +0.50 cylinder axis 180 for distance and requires the usual additional spheres for the increasing years for his reading distance.

CASE VI.—Accepts +1.00 sph. ⊂ +1.00 cyl. axis 180 for distance and requires the spheric additions as the years increase. Two pairs of glasses should be prescribed.

CASE VII.—Accepts —1 cyl. axis 90 for distance, and requires +1 cyl. axis 180 to read with at forty-five years of age; at fifty years he requires +1 sph. ⊂ +1 cyl. axis 180; and at sixty years requires +2 sph. ⊂ +1 cyl. axis 180. At forty-five years of age this patient is commonly spoken of as having simple myopic astigmatism for distance (against the rule) and simple hyperopic astigmatism for near (against the rule also); two pairs of glasses are indicated throughout life.

CASE VIII.—Accepts —1.00 sph. ⊂ —1.50 cyl. axis 180 for distance, and at forty-five years will need —1.50 cyl. axis 180 for reading; at fifty years will require +1.00 sph. ⊂ —1.50 cyl., axis 180 degrees; at sixty years, +0.50 sph. ⊂ +1.50 cyl. axis 90 degrees.

Two pairs of glasses should be used throughout life. At forty-five years this patient has a compound myopic correction for distance and simple myopic astigmatism for near; at fifty years the correction for near is that of crossed cylinders (mixed astigmatism); and at sixty years the near correction is that for compound hyperopic astigmatism.

Case IX.—Accepts —1.00 sph. ⊃ +2 cyl. axis 90 for distance (mixed astigmatism); at forty-five years, +2 cyl. axis 90 is required for reading; at fifty years, +1.00 sph. ⊃ +2.00 cyl. axis 90. Two pairs of glasses are required. At forty-five years the distance correction is for mixed astigmatism and the reading correction is for simple hyperopic astigmatism.

Case X.—Accepts —2.00 cyl. axis 180 for distance; at forty-five years requires a mixed astigmatism correction for near; at fifty years, a simple hyperopic correction; and a compound hyperopic correction at sixty years.

In the above illustrative cases the working distance has been calculated at 33 cm., or 13 inches; but as some patients use their eyes at a greater or less distance than this, the additional convex lenses must be calculated accordingly. For instance, the weaver at fifty-five years of age who requires +2 spheres for distance could not see to weave at 50 cm.; if +2.50 spheres were added to his distance correction, all he needs is +3 for his working distance. Or the diamond cutter who wishes glasses to see his work at 8 inches, if he accepted —1.00 sph. for distance, he would require +2 sph. at forty-five years of age.

In conclusion, there are three facts in the refraction of presbyopic patients that should receive attention:

1. Many accept a weak plus cylinder (+0.50 at axis 180) against the rule. This is presumptive evidence that the astigmatism is acquired, is lenticular, and is due to the sclerotic changes previously mentioned. The only positive way to prove this fact is by the retinoscope, and by the absence of corneal astigmatism with the ophthalmometer. If the case has been previously refracted by the same surgeon, his record will also confirm this extremely interesting occurrence. According to able authorities, hyperopic eyes

become more hyperopic after the age of seventy years, and emmetropic eyes may become hyperopic, and myopic eyes less myopic, from the same sclerotic or shrinking process which takes place in all the ocular tissues as a result of senility. The method of correction by glasses, however, is just the same, and that is to correct the distant vision first and then add the near correction.

2. An attack of glaucoma may precipitate presbyopic symptoms, so that when a presbyopic patient asks for frequent changes in his corrections, this complication should be borne in mind.

3. The swelling of the lens which occasionally precedes the formation of some forms of cataract should be remembered when the patient develops symptoms of myopia—*i. e.*, a reduction in the strength of convex glasses.

Aphakia (*ά*, priv.; *φακός* "lentil") literally means an eye "without a lens." (See Fig. 174.) An eye which has had its lens dislocated has been erroneously spoken of as aphakic. The absence of the lens means a total absence of all accommodation, no matter what the age of the patient may be.

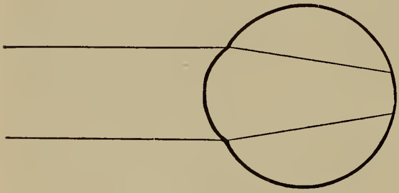

Fig. 174.

Causes.—Aphakia may be congenital, but in most cases is the result of removing the lens by operation.

Diagnosis.—Aphakia may be diagnosed by inspection—*i. e.*, corneal scar, depth of anterior chamber, tremulous iris, coloboma of the iris, opaque capsule whole or in part, erect corneal image, with absence of lenticular images, and by the patient's history.

The ametropia of an aphakic eye depends in great part upon the previous refractive condition of the eye, and also upon the kind of operation that was performed for the removal of the lens. It has been calculated that an eye, to be emmetropic after the removal of its lens, would have to be myopic at least twelve diopters. If this is always true, then the correcting lens which is selected by an aphakic eye is a guide to its former ametropia. An eye which selects a weak plus sphere would, therefore, have been myopic before the operation; and if about a + 12 S., its previous refraction approximated emmetropia; if a plus sphere stronger than 12, then the previous refraction was very likely hyperopia.

An eye which has had its lens removed by absorption (needling) is not likely to be astigmatic; whereas, when the lens has been removed by extraction, astigmatism against the rule of one or more diopters almost invariably results, and the axis of the correcting cylinder generally coincides with the points of puncture and counterpuncture in the cornea. If a patient had 2 or 3 D. of myopic astigmatism with the rule, this would be neutralized by the corneal section.

Correction of Aphakia.—As in presbyopia, two corrections are necessary—one for distance and one for near. Astigmatism must always be looked for and carefully corrected, especially if the lens has been removed by extraction.

Case I.—

O. D., + 8.00 sph. ⌒ + 3.00 cyl. axis 10 degrees. V. $= \frac{VI}{X}$.
O. D., + 11.00 sph. ⌒ + 3.00 cyl. axis 10 degrees = reading at 33 cm.

This patient was presumably myopic before operation.

Heterometropia (ἕτερος, "different"; μετρον, "a measure"; ὤψ, "the eye") literally means that the ametropia of the two eyes is different in character; examples, O. D. +1 D. and O. S. —1 D., or O. D. +3 cyl. axis 90° and O. S. —3 cyl. axis 180°, or O. D. —5 D. and O. S. —5 cyl. axis 180°, etc.

Anisometropia (ἄνισος, "unequal"; μέτρον, "a measure"; ὤψ, "the eye") literally means that the ametropia of the two eyes is *the same in character* but of unequal amount. Examples, O. D. +2 D. and O. S. +6 D., or O. D. —0.50 D. and O. S. —5 D., or O. D. +3 cyl. axis 90° and O. S. +6 cyl. axis 90°, etc. This condition may be slight or one of the most extreme conditions imaginable.

For instance, if both eyes have compound hyperopic astigmatism, they are not considered as heterometropic, even if the sphere and cylinder are of different strength in the two eyes. Bearing this distinction in mind, the percentages already given for myopia, hyperopia, the different astigmatisms, etc., have been calculated accordingly, that for heterometropia being about thirteen per cent.

Causes.—Usually the condition is congenital, or it may be acquired.

Difficulties.—Two difficulties are encountered when ordering glasses for cases of anisometropia or heterometropia: (1) The lens for one eye may be concave and that for the other may be convex, or both eyes may require a convex or both may require a concave lens, but one very much stronger than the other; under these circumstances, when the eyes are rotated there will be a prismatic result of different amount in each eye, and this may mean diplopia, or at least an exertion on the part of the extraocular muscles to prevent diplopia which will cause dizziness, nausea, headache, etc. (2) With lenses as just mentioned, the size of the two retinal images will not be exactly the same, and this will mean an interference with clear binocular vision.

For purposes of study, the writer would divide cases of heterometropia and anisometropia into four different classes.

Class I.—This class embraces those cases in which the difference in the ametropia between the two eyes is very slight or does not exceed two diopters. In fact, there are very few pairs of eyes that are not slightly anisometropic; such eyes usually receive their exact corrections with comfort, regardless of the condition.

Class II.—Cases that come under this head also accept their exact correction for each eye, but do not attempt binocular fixation, and may never suffer the least inconvenience; these cases are extremely rare. They do not complain of diplopia, as they have learned to ignore the false image. Cases of alternating squint, one eye myopic and the other eye hyperopic, may be included in this class.

Class III.—This is a class which will accept the exact correction before one eye only, and the eye which has the greatest amount of ametropia will refuse almost any lens except the very weakest. The eye that has the most ametropia is often quite amblyopic.

Class IV.—This class includes young children especially; cases of squint. In children the correction as found by the static refraction is usually accepted.

The Prescribing of Glasses in Cases of Heterometropia and Anisometropia.—Excluding Class I, there is no fixed rule to follow when ordering glasses in decided cases of heterometropia or anisometropia, and, in fact, such eyes are a constant study to the most able ophthalmologist. The younger the patient, however, the more likelihood of a favorable result from the careful selection of a glass for each eye; but when the patient is an adult, it becomes a very serious question as to what glass to prescribe that will give satisfaction. As good results are to be expected in children, they should receive the most careful retinoscopic refraction. The child comes under observation on account of a squint, and an operation for the deformity is often demanded; but the operation must be refused until the ametropia has been carefully treated. Glasses having been prescribed, the squinting eye is put to work to develop its seeing qualities, which have been permitted to lie dormant for want of a proper glass. To do this, the "good" eye is shielded or blinded with a handkerchief tied over it, or a blinder (see Fig. 160) placed over its correcting lens, for an hour or two each day, and in this way an attempt is made to bring the vision in the squinting eye up to that of its fellow.

Or another way to develop the vision in the squinting eye is to use a cycloplegic in the "good" eye, so that the squinting eye must do most of the work. This is rather trying to the little patient, and often means the additional use of dark glasses. As a rule, the "good" eye has the least amount of ametropia, but occasionally the reverse condition may exist.

In a case like the following, the little girl, five years of age, was brought on account of convergent squint in O. S., which developed or commenced to appear when ten months of age, and the parents attributed it to the habit of sucking her thumb at the time of being weaned. Refraction, with atropin as the cycloplegic, and obtained with the retinoscope, showed O. D., +2.00 sph.; O. S., +4.00 sph. ⊃ +1.00 cyl. axis 75 degrees.

This child developed the squint on account of the monocular astigmatism and because it could not accommodate sufficiently with the left eye. To avoid diplopia at the same time that the eyes were converging, the left eye naturally turned inward. With correcting glasses, and practising as above directed, the squint entirely disappeared, and vision one year later was $\frac{VI}{V}$ in each eye with the correcting glasses. If the glasses are laid aside for any length of time, the squint returns. This child must wear the glasses or have "squint."

To make sure that no injustice is done to an apparently amblyopic eye in an adult (Class III, p. 270) where amblyopia exanopsia has existed for many years and nothing has been done to improve its correction, the writer makes it a rule to prescribe the exact correction for each eye, and at the time of ordering the glasses explains to the patient what the purpose and desire is, and that if there is any great amount of discomfort in any way, he must return and have any necessary change made in the glass. These patients should be kept under observation and the amblyopic eye given some sort of a correction and improved as much as possible; the purpose being not to allow the eye to degenerate or grow more amblyopic, for if any accident should befall the "good" eye, then the amblyopic eye will often be a friend indeed.

Glasses for Presbyopes and Cases of Aphakia.—Unless the distant vision is improved or asthenopic symptoms are relieved by glasses, it will be sufficient to prescribe the near correction only. When a distant and near correction are required, they may be prescribed as two pairs of glasses in separate frames, or two pairs in one frame, known as bifocals. Bifocals, or what is equivalent to bifocals, are made in different ways.

1. **Franklin * or Split Bifocals** (Figs. 175 and 176).—This form of bifocals consists of an upper and a lower lens, each with its individual center; the upper lens is for distance and the lower for near vision. Such lenses must have the frame all around the edges, so as to hold them in posi-

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* "History of Spectacles," L. Webster Fox, "Med. and Surg. Reporter," 1890, vol. LXII, 513–519.

tion. Bifocals of this kind are not in common use. The field of distant vision is limited by the unnecessarily large near correction, and where the two lenses come together,

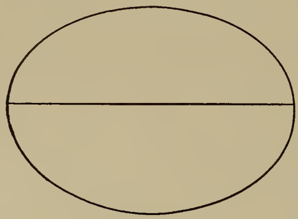

Fig. 175.

Fig. 176.

there is apt to develop chromatic aberration and a decided prismatic effect when the vision is directed through this space.

℞. O. D., +2.00 sph.
O. S., +2.00 sph.
Sig.—For distance.

℞. O. D., +4.00 sph.
O. S., +4.00 sph.
Sig.—For near.

Directions to Optician.—Make into Franklin or split bifocals.

2. **Morck's Patent or "Perfection" Bifocals** (Fig. 177).—These are a modification of the Franklin or split bifocals, and in place of having lenses united in a horizontal line, the near and distant lenses are fitted together with corresponding crescent edges. This form of bifocal gives a larger field for the distance correction, and, like the Franklin, is much better for those who work in a damp atmosphere and can not wear the cement bifocal. It is,

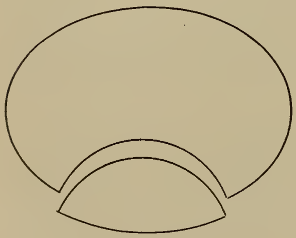

Fig. 177.

however, more expensive than the cement form; but, like the Franklin, it often looks clumsy or heavy on account of the frame. "Perfection" or "Morck" bifocal must be signified in writing the prescription.

3. **Cement Bifocals** (see Figs. 178 and 179*).—This is the most common form of bifocal and the least expensive in its original cost, as also when making changes in the near correction. This bifocal is made by cementing a seg-

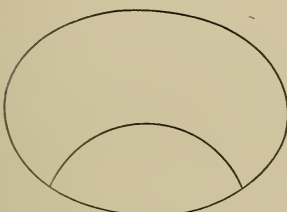

FIG. 178.

FIG. 179.

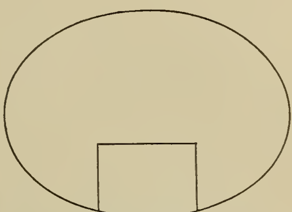

FIG. 180.

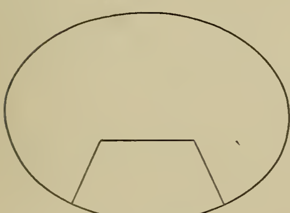

FIG. 181.

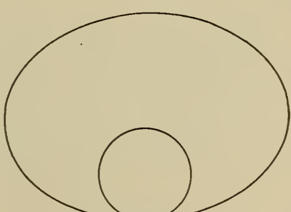

FIG. 182.

ment of a small periscopic sphere on to the lower part of the distance correction. This periscopic sphere or disc or segment, as it is called, has a prismatic quality (see Fig. 179) suitable to the exigencies of the individual lens to which it is cemented. The segment may be of any shape desired. Those in common use are shown in figures 180, 181, and 182. It is cemented to the distance correction

* Described by Dr. Geo. M. Gould, "Med. and Surg. Reporter," Nov. 3, 1888.

with Canada balsam. While this is the usual method of making a cement bifocal, yet it may be made by cementing

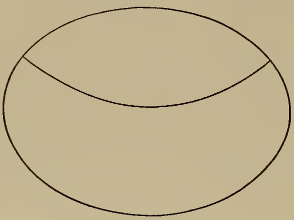

FIG. 183.

FIG. 184.

a concave segment to the upper part of the near correction. (Figs. 183 and 184.) This form is not in common use.

℞. O. D., +2 S.
O. S., +2 S.
Cement on the lower part of the above O. D. and O. S., +2.00 S.
SIG.—Make frameless bifocals.

Or,

℞. O. D., +4 S.
O. S., +4 S.
Cement on the upper part of O. D. and O. S., —2.00 S.
SIG.—Make frameless bifocals.

4. **Achromatic Bifocals** (Figs. 185 and 186*).—This

FIG. 185.

FIG. 186.

form of bifocal is used principally in cases of aphakia where the plus sphere is quite thick and correspondingly heavy. It

* Borsch patent.

is made in one of two ways: (1) By grinding out a portion of the lower part of the distance correction (in crown glass) and cementing into the concavity a biconvex segment of flint glass. This form of bifocal is a combination of the "perfection" and lenticular. (2) In place of grinding the concavity in one lens, as just described, this achromatic bifocal is also made by taking two planoconvex spheres and grinding out a concavity in each, and then inserting a convex sphere of flint glass, as shown in figure 186; these three lenses are then cemented together, and when completed, look like the cement bifocal, as shown in figure 182. It is a matter for very careful calculation as to just how strong to make the flint glass segment, so that the result may be just exactly right. The merits of this bifocal are lightness and the absence of chromatic aberration. These lenses are very expensive.

5. **Solid or Ground Bifocals** (Figs. 187 and 188).—Lenses of this character are made in one piece by grinding

FIG. 187.

FIG. 188.

on to the upper part of the near correction the necessary minus spheric correction for distance. They look neat, but are not always comfortable, on account of the resulting prismatic effect, which is especially apt to occur when the lens is convex, though this may not be so troublesome a feature when the lens is moderately concave.

Single Crystal Bifocals.—Lenses of this character are made in one piece, and in this respect are like the solid bifocal, but they differ from the solid bifocal in two ways: the near correction is made by grinding on to the lower part of the distance correction, the necessary plus sphere. The solid bifocal gives a decided prismatic effect where the

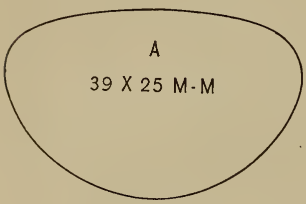

Fig. 189.

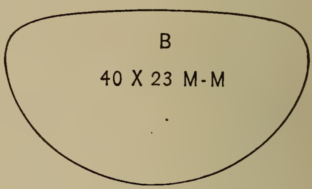

Fig. 190.

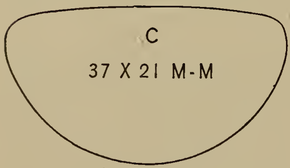

Fig. 191.

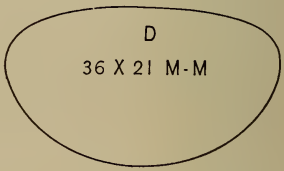

Fig. 192.

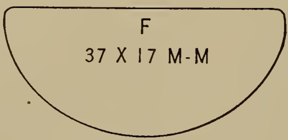

Fig. 193

two corrections meet, whereas this defect is said not to exist in the crystal bifocals. These bifocals are expensive.

6. Patients who have a very weak distance correction, and could do without it, sometimes accept it for the convenience of wearing bifocals; they do not wish to be annoyed by taking off or putting on a near correction, prefer-

ring to have the glasses where they can find them; business men especially. Other patients prefer to do without a distance correction, and will often use a near correction that has one-third or nearly one-half of its upper part cut away, so that they can look over the near correction when they wish to see at a distance. (See Figs. 189, 190, 191, 192, and 193.) Myopes who do not need a near correction will wear their distance correction with its lower portion cut away, so that when they wish to see near at hand, they can look under the distance correction.

7. Patients who require a distance correction, and can not get accustomed to cement segments, and at the same time do not wish to change the distance correction, but prefer to keep it on all the time, can put on their addition for near vision in the form of hook or "grab" fronts of the same size as the distance lenses or reduced one-half in the vertical diameter. This is not always a good combination, as in every instance the lenses do not lie in contact with each other.

8. Lorgnettes may be used as a distance correction or as a substitute for hook fronts. Some myopic women who wear their near corrections constantly often carry lorgnettes, which they hold up in front of the near correction to improve distant vision for a few minutes, or, wearing the distance correction, can use a plus lens in the lorgnettes for near vision.

9. Cases of monocular aphakia where the vision in the fellow-eye is very defective can wear reversible frames, one lens for distance and the other for near,—that is to say, a frame which has a free joint at the temples,—and in this way they avoid bifocals, and can change the distance for the near correction, by turning the temple-pieces.

In some cases of aphakia where the lens is very powerful, a bifocal segment can sometimes be dispensed with, if the patient has a long nose, by sliding the lens down from the eye and then holding the reading matter at the conjugate focus. A toric lens (Fig. 194) is very acceptable in occasional instances, as it reduces somewhat the weight and thickness of the lens, and also enlarges the field of vision. A toric (*torcine* or *torique*, "twisted") lens is one which

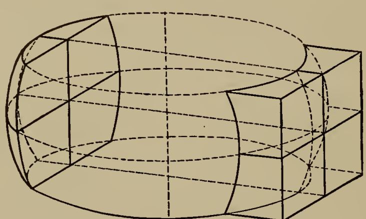

FIG. 194.

has, combined in one surface, the optic effects of a sphero-cylindric lens, or two cylinders of different strength at right angles to each other. Unfortunately, this form of a lens is quite expensive.

General Considerations.—Before prescribing any pair of glasses, the patient should have the opportunity to wear the correction in the office for a short time, that he may study its effect; this is especially necessary (1) when the glasses are strong ones; (2) when there is monocular astigmatism; (3) when one lens is much stronger than the other (anisometropia); (4) when the astigmatism is asymmetric; or (5) when there is a strabismus, etc. The patient loses confidence (and the surgeon is not made happy) when the patient returns with his glasses in his hands and states that he can not wear them—that they make him "dizzy" or "tipsy"; that the glasses make the pavement, houses, trees, people, pictures on the wall, chairs, tables, etc., all appear as if they were going to fall to one side. The surgeon should have anticipated all this, and assured the patient beforehand that, after a little perseverance and practice, this distortion (parallax) will disappear; and if not, then a change will have to be made in the glasses. Very often the whole difficulty is due to a want of proper centering of the lenses, presuming, of course, that the glasses ordered are perfectly correct.

Patients who require weak lenses—spherocylinders or cylinders alone—may at some time be informed that "the correction is but window-glass," and thus the surgeon may be put in disgrace as having prescribed for mercenary reasons, when in truth the glasses have already cured an old blepharitis or asthenopia. In ordering weak corrections, therefore, the character and purpose of the glasses should be imparted to the patient.

It is interesting to notice that strong glasses are usually ordered to improve the vision, and not always for the relief of asthenopia, whereas weak corrections are prescribed for the relief of headaches, etc., without any decided improvement in the vision which the patient can appreciate when looking at a distance, and many such patients will say they can see just as well without their glasses. When strong plus spheres are prescribed for a child, it will do no harm to inform the parents of the character of the glasses, so that when a presbyope tries the child's glasses, the surgeon may not be accused of ruining the child's eyes by having ordered a pair of glasses strong enough for a grandmother to read with, and the child hurried off to a rival confrère to have the "outrage" rectified.

A patient who has fought against the inevitable, using headache powders, liver pills, etc., in the vain hope of not having to put on glasses, may still object to their use for various reasons. It may be that glasses will not add to the personal appearance, or the parents may dislike the idea, fearing that "the oculist puts glasses on every patient," or that "the eyes will never be the same again," or that "the habit of wearing glasses, once established, can never be stopped." These and many other statements will serve to enliven the daily routine of ophthalmic practice. These objections having been met from the point of view of the patient's individual welfare and future good of his eyes, the next question that arises is what form of glasses shall be prescribed.

Spectacles.—The child is certainly a candidate for spectacles. The frames must be very durable, and preferably of 14-carat gold. Spectacle frames keep the lenses in position, and the lenses are then less liable to be broken than in the form of eye-glasses, and for most occupations are to be preferred. Occasionally, the shape of the nose will preclude the use of anything else but spectacles. When one lens is very heavy or both have considerable weight, or when one or both lenses are cylindric, with axes inclined, spectacles are certainly indicated.

Eye-glasses, also called "pinc-nez," are for the adult, and may be prescribed when the lenses are not too heavy, or the cylinders too strong or their axes inclined. Eye-glasses are easily bent, and lose their exact positions before the eyes. For the young society girl nothing but the most delicately made eye-glasses will, as a rule, be accepted.

Bifocals.—These should not, *as a rule*, be prescribed if the lenses are very strong or the correction a complicated one, or the patient advanced in years and has never attempted them before, or if the patient is very portly or uncertain in his gait, or the vision is not brought close to the normal. Two separate pairs of glasses are to be recommended under these circumstances. When ordering any pair of bifocals, the patient should be cautioned and instructed that when looking downward, going up or down stairs, getting into or out of a conveyance, he is to look to one side or over the segment of the bifocal and *not* through it, otherwise he will be liable to make a false step or misjudge the distance, which might mean serious bodily injury, for which the surgeon does not wish to hold himself responsible.

Glasses for constant use should be placed perpendicularly or at an axis of about 5 degrees to the plane of the face, with the optic centers corresponding to the pupillary centers when the eyes are directed to a distance. If the lenses are unusually strong and to be used principally at near-work, then it may be necessary to consider the advisability of having two pairs of glasses, one for distance and one for near, each with the centers to answer for the object in view. If only one pair of glasses has been ordered, and they happen to be very strong, then a pair of prisms in hook fronts may have to be used at the near-work, so as to counteract the prismatic effect of looking through the distance glasses during convergence. Glasses for near-work only should be put into a frame made especially for the purpose, so that the lenses may have an inclination in keeping with the downward turn of the eyes, and thus be perpendicular to the axis of the eyes, and the lenses should be decentered inward to equal the convergence. The one serious objection to bifocals in certain instances is that the glasses can not be made with the inclination suitable for both distance and near vision, and very often there must be a compromise between the two.

The surgeon should make it a point to carefully inspect every pair of glasses which he orders, as his painstaking efforts and best endeavors may be completely frustrated by poorly fitting lenses.

1. The lenses should neutralize. (See p. 58.)

2. The optic centers should be at the points indicated.

3. The cylinder axes must be exact.

4. The lenses must be perpendicular or inclined to the front of the eye, as necessary.

5. The distance of the lenses from the eyes should always be sufficient to clear the lashes; and if these are very long, they may have to be trimmed.

6. The most convex or the least concave surface of the lens should be placed away from the eyes. Or the most concave surface toward the eye.

7. The lenses should be of the correct size for the individual face. These and many other points for the average case must receive the careful consideration of the surgeon.

Tinted or Colored Glasses.—Except for the relief of photophobia following cataract extraction, mydriasis, or inflammatory diseases, the surgeon does not order colored glasses. Colored lenses are to be deprecated except in the cases just mentioned, as they only increase the tendency to photophobia instead of correcting it.

Perimetric Lenses.—These are made to conform in outline to the normal field of vision as recorded by the perimeter, hence the name.*

The usefulness of the perimetric lens is limited to those cases in which the correction contains a plus cylinder and the lens is of moderate strength. It is not a lens that can

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* The writer described this form of lens before the Section in Ophthalmology of the College of Physicians of Philadelphia, in March, 1897.

be prescribed in myopia or aphakia. The purpose of the perimetric lens is to give a normal field and have the edge of the lens sufficiently removed that the patient may not be disturbed by seeing it. It certainly enlarges the field of vision, and in this way is a great advantage in certain occupations, playing the piano, etc. Figure 203 or 204 may answer the same purpose if properly centered.

Trifocals.—Occasionally, a patient is not content with bifocals, but will demand a focal point somewhere between infinity and his working distance; this can only be produced by cementing two segments of different sizes and strength

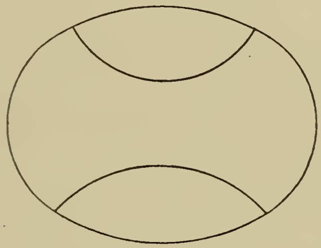

FIG. 195.

FIG. 196.

on the intermediate correction. (Figs. 195 and 196.) Bookkeepers who have to work at large and lengthy ledgers find great comfort in this combination, though to be of special service the lenses must be made large. Example: +2.00 equals working distance at 1 meter. Minus 1 diopter added above equals infinity vision. +2.00 added below gives near vision at 13 inches.

Decentering of Lenses.—Instead of writing a prescription for a lens and prism, the prismatic effect of the lens may be obtained by decentering the lens. The rule is that for every centimeter of decentering there will result just as many prism-diopters as there are diopters in the meridian of the correcting lens. For example, +4 sph. ⊃ 4 P. D., base out, is the same as +4 sph. decentered 1 cm. outward; or +4 sph. ⊃ 2 P. D., base in, equals +4 S. decentered 5 mm. inward; or +2 sph. ⊃ +2 cyl. axis 90 degrees ⊃ 2 Δ, base outward, equals +2 sph. ⊃ +2 cyl. axis 90, decentered 5 mm. outward.

While it is well for the student to know how to decenter lenses, yet the writer does not recommend such lenses, preferring, when necessary, to order a prismatic combination, and have the optician fill the prescription, starting direct from the prism.

CHAPTER XII.

LENSES, SPECTACLES, AND EYE-GLASS FRAMES. HOW TO TAKE MEASUREMENTS FOR THEM AND HOW THEY SHOULD BE FITTED.

The selection of the size and shape of lenses, the character of the spectacle and eye-glass frames and their adjustment, is the work of the optician. It occasionally happens, however, that the surgeon may not have an optician in his town, and will, therefore, have to take the necessary measurements himself and send them, with his prescription, to an optician in a neighboring city. This chapter is therefore added for the benefit of such surgeons. It is hardly necessary to state that the frames should be very carefully adjusted and the lenses centered to the patient's eyes. A lens improperly adjusted may utterly destroy the good effect of the most skilfully selected correction, giving discomfort to the patient and reflecting seriously upon the surgeon's ability. In fact, it is always well for the surgeon to personally inspect every pair of glasses which he may order.

Lenses.—These are spoken of as "eyes," and come in various sizes and shapes. They are spoken of as O, double O (OO), triple O (OOO), etc. (See Figs. 202, 203, 204, 205, and 206.) Or sizes smaller than O are numbered 1, 2, 3, or 4. (See Figs. 197, 198, 199, 200.) Different shapes and sizes are lettered A, B, C, D, F, or X. (See Figs. 189, 190, 191, 192, 193, 201.) All these lenses are also marked in millimeters of breadth and length. The lenses for individual patients are selected according to the purpose for which they are intended, and particularly to be in keeping

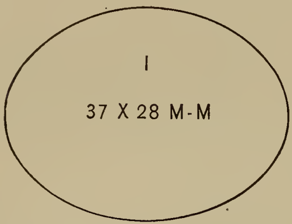

FIG. 197.

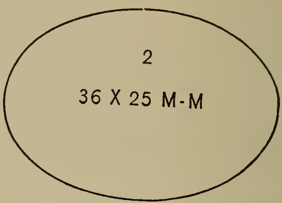

FIG. 198.

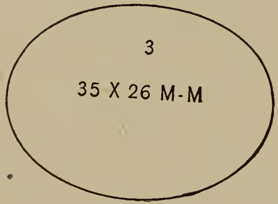

FIG. 199.

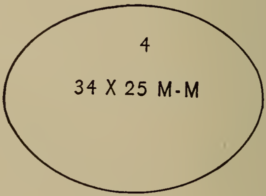

FIG. 200.

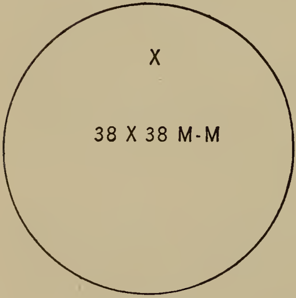

FIG. 201.

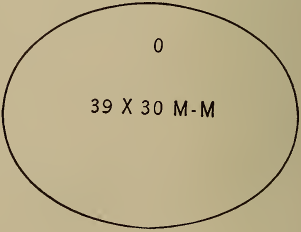

FIG. 202.

with the facial measurements. The size or "eye" O (39 × 30 mm.) is the usual size for the average adult, and number 2, 3, or 4 is for a child. C, D, or F may be ordered for a presbyope who does not need a distance glass and who does not wish to be taking off the near correction to see at

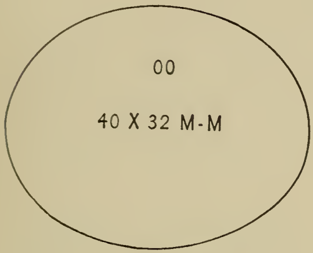

FIG. 203.

FIG. 204.

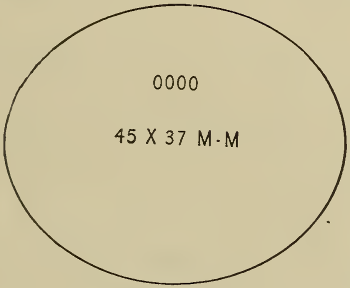

FIG. 205.

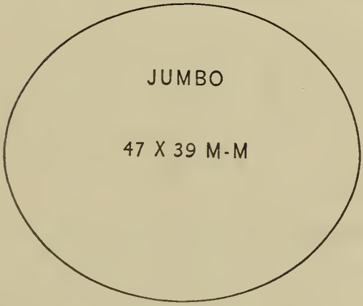

FIG. 206.

a distance; in other words, such a shaped lens can be looked over without any difficulty. Or the presbyope who requires a —2 for distance and can see to read without any near correction,—being about fifty years of age,—could have his minus lenses made in the shape of A, B, C, or D inverted, and, wearing this for distance, would look under it when he wished to see near at hand. As a rule, the patient with a narrow face and short interpupillary distance will require a small "eye," whereas the patient with a broad face and long interpupillary distance will require a large "eye."

Spectacle Frames (Fig. 211).—These consist of a nose-piece (called the bridge) and temples (called sides). These are attached to the lenses ("eyes") by screws passing through holes which have been drilled through them, making what is known as the frameless spectacles; or a wire is fitted around the lenses, to which the bridge and sides are attached with solder, forming the "framed" spectacles.

Eye-glass Frames (Fig. 212).—These consist of a spring and nose-pieces; the latter are called guards. Framed and frameless eye-glasses have the nose-pieces or guards attached to the lenses as in the spectacles.

How to Take Measurements.—There are three points that require particular attention: (1) The center of the lens should correspond with the center of the pupil; (2) the lens must be just far enough from the eyes to avoid the lashes, and if these are *very* long, they must be trimmed; (3) the lens must be at such an angle that the visual axis will be perpendicular to it.

First Measurement.—*The Interpupillary Distance.*—To accurately measure the distance from the center of one pupil to the center of the other is not always an easy thing to do, especially if the pupils are dilated; hence, it is good practice to measure this distance from the inner side or edge of one pupil to the outer edge of the other. This measurement can be made with an ordinary rule divided to sixteenths of an inch or in millimeters, or with a special instrument for the purpose, called a pupilometer. The patient is told to look directly to the front, at an object across the room, and the surgeon, in front, with his head nearly in the line of sight, holds the rule across the patient's face, as close as the bridge of the nose or eyelashes will permit. With his thumb-nail as a marker, the surgeon gages the distance as indicated (see Fig. 207), which illustrates the conditions. In taking this measurement the surgeon should be at an arm's length from the eyes, for the reason that his

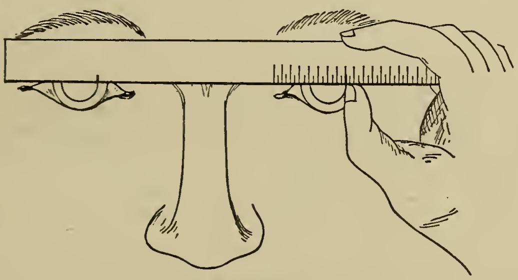

FIG. 207.

own eye forms the apex of a triangle of which the eyes of the patient form the base, and the measurement is apt to be two or three or four millimeters short if he gets too close.

If the glasses are to be worn for distance only, then the measurement must be for the full interpupillary distance, as the patient looks into infinity; but if the glasses are for near-work only, then the distance between the pupils must be correspondingly diminished, and the measurement taken as the patient looks at a near point. If the glasses are to be worn for both near *and* far vision, for constant use, then the center of the lenses must be placed intermediate between the distance and near measurements.

Second Measurement.—*The Bridge.*—The regulation spectacle bridge is known as the saddle-bridge, and should conform to the exact shape of the patient's nose. It is intended to remain in just one place, and that is at the bridge of the nose (see B in Figs. 208 and 209), the place where the nose begins to extend outward after passing down from the forehead. The points B and D, as shown in figure 210, represent the widest part or base of the bridge. A and R are the arms, which extend upward or outward and are fastened to the lenses. The length of the arms controls in

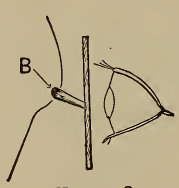

Fig. 208.

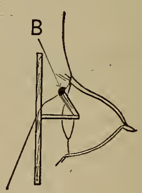

Fig. 209.

great part the distance of the lenses from the eyes. To raise or lower the position of the lenses in front of the eyes, the posts or arms alone should be bent ; *the bridge itself should never be tilted*, as its edge will cut into the skin of the nose ; this is a most important consideration for the patient's comfort.

The Shape and Size of the Bridge.—To take this measurement, the surgeon should have a piece of lead-wire or thin, pliable copper-wire ; the lead-wire is best. This wire is accurately molded to the bridge of the patient's nose, the arms (A and R) are bent to the proper angle, and then the ends of the wire are curved or bent outward to show the plane of the lenses. (See Fig. 210.)

When the wire has been bent into place and the eyelashes do not touch at L and L, it is removed and placed on the under surface of a piece of paper, when an impression and lead-pencil tracing is made of it. If the measurement is not taken in this way, then the surgeon, with a pair of moderately blunt-pointed compasses, measures the breadth of the nose from B to D, and also the height of the bridge from F to E. The height of the bridge is spoken of as "out" or "in"; the former when F extends beyond the plane, and "in" when F is behind the plane of the lenses. (See Figs. 208 and 209.)

Another good way to take the foregoing measurements is to have several ordinary steel frames of different sizes and

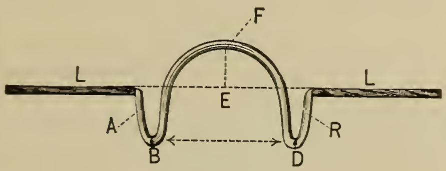

FIG. 210.

shapes, using whichever one of these seems to fit the best, and then making any additional alterations in the measurements that may be required.

Third Measurement.—This is the length of the sides or temples. This measurement is taken from the top of the ear to the plane of the lens, or a horizontal line extending out from the eyelashes.

Fourth Measurement.—*The Size of the Lenses.*—This will depend upon the breadth of the face, the amount of space taken up by the bridge, its arms and attachments, as also the space occupied by the hinge and attachment of the temples. Ordinarily, as stated before, the adult will select size O and the child No. 2.

The following blank is a good guide, as covering all the necessary measurements as referred to in this description for ordinary glasses.

STYLE OF BLANK FOR THE SURGEON TO FOLLOW WHEN ORDERING GLASSES FOR HIS PATIENT.

Patient's Name, ...

Forward to, ...

. . . .

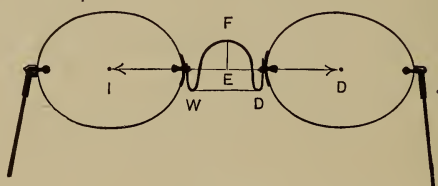

FIG. 211.

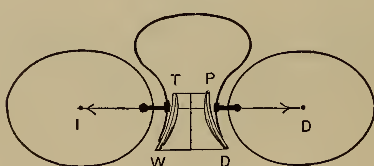

FIG. 212.

℞. O. D.
O. S.

Distance or Near Frames.

Frames of . . . .

MEASUREMENTS.

Spectacles.	*Eye-glasses.*
Interpupillary distance, ...	Interpupillary distance, ...
Height of bridge, ...	Length of guard, W to T, . . .
Base of bridge, ...	Width at base, W to D, ...
Shape of bridge (see drawing), . .	Width at top, T to P, ...
Bridge, "in" or "out,"	Length of arm of guards, . . .
Length of temples, ...	Shape of spring (see drawing), .
Size of "eye,"	Size of "eye," . . . .

Additional notes, ...

Date, ...

. . . ., M.D.

Style of Frames.—If the glasses are to be worn constantly, they should be perpendicular or inclined about 5 degrees from the perpendicular to the front of the eyes. (See Fig. 213.) They are spoken of as "distance" frames.

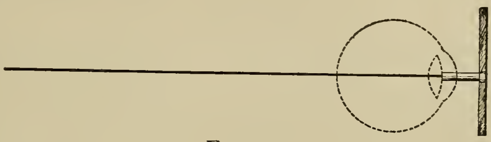

FIG. 213.

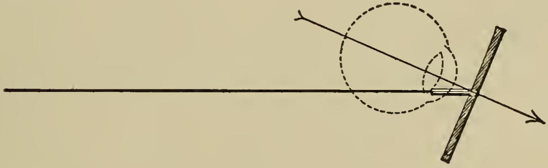

FIG. 214.

If the glasses are to be worn only at near-work, then the lenses should be tilted downward; this is known as the "near" frame. (See Fig. 214.)

Fitting Eye-glasses.—The position of the lenses applies equally well to eye-glasses. The principal measurement is for the nose-pieces or guards and the arms or offsets from the guards. (See Fig. 215.) The width of the patient's nose where W and D, and also T and P, will press, depends, of course, upon the length of the guard itself—usually about 14 mm. It is also necessary to measure the position of the guards relative to the plane of the lenses; that is, whether the arms should be long, medium, or short, and whether they are "out" or "in"

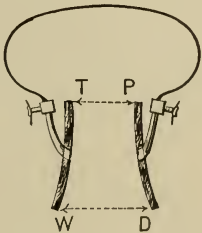

FIG. 215.

from the plane of the lenses. The style of spring is usually that shown in figure 215.

Bifocals.—The measurements for bifocals are the same as for the spectacle or eye-glass, except the size and shape of the segment, and this should never extend above the median line of the lens, and seldom to it.

Quality of Frame.—These are made of silver, steel, aluminium, or gold; the latter are always to be preferred, as more durable in every way. Silver and aluminium bend easily, and steel frames rust and break. Every surgeon who does his own fitting should possess a small screw-driver, two pairs of delicate and yet strong pliers (one with round and the other with flat ends), and also a small rule.

APPENDIX.*

The Visual Acuity under definite conditions is an index of the strength of the necessary spheric lens (plus or minus) which will give a vision of $\frac{VI}{VI}$ or more.

For several years the writer has been making a careful examination of his private cases for the purpose of coming to the positive and demonstrable fact as above stated. For instance, the question which has been decided is this: if an eye, hyperopic or myopic, without astigmatism (or an eye with its astigmatism corrected with a cylinder), and it has the ability to see $\frac{VI}{VI}$ and its ciliary muscle under the effect of "drops," what strength spheric lens would be required to give it normal vision?

For purposes of study the eyes selected were those which obtained standard or more than standard vision with correcting lenses, and all eyes which from any cause could not attain at least $\frac{VI}{VI}$ vision were excluded from the tests and are not a part of the subject-matter under consideration. To make these tests reliable two essentials were absolutely necessary: namely, the ability to read $\frac{VI}{VI}$ or more and the ciliary muscle under the effect of a reliable cycloplegic.

To begin with, the writer had to work backward, so to speak, and in the following manner: the eyes were tested at six meters, and *with* the lenses which gave standard vision, the eyes were tested to find out what their visual acuities

*This paper was read before the Ophthalmic Section of the College of Physicians of Philadelphia, Dec. 17, 1908.

would be when plus spheres were placed in front of the correcting lenses. The spheric lenses used ranged from +0.25 to +2.50 in quarter diopter intervals. The resulting visions obtained are shown in the following table.

TABLE I.

Static refraction with correcting lenses		.... Vision	$= \frac{VI}{VI}$
" " " " "	adding	+0.25.... "	$= \frac{VI}{VI\frac{2}{3}}$
" " " " "	"	+0.50.... "	$= \frac{VI}{VIISS}$
" " " " "	"	+0.75.... "	$= \frac{VI}{VIIIS}$
" " " " "	"	+1.00.... "	$= \frac{VI}{X}$
" " " " "	"	+1.25.... "	$= \frac{VI}{XII}$
" " " " "	"	+1.50.... "	$= \frac{VI}{XV}$
" " " " "	"	+1.75.... "	$= \frac{VI}{XX}$
" " " " "	"	+2.00.... "	$= \frac{VI}{XXX}$
" " " " "	"	+2.25.... "	$= \frac{VI}{LX}$

With +2.50 added the vision was less than $\frac{VI}{LX}$.

Studying the table in reverse order it was then found that all healthy eyes, hyperopic or myopic (or eyes with the astigmatism corrected), and under the effect of "drops" required a spheric lens (plus or minus as the case might be) consistent with the visual acuity as given in this table. The interesting fact was also apparent that a +2.50 spheric lens reduced the vision so that the "LX" letter *could not* be distinguished, thus the 2.50 obscured the vision to zero as the eye could not detect *any* letter at six meters. It therefore became evident that an eye with the two essential conditions mentioned, and having a vision of more than $\frac{VI}{LX}$, would require a spheric lens of less strength than 2.25, and if its vision was less than $\frac{VI}{LX}$ it would require a spheric lens of 2.50 or stronger.

To meet the visual conditions shown in Table 1, the author had made a series of letters on duplicate cards, and for obvious reasons called them "Metric Test Letters." These letters conform to the tangent of the angle of five meters and of the Gothic character in preference to the English block letters. These letters are arranged in series to be seen at the varying distances as indicated in meters and the

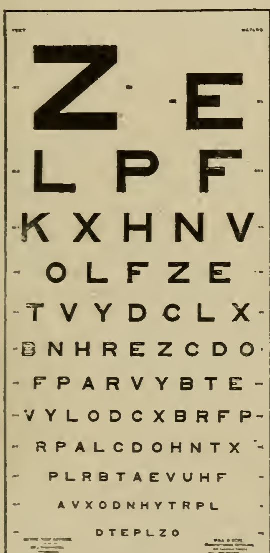

FIG. 216.

FIG. 217.

equivalent in feet. The confusion letters are conspicuous and the two cards have corresponding letters on the same lines but differently arranged. These cards also differ from the cards in ordinary use, as there is a line of letters to be seen at VI$\frac{2}{3}$ meters and also at VIIISS meters; the XXV meter line as seen on other cards has purposely been omitted. The question is often asked why test types are not arranged so as to give a visual acuity at 55, 50, 45, and 40 meters, but the uselessness of such letters is easily understood by a review of the visual acuities just tabulated. The writer has, however, placed one letter on each of the cards here shown (Figs. 216 and 217), which letters can be seen at 40 meters, but these are not a part of the test here described, but will be found convenient in an office with a four meter range. It will be seen from the following table that by the arrangement of the size of the letters the visual acuity can always be reduced to tenths as follows:

TABLE 2.

Vision	$\frac{VI}{LX}$	equals	$\frac{1}{10}$
"	$\frac{VI}{XXX}$	"	$\frac{2}{10}$
"	$\frac{VI}{XX}$	"	$\frac{3}{10}$
"	$\frac{VI}{XV}$	"	$\frac{4}{10}$
"	$\frac{VI}{XII}$	"	$\frac{5}{10}$
"	$\frac{VI}{X}$	"	$\frac{6}{10}$
"	$\frac{VI}{VIIISS}$	"	$\frac{7}{10}$
"	$\frac{VI}{VIISS}$	"	$\frac{8}{10}$
"	$\frac{VI}{VI\frac{2}{3}}$	"	$\frac{9}{10}$
"	$\frac{VI}{VI}$	"	$\frac{10}{10}$

As the visual acuity is now reducible to tenths it becomes a rule of thumb, so to speak, to calculate the strength of the correcting spheric lens necessary to produce normal or standard vision when it is remembered that +2.50 just reduces the vision of a standard or emmetropic eye to zero, or that plus 2.25 gives $\frac{1}{10}$th vision. Take, for instance, a vision of $\frac{1}{10}$th; that means that the eye is deficient $\frac{9}{10}$ths or requires $\frac{9}{10}$ths additional to give it $\frac{10}{10}$ths or standard sight.

As $\frac{1}{10}$th of 2.50 is 0.25, then nine times 0.25 would be 2.25, the amount of spheric lens required. Or if an eye sees the xxx meter letters it has $\frac{2}{10}$ths vision and requires $\frac{8}{10}$ths additional to give it $\frac{10}{10}$ths or normal vision, namely, eight times one-tenth of 2.50, which is 2.00 (plus or minus). If the vision is $\frac{4}{10}$ths, the eye would require $\frac{6}{10}$ths more, or 1.50, to give it standard vision. The following table, which includes the two just given, shows the strength of the spheric lens required in each instance when the visual acuity is expressed in tenths.

TABLE 3.

English Feet.	Meters.	Vision at six meters.	Vision in tenths.	Spheric lens required for VI vision. $\frac{\quad}{VI}$
197.	lx	$\frac{VI}{LX}$	$\frac{1}{10}$	2.25
98.5	xxx	$\frac{VI}{XXX}$	$\frac{2}{10}$	2.00
65.6	xx	$\frac{VI}{XX}$	$\frac{3}{10}$	1.75
49.2	xv	$\frac{VI}{XV}$	$\frac{4}{10}$	1.50
39.4	xii	$\frac{VI}{XII}$	$\frac{5}{10}$	1.25
32.8	x	$\frac{VI}{X}$	$\frac{6}{10}$	1.00
27.9	viiiss	$\frac{VI}{VIIISS}$	$\frac{7}{10}$	0.75
24.6	viiss	$\frac{VI}{VIISS}$	$\frac{8}{10}$	0.50
21.8	vi$\frac{2}{3}$	$\frac{VI}{VI\frac{2}{3}}$	$\frac{9}{10}$	0.25
19.7	vi	$\frac{VI}{VI}$	$\frac{10}{10}$	0.00
16.4	v	$\frac{VI}{V}$	$\frac{12}{10}$	0.00
13.9	iv$\frac{1}{4}$	$\frac{VI}{IV\frac{1}{4}}$	$\frac{14}{10}$	0.00

By his previous ophthalmoscopic findings and with his retinoscope, and obtaining the patient's near point, etc., the observer will know when to employ a plus or a minus spheric lens.

To make the metric test letters of value when the eyes are astigmatic, it will be necessary to correct the astigmatism with the necessary cylinder *before* testing the visual acuity. For this purpose the writer has also prepared metric lines in the form of the clock dial (Fig. 218). This dial has been made in two sizes, one for five and the other for a six meter distance. These charts vary somewhat from the ordinary in that the lines from xii to vi and from ix to iii cross each other at the center. And also the Roman characters conform to the tangent of the angle of five minutes, as do the lines and spaces. While using these charts it will be well to ask the patient whether the Roman characters correspond with the lines in their shade of black. As a matter of practical experience the writer is partial to just such lines and spaces as here described, notwithstanding the fact that others recommend wider lines and spaces. In using the metric letters and lines the writer follows the method recommended by Dr. J. S. Johnson, of St. Paul, and described in the "Ophthalmic Record," Oct., 1901; that is to say, to correct the astigmatism with the cylinder as the patient looks at the lines, and when they all appear equally black (not necessarily distinct) then the visual acuity is taken and the necessary spheric lens employed as indicated in the above table.

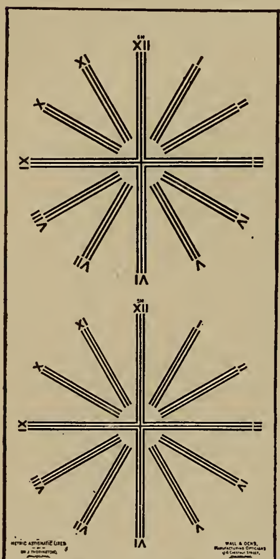

FIG. 218.

To expedite matters and have the patient read the lowest line of letters which he can see without naming the letters from the top of the card, the writer makes use of the red and green strips of paper suggested by Dr. Holbrook Lowell, of Boston, in his description published in the "Archives of Ophthalmology," Vol. xxxv, No. 5, 1906.

In tabulating the strength of lenses which all patients select, it is found to be an interesting fact that about 86 per cent. of all patients coming for correcting lenses, select a lens not stronger than a four diopter sphere or cylinder or both in one or both eyes, so that this 86 per cent. could be successfully refracted with a limited number of lenses in the trial case; but the point which is still more interesting is, that nearly 70 of this 86 per cent. accept lenses of less than 2.50 and obtain a vision of $\frac{VI}{VI}$ or more in one or both eyes. With these facts in mind the value of the metric test letters and lines is self-evident. This quick method of arriving at the correct lenses may not appeal to the slow ophthalmologist who criticizes "quick work as poor work," but in clinical work at least the assistant has a time-saver which he will enjoy. However, when by this method the vision has been brought to normal, the ophthalmologist should not prescribe until he has verified the correction by trying the various weaker spheres and cylinders as described on page 229. At this final testing the examiner should use the twelve one-hundredths lenses, as no provision has been made in the metric letters for a visual acuity in fractions of less than one-tenth, as this would have necessitated additional lines of letters and a much larger card.

The metric letters and lines may be used when practising the "fogging method," but as most eyes do not entirely relax the ciliary muscle when so tested, the visual acuity is liable to be one-tenth or sometimes two-tenths more than it would be if the eye were under "drops."

In presbyopic cases the metric letters prove very satisfactory if there are no structural changes to interfere with normal vision.

To summarize:—

1. The eye which is being tested should have its ciliary muscle at rest with a reliable cycloplegic.

2. The eye *must* be capable of obtaining $\frac{VI}{VI}$ vision or more than $\frac{VI}{VI}$.

3. All testing must be done at a distance of six meters.

4. If the eye is astigmatic this must be corrected with the necessary cylinder lens before taking the visual acuity and adding the spheric lens.

5. The visual acuity obtained if the eye is hypermetropic or myopic (or astigmatism corrected) is an index of the strength of the spheric lens required to give $\frac{VI}{VI}$ vision.

6. The same lens or lenses which give a vision of $\frac{VI}{VI}$ will at the same time give a vision of more than $\frac{VI}{VI}$, and without any change if the lenses have been carefully selected and the eye is capable of seeing more than $\frac{VI}{VI}$.

7. This metric letter testing is of advantage in proving the static correction, as shown in Table 1.

Distance or Range.—For a number of years the writer obtained a six meter range in his otherwise small office, by use of the plane mirror and reversed letters, as described on page 75 and Fig. 74, but has abandoned this method for two other ranges, one at six meters and the other at twenty meters (sixty-six feet.) These distances are obtained by use of the side yard. Test cards covered with the best quality of quarter inch plate glass and securely framed, so that dampness cannot reach them; are fastened to the fence at the distances mentioned; and are seen by the patient as he looks through the window, also of the best plate glass. The writer takes great pleasure in recommending this method of long-range testing, as it has proven of intestimable value. In explanation of this statement the writer finds that when the correcting lenses at six meters give a vision of $\frac{VI}{VI}$ or more and the prescription is written for —0.25 added to the static refraction, occasionally his patients and those of other oculists complain of distant objects (beyond twenty feet) looking dim. However, when the correcting lenses (static refraction) give a vision of $\frac{XX}{XX}$ or $\frac{XX}{XV}$ (meters *not* feet) and —0.25 is added for this unusually long range, none return with the unfavorable

FIG. 219.

criticism that "distant objects look blurred" or that they "can see better at a distance without glasses."

Axonometer.—Fig. 219 shows the latest model of this useful little instrument used in finding the axis of the band of light when using the retinoscope, and is a decided improvement over the old model as shown in Fig. 155. The broader white line is of signal advantage as compared with the narrow line.

Fused Bifocals (Kryptok).—This variety of bifocal is also known as "invisible." It is not unlike the bifocal shown in Fig. 185. It is made by taking a small circular piece of flint glass and by great heat fusing one surface to a piece of crown glass; both the crown and flint glass have plane surfaces and the crown glass is square in shape. This is the form in which the Kryptok Sales Company supply the opticians, who then grind the various curves to meet the conditions of the oculists' prescriptions.

One Piece Bifocals.—This is not unlike the solid or ground bifocals, Figs. 187 and 188, but it is now made in the toric curve and of much neater and more delicate workmanship than the previous solid bifocal. This one piece bifocal is frequently called "invisible" also, but there is really no bifocal that is absolutely "invisible." Close inspection by reflected light will generally show where the two edges come together. Patients frequently think they will avoid seeing where the upper and lower corrections come together, but they will see it in any bifocal, and the term "invisible" applies to the friends of the patient, who cannot always see that bifocals are being worn. Patients of unknown age wearing bifocals of the "invisible" variety enjoy the fact that their friends still think that they are young (?).

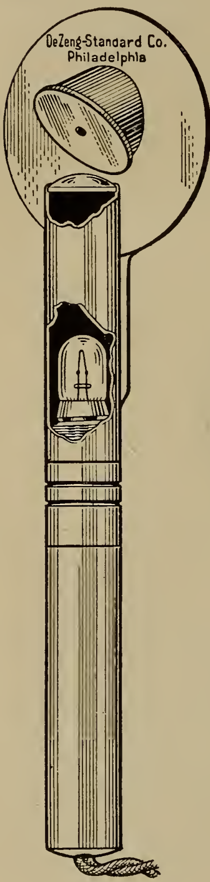

FIG. 220.

The Luminous Retinoscope (Fig. 220; De Zeng Patent).—This latest model of luminous retinoscope does away with the tilting light as shown in the old model, Figs. 161 and 162, and is therefore a much better instrument and much to be preferred.

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