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PRISMS

THEIR USE AND EQUIVALENTS

BY

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PREFACE

The preparation of this book on "Prisms, their use and equivalents," has been prompted by the request of many students and correspondents, though it is written primarily for those who may desire a more extended knowledge on this branch of refraction than is contained in works on Ophthalmology.

In fact, this volume is in part a compilation of the writer's lectures on prisms delivered during the winter course at the Philadelphia Polyclinic.

The author's double prism, a new and delicate test, for the detection of errors of muscular imbalance whether of small or great amount, is incorporated in the text.

To make the subject-matter more entertaining, the writer has not limited himself to the consideration of prisms in ophthalmic practice alone, and by omitting mathematic formulas and inserting many illustrations, the text is made easy of comprehension.

CONTENTS

PRISMS

CHAPTER I

GENERAL DESCRIPTION

A Prism is a wedge-shaped portion of a refracting medium (usually of glass) contained between two plane polished surfaces (Figs. 1, 2, 3 and 5), or a prism is a transparent homogeneous medium with two plane surfaces which are not parallel to each other. Prisms used in the practice of ophthalmology are seldom very

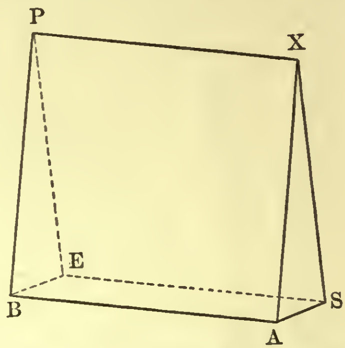

FIG 1.—Prism on base. PX = Edge or Apex. BASE = Base. PBAX and PESX = Faces or Surfaces. BPE and AXS = Angle.

strong and therefore have their surfaces placed at a very acute angle.

The sides of a prism are the inclined surfaces, also spoken of as *refracting surfaces* or *faces* (P B A X and P E S X in Figs. 1, 2 and 3).

The edge (also frequently spoken of as the *apex* of a prism) is that part of the prism where the two plane surfaces meet (P X in Figs. 1, 2 and 3).

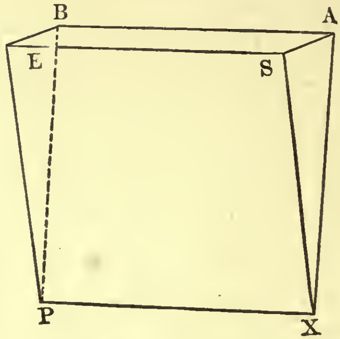

FIG. 2.—Prism on edge. PX = Edge or Apex. BASE = Base. PBAX and PESX = Faces or Surfaces. BPE and AXS = Angle.

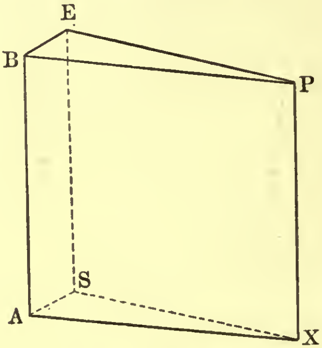

FIG. 3.—Prism on side. PX = Edge or Apex. BASE = Base. PBAX and PESX = Faces or Surfaces. BPE and AXS = Angle.

The base of a prism is the thick part of the prism and is opposite to the edge or apex (B A S E in Figs. 1, 2 and 3). The base of the prism is occasionally referred to as the third surface.

The refracting angle is a physical feature of the prism and is the angle at which the two sides or refracting surfaces come together; it is this angle together with the index of refraction of the glass (or medium) which

FIG. 4.—Principal section of a prism.

determines the strength of the prism (B P E and A X S in Figs. 1, 2 and 3).

Section of a Prism.—Dividing or cutting through a prism at right angles to its refracting surfaces or faces

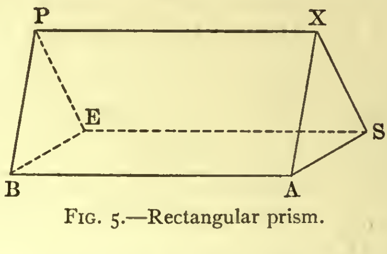

FIG. 5.—Rectangular prism.

makes a *principal section;* this is shown in Fig. 4, and will assist in explaining what has just been described.

Shape or Form of a Prism.—By this is meant the outline or contour of the prism and not the section, this

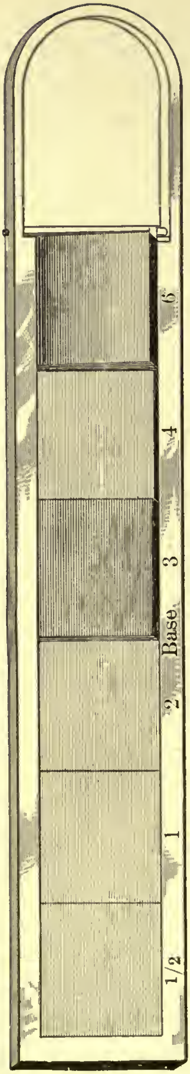

FIG. 6.—Dr. Noyes' prism bar or battery.

latter being wedge-shaped (Fig. 4). Figs. 1, 2 and 3 illustrate square prisms. Fig. 5, a rectangular prism and Figs. 7, 8 and 9, round prisms. Rectangular prisms are not ordinarily used in ophthalmology. Square prisms, while easily handled cannot be placed in the ordinary trial-frame.

The late Dr. Noyes recommended a battery of prisms which was a series of small square prisms of increasing strength, numbered in degrees, 1/2, 1, 2, 3, 4, and 6, mounted in a frame as shown in Fig. 6. The operator or patient held this vertically in front of the eye and moved it up or down when it was desired to get a stronger or weaker prism before the eye. Two of these batteries or "bars" were required, one with the bases of the prisms placed laterally and the other with the bases placed vertically. These batteries of prisms are not now in general use.

Round or Circular Prisms (Figs. 7, 8 and 9).—These are found in the trial case and as their diameters (set in cells) are the same as the spheres and cylinders they fit easily into the trial-frame. Unfortunately the base of the prism being quite thick in some instances (Fig. 10) takes up considerable space in the trial-frame and therefore when in the frame it has to be placed in the outer opening, so as to leave room for the sphere and cylinder back of it. If placed in the back opening of the frame it is liable to rub against the eye lashes or the eye lid.

Recognition of the Edge or Apex and Base of the Prism.—When a prism is square (Fig. 1) in contour its long edge or apex is immediately and easily detected

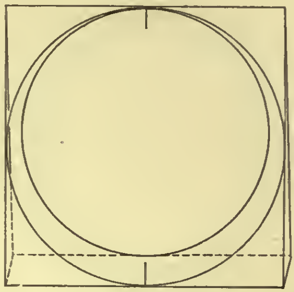

FIG. 7.—Spuare prism marked for cutting out the round or circular prism.

and likewise its base (Fig. 7), but when round or circular (Figs. 8 and 9) in contour, its thinnest part will then be recognized as a point in the apex or edge of the original square prism (Fig. 7). The thickest part or base of the round or circular prism is diametrically opposite to the edge or apex and it too corresponds to a point or line in the base of the original square prism (Fig. 7). These two points indicating the edge (or apex) and base of a round or circular prism are marked with a broad diamond scratch on the glass (Fig. 8) the same as seen on cylinder lenses, to indicate the axis of the cylinder. Likewise the number of the prism is also scratched upon the glass. The position of the base of a circular prism is occasionally marked with a white or black line connecting the two plane (circular) surfaces or faces at their greatest separated points (Fig. 7). This method of marking the position of the prism edge, base and number, does not meet with the writer's approval, as they are not sufficiently distinct and he therefore has the prisms in his own trial case marked as shown in Fig. 9. These prisms have very wide black metal frames without

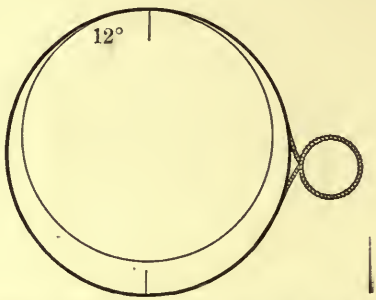

FIG. 8.—Prism in wire frame. Diamond scratches on glass to indicate base and apex line, also number of prism.

handles, the wide frame or cell acting as a handle. The direction of the edge and number of the prism are marked in white on this black metal frame as shown in the figures referred to and the base is indicated by an arrow head, also marked in white.

Base-apex Line.—This is an imaginary straight line connecting the edge (apex) with the center of the base (A B in Fig. 11). This base-apex line is of as great importance to a knowledge and use of prisms as the axis line of a cylinder lens. In Chapter II it will be shown that an object viewed through a prism always appears displaced in the direction of the edge of the prism and exactly parallel to the base-apex line (Fig. 31).

The Axis of a Prism.—This is an imaginary straight line midway between the edge and the base and at right angles to the base-apex line, therefore parallel to the edge (X S in Fig. 11).

The Plane of a Prism.—This is midway between the two plane surfaces, bisecting the angle of the prism (Fig. 11).

FIG. 9.—Prism with wide frame showing markings of base and apex and number on frame or cell.

Position of a Prism.—When a prism is placed in front of an eye its position is indicated or described by the direction of the base-apex line and this direction of the base must always be carefully specified in the prescription. *Base down* means that the thickest part of the prism is toward the cheek, this may be written in the prescription, Base down axis 90°. *Base up* means that the base-apex line is still vertical but the base is directed upward or toward the brow and this may be written in the prescription, Base up axis 90°. *Base in* means that the base-apex line is horizontal and the base of the prism toward the nose, this may be written in the prescription, Base in axis 180°. *Base out* means that the base-apex line is horizontal and the base of the prism is toward the temple, this may be written in the prescription, Base out axis 180°.

The base of the prism may be placed in any desired direction or meridian but the prescriber must specify definitely in his prescription—(1) the strength of the prism, (2) which eye the prism is for, and (3) whether

Fig. 10.—Profile view of Fig. 9.

the base is up, down, in or out; or up and in, or up and out, or down and in, or down and out; for instance, the following:

Right Eye, 2 Prism, base down axis 75°; 2 Prism base up axis 75°; 2 Prism base down axis 45° or 2 Prism base down and out axis 45°; 2 Prism base up axis 135° or 2 Prism base up and out axis 135°, etc. The reader may obtain a clearer idea on this point by referring to the arrow marking on the cell of the prism pictured in Fig. 9, and if he will place a prism in a trial-frame and study it in the positions just described he will obtain a definite knowledge of the position of prisms before the eye.

The prisms in the trial case are made of crown glass which is practically isotropic and therefore has but little dispersive power, whereas prisms made of flint glass or rock crystal are not found in the trial case as such prisms are highly dispersive (anisotropic) and are principally used for the production of the spectrum (Fig. 43).

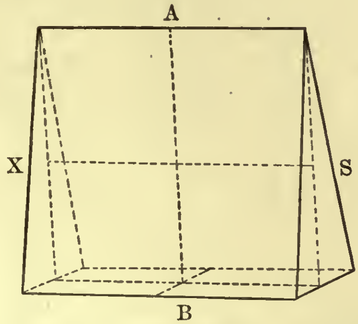

FIG. 11.—BA = Base-apex line. XS = Axis.

Achromatic Prisms.—These are seldom if ever prescribed, because they are heavy, cumbersome and expensive. Such prisms can be made by joining or cementing together two prisms of different strength and of different index of refraction, one of flint and the other of crown glass, with the base of one to the edge of the other.

CHAPTER II

REFRACTION OF LIGHT AND REFRACTION OF LIGHT BY PRISMS

For a proper understanding of the action of prisms upon light it is necessary to briefly review some facts on the subject of refraction in general.

Refraction.—From the Latin "refrangere," meaning to bend back, *i.e.*, to deviate from a straight course.

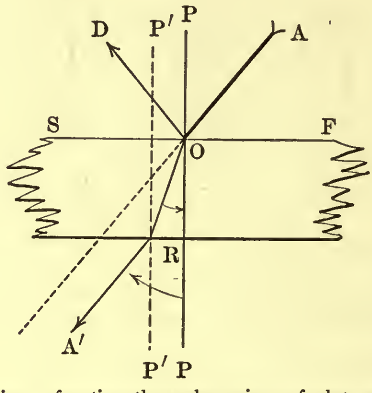

FIG. 12.—Illustrating refraction through a piece of plate glass with parallel surfaces.

Refraction may therefore 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.

Two laws govern the refraction of rays of light:

1. A ray of light passing from a rare into a dense

medium is deviated *toward* the perpendicular (A in Fig. 12).

2. A ray of light passing from a dense into a rare medium is deviated *from* the perpendicular (R in Fig. 12). Aside from these laws, there are other facts in regard to rays of light which should have consideration. A ray of light will continue its straight course through any one or any number of different transparent media, no matter what their densities, so long as it forms right angles with the surface or surfaces (P P in Fig. 13).

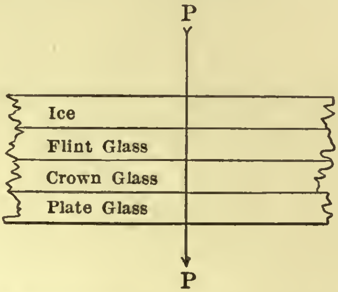

FIG. 13.—Illustrating the passage of a perpendicular ray through transparent media of different density with parallel surfaces.

Such a ray is spoken of as the perpendicular or normal. Such surfaces are plane, the surfaces and perpendicular forming right angles.

In the study of refraction the incident and refracted ray may be reversed, that is to say, the refracted ray may be called the incident ray, and the incident ray may be called the refracted ray; for instance, in Fig. 12, the incident ray A becomes the refracted ray R; now if R is considered the incident ray, it would become the refracted ray at A.

Figure 12 shows the ray P P perpendicular to a piece of plate glass with plane surfaces. The thick ray A in air is incident at O on the surface S F and is bent in the glass *toward* the perpendicular (P P), fulfilling the first law of refraction. The dotted line indicates the original direction of the incident ray A and the direction it would have pursued if it had not been refracted. As the ray A in the glass comes to its second surface at R it undergoes the second law of refraction and passing into the

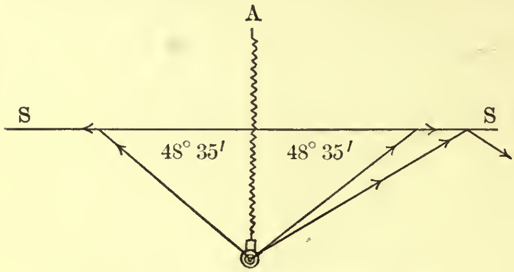

FIG. 14.—Illustrating the critical angle.

rarer medium (air) it is bent *from* the perpendicular (P P). The ray now continues its original direction parallel with the dotted line, but it has been deviated from its original course, it has undergone lateral displacement. Attention must be directed to the thickness of the incident ray A as it falls upon the surface S F, as only part of it is refracted, and part of it is reflected, the reflected portion is marked D. This accounts for the thinness of the ray A in the glass. 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. Finally if the refracted ray A′ in Fig. 12 is, for illustration, considered the incident ray at R, it would be deviated toward P′ P′ in the glass and make its exit at O and be the refracted ray at A. This demonstrates the path of the incident ray to become the refracted, or the refracted to become the incident ray, *i.e.*, **the path of the ray is reversible.**

Critical Angle. Limiting Angle of Refraction.—This is the angle of incidence which just permits a ray of light in a dense medium to pass into a rare medium. The size of the critical angle depends upon the index of refraction of different substances. The critical angle for crown glass is 40° 49′.

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 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 beyond this point of 48° 35′ becomes a reflecting surface and acts as a plane mirror.

Index of Refraction.—By this is meant the relative density of a substance (not its specific gravity) or the comparative length of time required for a ray of light to travel a definite distance in different substances. *The absolute index* of refraction is the density 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 substance 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 Figs. 15 and 16. The greater the density, the slower the velocity, or the more effort apparently

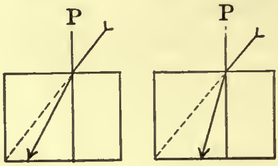

FIG. 15. FIG. 16.
FIG. 15.—Angle of deviation in glass.
FIG. 16.—Angle of deviaticn in diamond.

for the wave or ray to pass through the substance. A ray passes through a vacuum without resistance, but in its course through air it is slightly impeded, so that air has an index of refraction compared with a vacuum of 1.00029+, but this is so very slight that air and a vacuum are considered as one for all purposes in ophthal-

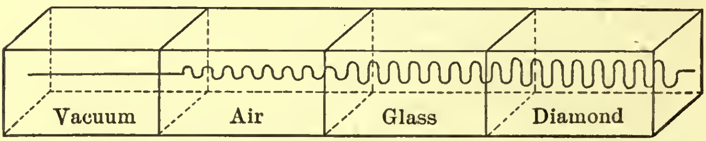

FIG. 17.—Illustrating the comparative density of different substances.

mology (Fig. 17). To find the index of refraction of any substance as compared with a vacuum it is only necessary to divide the sine of the angle of incidence by the sine of the angle of refraction and the quotient will be the index. In Fig. 18 the angle of incidence I C P is the angle formed by the incident ray I with the perpendicular P P. Drawing the circle P H P O around the point of incidence C and then drawing the sines X D and F B perpendiculars to the perpendicular P P, divide the sine X D of the angle of incidence by the sine F B of the angle of refraction, in this instance water compared with air, X D equalling 4 and F B equalling 3, then 4 divided by

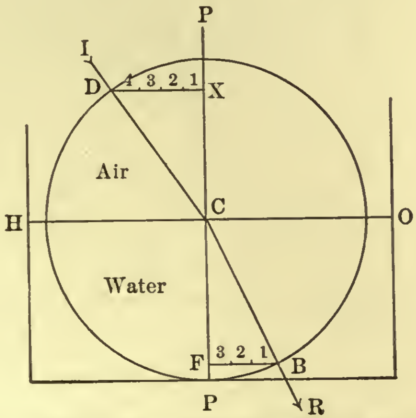

FIG. 18.—Illustrating the comparative index of refraction.

3 equals 4/3 or 1.33+, the index of refraction of water compared with air. To find the index of refraction of a rare 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 3/4 or 0.75.

THE REFRACTIVE INDEXES OF SOME ORDINARY MEDIA

Vacuum	1	Canada balsam	1.530
Air	1.000,294	Crown glass	1.540
Pure water	1.3336	Rock salt	1.545
Sea water	1.343	Rock crystal	1.548
Alcohol	1.365	Flint glass	1.635
Diamond	2.487		

Besides a knowledge of refraction preliminary to understanding the action which prisms have upon light, the reader should also understand or know what is meant by the following terms in trigonometry.

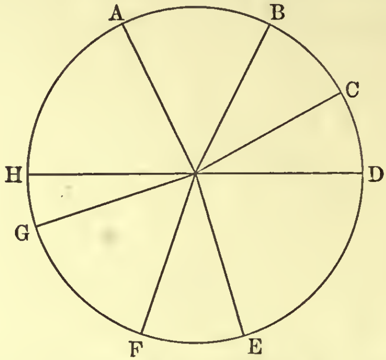

FIG. 19.—AB, BC, CD, DE, EF, FG, GH and HA = Arcs of the circle.

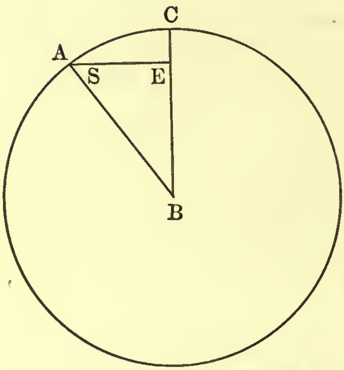

FIG. 20.—SE = Sine of the Arc AC.

Arc and Arc of an Angle.—This is the portion of the circumference of a circle included between two radii (Fig. 19 and A C in Fig. 20).

Sine of an Arc.—A perpendicular line extending from one end of an arc to the diameter drawn through the other end of the arc (S E in Fig. 20 is the sine of the arc A C).

Tangent (Latin "tangere"—"to touch").—The touching or meeting of a curve or surface at a point. A tangent is a straight line which touches the circumference but does not intersect it (Fig. 21).

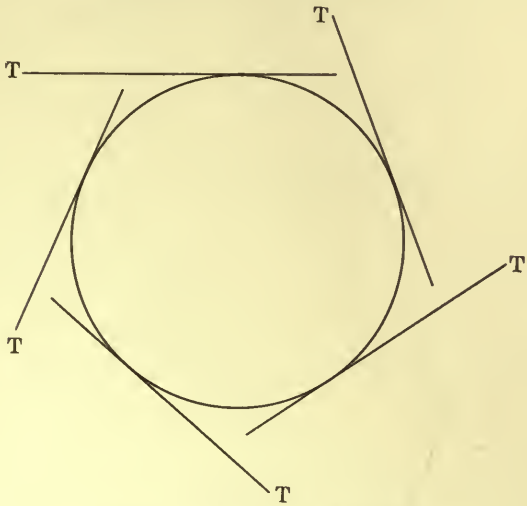

FIG. 21.—TTTTT = Tangents.

The tangent of the angle is a line drawn perpendicularly from the extremity of one radius to meet the other radius prolonged (T S in Fig. 22). A reference to Figs. 19, 20, 21 and 22 will show that the arc is less than the tangent and greater than the sine, in fact these quantities are always controlled by the magnitude of the angle.

Radian.—A radian is an angle subtended at the center of any circle by an arc equal in length to the radius of the circle (Fig. 23).

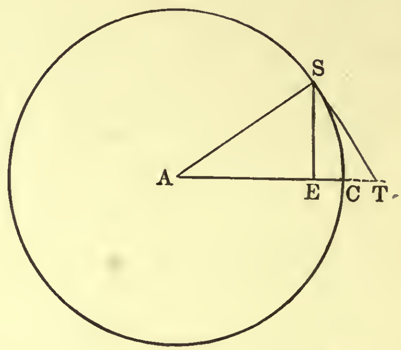

FIG. 22.—SAC = Acute Angle. SE = Sine. SC = Arc. TS = Tangent.

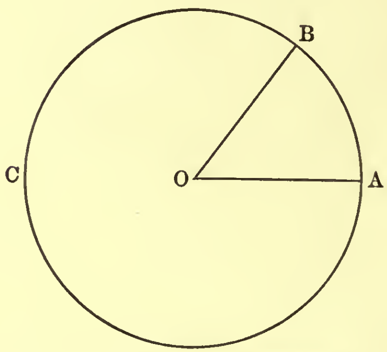

FIG. 23.—Illustrating the radian.

Prismatic Action.—Rays of light in a prism continue in straight lines and are not perceptibly broken up into different wave lengths (colors) so long as the glass composing the prism is isotropic. The surfaces of a prism alone deviate the rays and not the glass between the surfaces, hence the reason for speaking of the faces of a prism as refracting surfaces. Rays of light which pass through a prism are always refracted away from the edge and toward the base of the prism.

Maximum Deviation or Refraction.—By this is meant the greatest deviating power of the prism and it is obtained when all the refraction is done at one surface, namely, (1) if an incident ray is perpendicular to the

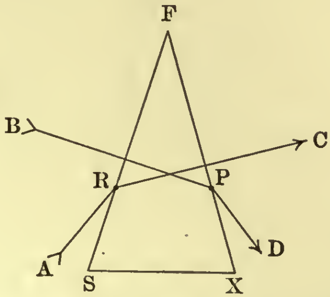

FIG. 24.—Illustrating maximum refraction or deviation. FS and FX = Surfaces. AR and BP = Incident Rays. PD and RC = Refracted Rays.

first surface of a prism, then it will pass to the second surface before it is deviated or refracted and all the refraction in this instance is done at this one surface, namely, as the ray emerges from the prism (B P, Fig. 24), (2) or if the entering (incident) ray is so bent or refracted on its entrance into the prism (A R in Fig. 24) that it becomes a perpendicular (R C) at the second surface, it will pass out of this second surface without any further deviation; all the refraction taking place at the first surface.

Minimum Deviation.—By this is meant the least effect or the smallest amount of deviating power of the prism; this takes place when the ray in the prism is parallel with the base in an equilateral prism or when it is equidistant from the edge at each surface or is deviated in an equal amount at each surface, or when the angle of incidence (I R N) is equal to the angle of emergence (V Y N′) (Fig. 25). The position of the prism

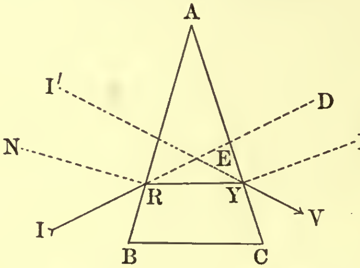

FIG. 25.—Illustrating position of minimum refraction or deviation. AB and AC = Surfaces. I = Incident ray directed toward D. RY = Course of ray in the prism and parallel to the Base (BC). V = Refracted Ray as if it came from I′. N and N′ = Perpendiculars or normals to surfaces AB and AC.

when this occurs is spoken of as the position of minimum deviation. Fig. 25 shows the prism B A C. The ray I incident on the surface A B at R is refracted to Y and emerging at Y is again refracted toward V. The ray R Y in the prism is parallel with the base (B C); R and Y are equidistant from the edge A.

Angle of Deviation (Fig. 25).—This angle is formed by the light and is situated between the directions of the incident ray carried forward (I to D) and the emergent ray (V to I′) carried backward, it measures the deviation (V E D). In all prisms of ten degrees or less the angle of deviation is slightly more than half the angle of the prism, but in prisms of more than ten degrees the angle of deviation is much larger.

Summary.—The deviation of a ray of light passing through a prism is influenced chiefly by two factors, *i.e.*:

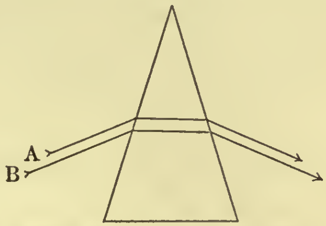

FIG. 26.—A and B, parallel rays entering the prism, are parallel as they leave the prism.

(1) The obliquity of the refracting surfaces: The more acute the edge angle, the less the deviation; the greater the edge angle, the greater the deviation.

(2) The index of refraction of the prism: The less the index of refraction, the less the angle of deviation; the

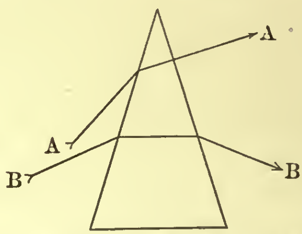

FIG. 27.—A and B are divergent as they enter and leave the prism.

greater the index of refraction, the greater the angle of deviation.

Prisms do not cause rays of light to converge or diverge: Rays of light that are parallel before refraction are parallel after refraction (Fig. 26). Rays of light that diverge (A B, Fig. 27) as they enter a prism will diverge as they leave it. Rays of light that converge

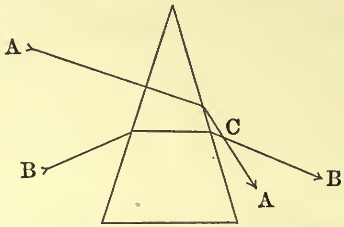

FIG. 28.—A and B are convergent as they enter and leave the prism, these rays cross at C.

(A B, Fig. 28) as they enter a prism will converge when they leave it. Prisms do not form images. Prisms have no foci. A prism and a plane mirror act similarly upon rays of light, namely, if the rays of light are par-

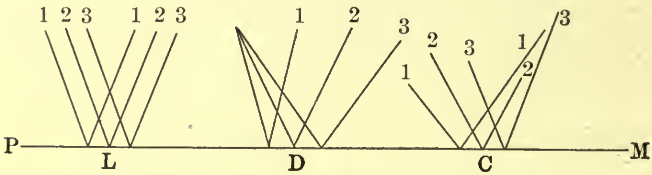

FIG. 29.—PM = Plane Mirror. L = Parallel rays 1, 2, 3, reflected parallel. D = Divergent rays reflected divergently. C = Convergent rays 1 2, 3, reflected convergently.

allel, divergent or convergent as they fall upon a plane mirror they will be reflected in like manner. See Fig. 29.

CHAPTER III

OPTICAL EFFECT OF A PRISM

The purpose, or use, or effect of a prism is to make an object looked at through the prism appear in a different place from that which it really occupies, the prism actually producing an optical illusion. In producing this effect the object always appears displaced and in a direction always opposite to the position of the base of the prism, namely, in the direction of the edge of the

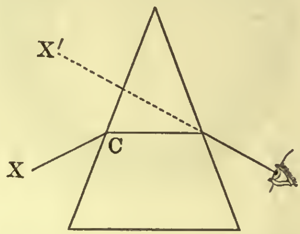

FIG. 30.—Optical effect of a prism. X appears in the position of X′.

prism. For instance, in Fig. 30, rays of light from the object X strike the prism at C, undergo minimum refraction and falling upon the retina of the eye are projected outward in the direction from which they came to the eye, and the position of X is apparently changed to X′, away from the base and toward the edge of the prism.

Before proceeding further, the mind of the reader must be impressed with the fact that the word *edge* and *apex* as applied to a prism are synonymous terms, because only too frequently the student confuses these terms with a difference. This confusion has arisen apparently from the markings on the circular or round prisms, but by observing Fig. 7 the reader will see, as already stated in Chapter I, that the apex mark of a circular or round prism corresponds to a point in the edge of the original square prism. If the reader will also bear in mind that

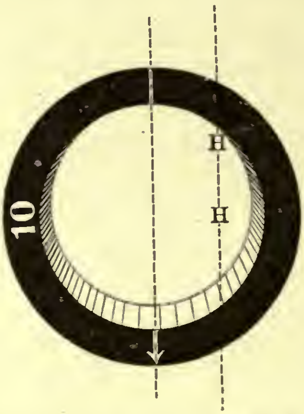

FIG. 31.—H appears displaced toward the edge of the prism and parallel to the base-apex line.

the base-apex line as marked on the prism is only a guide and that there are as many imaginary base-apex lines in the prism as there are imaginary lines parallel to the one base-apex line indicated on the prism, he will fully appreciate the statement that every point in an object seen through a prism is displaced toward the edge of the prism and on a line **parallel** with the base-apex line. It is a very erroneous idea to get the impression in mind that because the prism is round, the object looked at through the prism is displaced in all its parts toward the apex marking on the prism, as if it was to be crowded toward the apex of an angle. In Fig. 31 the letter H is seen through the prism to the right of the prism markings for the apex and base and this H is displaced immediately upward on an imaginary line exactly parallel to the base-apex line and not toward the apex marking of the prism.

A straight line, at a long distance viewed through a strong prism, held base-apex at right angles to the

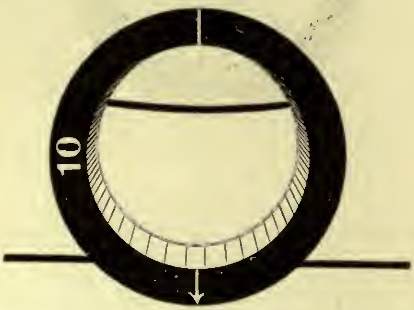

Fig. 32.—The straight line looked at through the prism appears curved, the concavity being toward the edge of the prism.

line, appears to be curved and with the concavity toward the edge of the prism (Fig. 32). This same straight line viewed through the prism held with the base-apex line in the same meridian as the line, does not at first appear displaced, although it is displaced, the displaced portion simply overlying the original line and toward the edge of the prism (Fig. 33), making the line appear a trifle darker and heavier. Any prism held before the eye and revolved on its plane gives an object looked at through the prism the appearance of moving in a circle about its real position. In a right-angled triangle prism (a principal section of which is a right-angled isosceles triangle) the hypotenuse may

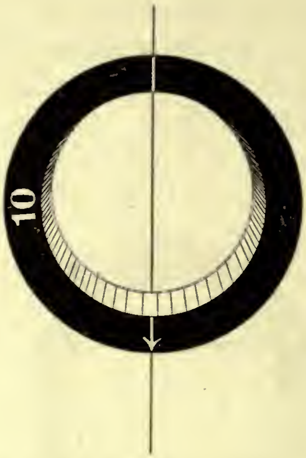

FIG. 33.—The straight line seen through the prism on its base-apex line does not appear displaced.

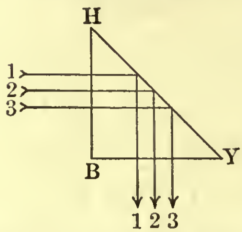

FIG. 34.—The hypotenuse HY acting as a plane mirror, producing total reflection.

act similar to a plane mirror (Fig. 34). Rays of light entering such a prism at H B as normals (1, 2 and 3) fall upon the hypotenuse (H Y) at an angle of incidence of 45 degrees and as this angle is greater than the critical angle (40° 49′) for crown glass, the rays are *totally* reflected. At the same time these rays are deviated

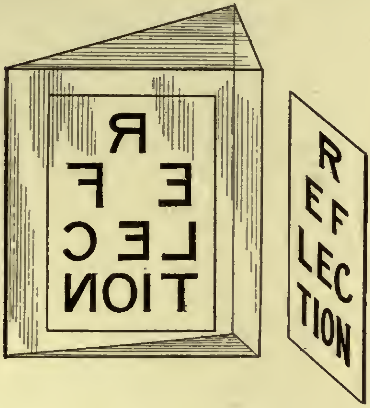

Fig. 35.—Hypotenuse acting as a plane mirror.

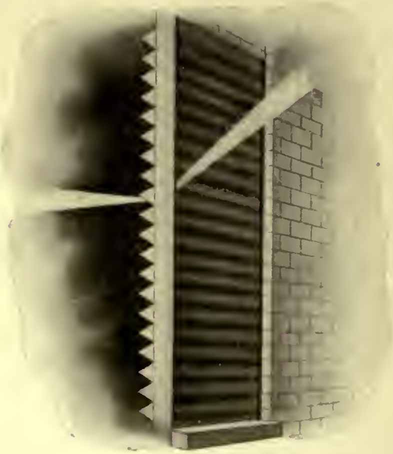

Fig. 36.—Showing how light rays are bent by means of prism angles.

through an angle of 90 degrees, consequently they emerge at B Y as normals from the other surface of the prism. See also Fig. 35. This fact is taken advantage of in a mechanical way by the use of these and other prisms for purposes of illumination or for deviating rays of light into dark basements, stair-

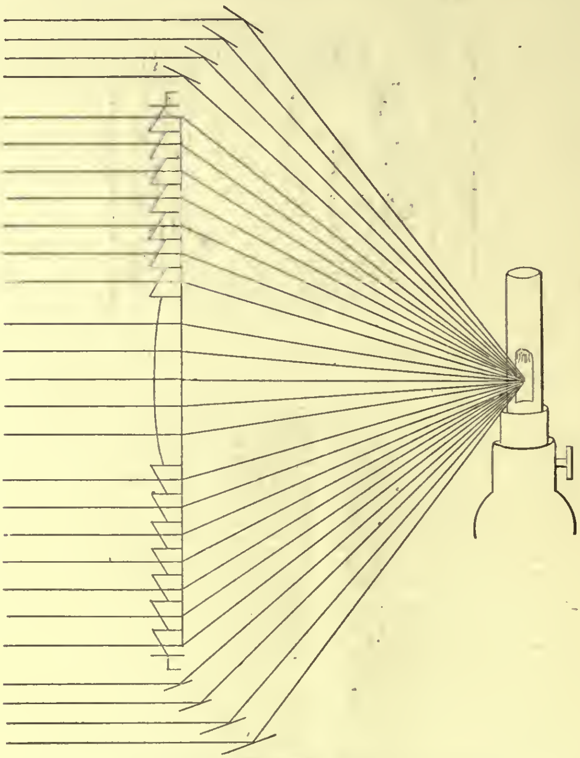

FIG. 37.—Illustrating Fresnel's lighthouse apparatus.

ways, etc. (Fig 36). Likewise prismatic action is employed in the construction of the lenses surrounding the light in a lighthouse (Figs. 37 and 38). "At the center of such an apparatus is a plano-convex lens, one foot in diameter, the focus of which corresponds with those of the concentric lenticular rings of glass which surround it. The rings are ground and polished with great accuracy and resemble in shape an ordinary quoit and in their refraction are equivalent to a plano-convex lens with its center removed. Such lenses are so powerful that the light in a clear atmosphere may be seen at a distance of fifty or sixty miles. The apparatus is octagon in shape and

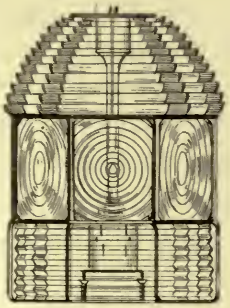

FIG. 38.—Lantern of a first-class lighthouse.

provided with reflecting mirrors at those parts above and below the light which are out of the range of the lenses. The oil flame, as the radiant, is so placed that when its rays pass through the lens and prism and are reflected by the mirrors, they are deviated so as to follow the horizon very closely and do not go promiscuously skyward or immediately downward."[1]

Corneal microscopes, marine glasses, and loupes are now most ingeniously constructed with prism combina-

[1] "Wonders of Optics," C. Scribner & Co.

tions whereby the object is greatly enlarged and given a flat surface.

Prism Aberration or Prismatic Astigmatism.—A divergent pencil of light passing through a prism and received into the normal 3 1/2 millimeter round pupil of an eye is naturally projected toward the edge of the prism as just described, but it is not seen as a distinct radiant point; it appears as a point, however, with those edges blurred or indistinct which coincide with the base-apex line of the prism, while the rays of light which were refracted in the meridian corresponding to the axis of the prism are distinct; in other words, the rays which fall upon the prism in the vertical meridian appear a trifle further off than the rays which fall upon the prism parallel to its edge. A circle viewed through a prism appears very slightly oval on this account and with the upper and lower edges faintly blurred. This effect of a prism is spoken of as prism aberration or prismatic astigmatism and the interval between the two focal planes is known as Sturm's interval. Very weak prisms (less than 2 centrads) have such a minute amount of aberration or astigmatism that it is really infinitesimal and often non-appreciable. It takes a strong prism (10 or more centrads) to demonstrate abberration and as strong prisms are seldom prescribed this astigmatic effect need not have further consideration at this time.

Metamorphopsia.—Rotating a prism on its axis or on its base-apex line as the observer looks through it at an object, the object becomes distorted and this distortion is spoken of as metamorphopsia; for instance, holding a strong prism base downward axis 90° before the eye and

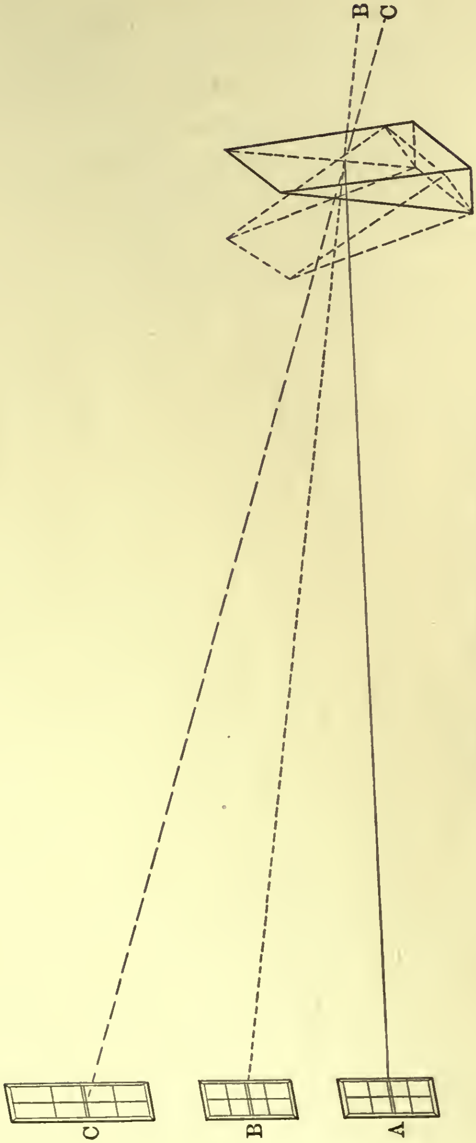

FIG. 39.—Illustrating metamorphopsia.

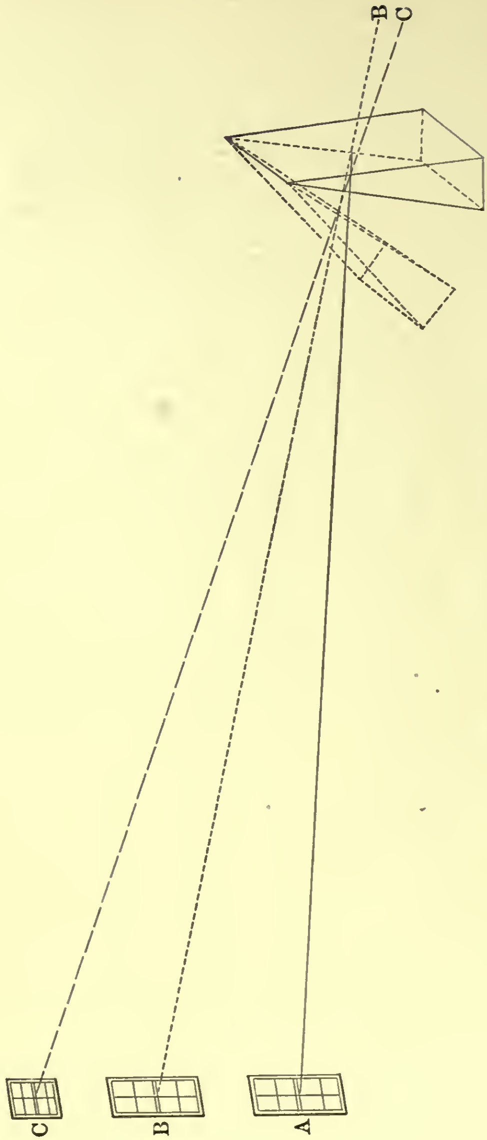

FIG. 40.—Illustrating metamorphopsia.

looking at an object (window A in Fig. 39) it naturally appears displaced upward (B in Fig. 39) then tilting the edge forward toward the object (dotted prism, same figure), thus bringing the base toward the observer's eye, gives B the appearance of being displaced still further upward (C in Fig. 39) and at the same time the object (window) is very much elongated (magnified) vertically, the horizontal width remaining unchanged.

Holding a strong prism base downward axis 90° before the eye and tilting the base toward the object (bringing the edge toward the observer's eye) (Fig. 40) gives the displaced object (B) the appearance of being still

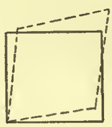

FIG. 41.

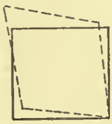

FIG. 42.

further displaced from B to C and very much reduced in size (minified) in the vertical meridian and the horizontal width of the object remains unchanged. Rotating a prism to the right on its base-apex line as it is held base downward axis 90° before the eye, and the eye views a square through the prism, the right side of the square appears to move upward (Fig. 41) and if the prism is rotated to the left, the left side appears to move upward (Fig. 42). In each instance the square object has a distortion resembling a rhombus.

Dispersion of Light.—When a beam of solar light (B in Fig. 43) is made to pass through a prism of rock crystal or flint glass it is broken up or divided into its constituent parts and this phenomenon is spoken of as dispersion. This beam of light directed toward E, if intercepted by a screen will be seen as a colored image, known as the solar spectrum at C. This image is rounded at the ends and the colors seen are red, orange, yellow, green, blue, indigo and violet in the order named —violet being the most refrangible and red the least.

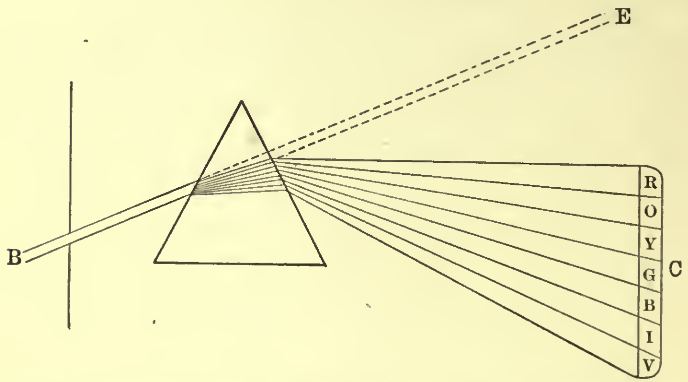

FIG. 43.—Dispersion or the production of a spectrum by a flint glass or rock crystal prism.

These colors do not have sharp lines of demarcation, but blend into each other. Dispersion plays but an infinitesimal part in ophthalmology for the reason that strong prisms are not prescribed and furthermore the prisms in the trial case are of crown glass.

COMPARING THE ACTION OF A PRISM, A SPHERE AND A CYLINDER

A Prism.—Looking at a straight line through a prism held in its position of minimum deviation and its base-apex line exactly at right angles to a line, the line appears displaced in the direction of the edge of the prism (Fig. 32) and this exact amount of displacement never changes so long as the prism and line are kept at a definite distance apart, no matter how far to the right or to the left the prism may be moved. As already stated, when the prism is held so that the base-apex line coincides with the straight line a displacement of the line exists but is not always apparent, because in this position the displaced portion is superimposed on the original line (Fig. 33).

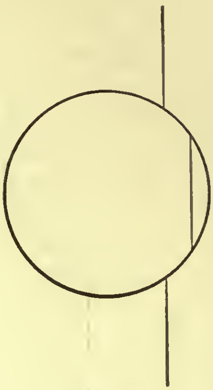

Fig. 44.

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 (Fig. 44) 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 (Fig. 45). Marking this straight line on the surface of the lens, and then turning the lens to the opposite meridian

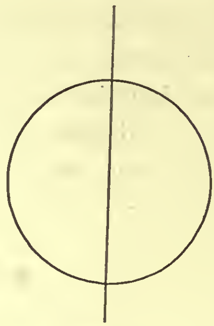

Fig. 45.

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 (Fig. 46).

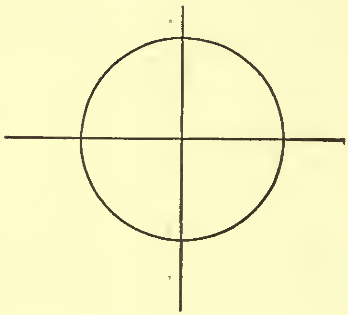

Fig. 46.

A Convex Sphere.—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.

A Concave Sphere.—When a concave sphere is moved before the eye from left to right and right to left

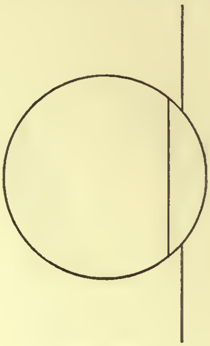

FIG. 47.

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 smaller and more distant as the glass is moved away from the eye, and if brought closer to the eye, it 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 (Fig. 47), 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 Fig. 45.

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

A Convex Cylinder.—When a convex 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

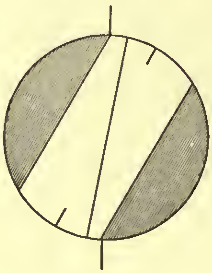

FIG. 48.

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 (Fig. 48).

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 (Fig. 49). A circle viewed

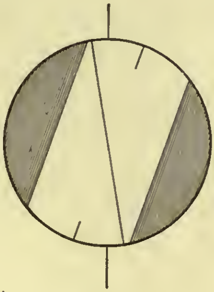

FIG. 49.

through a strong concave cylinder appears as an oval with its long diameter corresponding to its axis (Fig. 50).

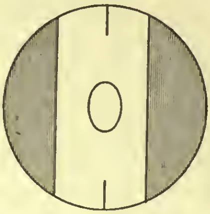

FIG. 50.

A circle viewed through a strong convex cylinder appears as an oval with its long diameter opposite to its axis.

CHAPTER IV

PRISM NOMENCLATURE. DENNETT'S METHOD. PRENTICE'S METHOD AND NEUTRALIZING PRISMS

Numbering of Prisms.—Formerly prisms were numbered by their refracting angles or the edge angle formed between the two refracting surfaces. Such prisms were known as one degree (1°), two degrees (2°), three degrees (3°), etc. Early trial cases had these prisms numbered in this way, sometimes as high as number twenty-four. They were often spoken of as number one, number two, number three, etc. The unit (number one) or any degree numbered prism does not, unfortunately, signify or designate definitely the amount of deviation a ray of light will undergo in passing through such a numbered prism; the degree simply designates the inclination or angle formed by the sides of the prism. It will be noted later that this method of numbering prisms was most unsatisfactory because it did not indicate the angle of deviation which the ray of light would make when it passed through the prism. Or to state it in another way, the degree notation of prisms did not inform the surgeon just how much such a prism would deviate a ray of light when in its position of minimum deviation (Chapter II, also Fig. 25).

When referring to the strength of a prism it is always better to mention its deviating power; for instance, a number 4 prism does not convey the proper meaning except that the surfaces of such a prism have an apical angle of four degrees, and therefore if we wish to say that a 4 prism will deviate a ray of light four degrees, we must insert the letter "d" after the 4, which would be "4 d prism." A change from this "degree" nomenclature of prisms was urged by Dr. Edward Jackson (now of Denver, Colorado) before the Ninth International Medical Congress and he very wisely and properly recommended that prisms be numbered or marked according to their power of deviating rays of light and the edge angle to be ignored.

An instrument for measuring the edge angle of the prism is made by the Geneva Optical Company and called a "prism measure," but it is of no use to the oculist as it does not register the deviating power of the prism. It is an instrument, however, which the optician can use to advantage.

Since Dr. Jackson's recommendation for a new or exact prism nomenclature, two methods have come into use, namely, Dennett's Method and Prentice's Method.

The size of the angle of deviation produced by a ray of light passing through a prism measures the strength or the effect of the prism and it is this angle which has given us the new nomenclatures now to be described.

Dr. Dennett's Method.—The Centrad. Abbreviated by an inverted Greek letter D (Delta)∇. The unit of this method (one centrad) is a prism which will deviate a ray of light the one-hundredth part of the arc of the radian. (See Radian, Chapter II.) This is an arc measurement and the arc of the radian always equals a little more than fifty-seven degrees (57.295+°). In Fig. 51 R A and R C are radii of curvature, A C is the arc of the radian and is equal in length to either R A or R C. This arc is now divided into 100 equal parts.

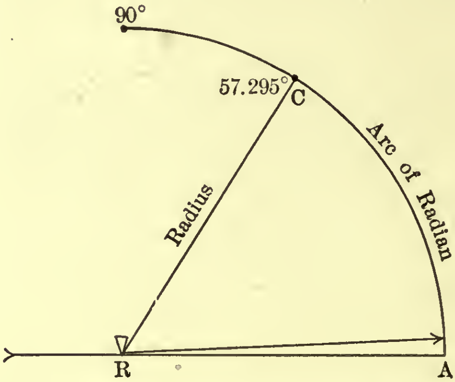

FIG. 51.—Illustrating Dennett's method of numbering prisms.

A prism base up axis 90° at the center of curvature (R) which will deviate a ray of light just one-hundredth part of this arc is a unit prism of one centrad (1^{∇}) and in its deviating power equals therefore the one-hundredth part of 57.295 degrees, or 0.57295 of a degree. This unit power tells at once the deviating power of any number of centrads by simply multiplying this unit power (0.57295) by the number of centrads in the prism; for instance, a five centrad prism (5^∇) will deviate a ray of light 5×0.57295 which equals $2.8647°$, and a ten centrad prism (10^∇) will deviate a ray of light 10×0.57295 which equals $5.7295°$ etc.

Mr. Charles F. Prentice's Method.—Prism-diopter or prism-dioptry. Abbreviated by the Greek letter D (Delta) △. The unit of this method (one prism-diop-

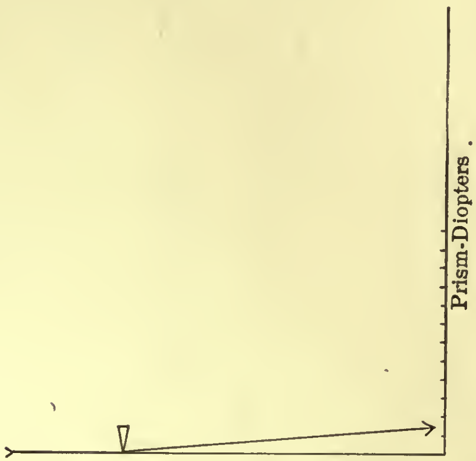

FIG. 52.—Illustrating Prentice's method of numbering prisms.

ter) is a prism which will deviate a ray of light just one centimeter for each meter of distance that it travels. The prism-diopter is strictly a tangent measurement (Fig. 52). As the deviation of a prism-diopter is always one centimeter for each meter of distance then one prism-diopter will deviate a ray of light two centimeters for two meters of distance, three centi-

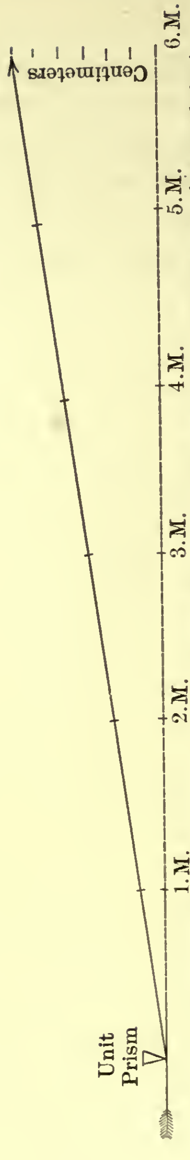

FIG. 53.—Illustrating prism power. One centimeter of deviation for each meter of distance. (Reduced size.)

meters for three meters of distance, four centimeters for four meters, etc. (Fig. 53).

The comparative values of centrads and prism diopters is quite uniform up to 20, but above 20 the centrad becomes the stronger (Fig. 54). As the every-day use

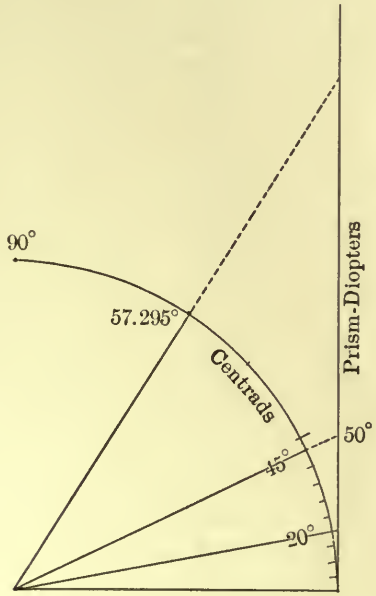

FIG. 54.—Comparing Dennett's and Prentice's methods of numbering prisms.

of prisms seldom calls for a prism stronger than 20 (centrad or prism-diopter) the surgeon need not be annoyed with any distinction between the two nomenclatures until he passes to a prism stronger than 20.

The following table is self explanatory.

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

"The actual difference between corresponding numbers of the two scales is the difference between the tangent and the arc of the same number of hundredth-radians. The practical difference within the limits of actual use is hard to see."[1]

"In 1891 the Ophthalmic Section of the American Medical Association passed a resolution recommending the adoption of the centrad unit and scale and equally with that up to 20, the prism-diopter."[1]

Neutralization of Prisms.—The word neutralization as used in opththalmology means to counteract or render inert or it may be described as antagonizing or as an opposite effect. For instance, if a ray of light passing through a prism is deviated two centimeters at one meter of distance, then to neutralize this effect or antagonize this deviation it will be necessary to find a prism of equal strength and place it with its base to the apex of the other prism, or to be able to neutralize a prism all that is necessary is to find its numeric strength. To do this, the prism to be tested must be held in its position of minimum deviation with base-apex line at right angles and over a series of numbered parallel straight lines separated by an interval of one centimeter (or multiple or fraction thereof) and note the amount of displacement that results when the prism is held at a distance in meters (or multiple or fraction of a meter) according to the interval between the lines. Fig. 55 shows a series of vertical, parallel straight lines one-half centimeter apart and numbered from 0 to 9. An X is placed at the foot of the zero line. All the parallel lines are at right angles to the black line B L.

[1] William S. Dennett, M. D.: "System of Diseases of the Eye," Norris and Oliver, Vol. II, page 150.

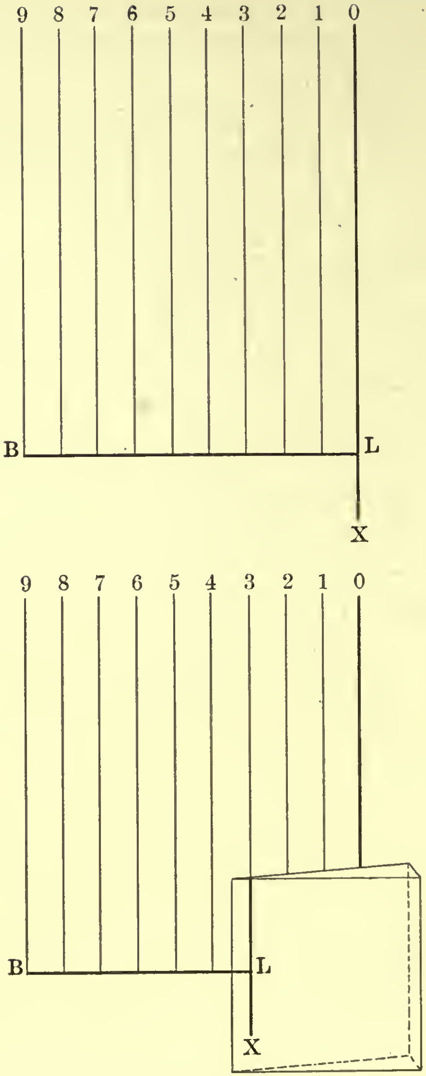

FIG. 55.—Author's method of estimating the strength of a prism.

Holding a prism base to the right, axis 180°, at a distance of 50 centimeters (half a meter) from the lines (as the lines are one-half centimeter apart) and looking through the prism at X on the zero line and also at the line B L, it will be seen that the X line has been displaced to the line to the left corresponding to the

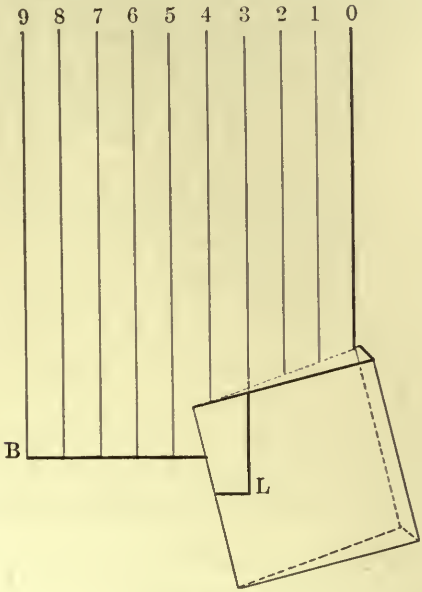

FIG. 56.

number of centrads or prism-diopters in the prism which is being tested—in this instance, three. The displaced portion of the B L line is carried forward and superimposed upon itself, otherwise it would appear out of alignment, if the prism was not held with the base-apex line corresponding to the B L line, as shown in Fig. 56. If the zero line (X) had been displaced between the lines marked 2 and 3 then the number of the prism would have been more than two or less than three centrads or prism-diopters. If it has been displaced to the line marked 5 then it would have been a 5 prism, etc. It might be just as well to remind the reader that it makes no difference at what distance his eye may be from the prism while making this test, but it is of the utmost importance to

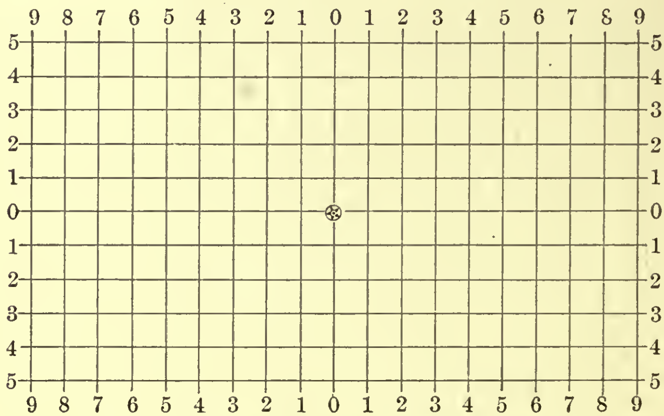

FIG 57.—Prismometric scale of Charles F. Prentice.[1]

hold the prism in the manner mentioned and at the exact distance in meters or fraction of a meter, corresponding to the centimeter interval between the lines. To find the strength of a prism, Mr. Prentice, who proposed the prism-diopter, recommends using a graduated card having lines upon it separated by an interval of six centimeters and this of course must be placed at a distance of six meters and used as in the former test. This scale is exact and called by its author a "prismo-

[1] Copyright, see footnote page 98.

metric scale" (Fig. 57). This scale may also be used for muscle testing and is described in Chapter VII.

A prism may be neutralized by placing another numbered prism from the trial case in opposition to it, the base of one to the edge of the other (Fig. 58), so that in looking through the two prisms at a straight line, no matter at what distance, the straight line will continue to make a straight line. The strength of the neutralizing prism will correspond to the number of the prism being neutralized. As the prisms in the

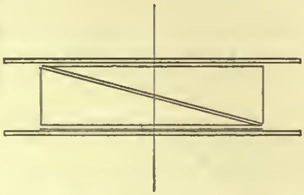

FIG. 58.—Neutralization of prisms.

trial case occasionally get loose in their individual frames or cells, it will be well for the surgeon to test the prism in the manner described in Fig. 55 to make sure that they are properly placed. The base-apex line should coincide with the B L line and with the makings on the frame. Dr. Ziegler's prism scale (Fig. 59) is an excellent one. The directions for its use are as follows:

This prism scale is to be used at a distance of a quarter meter, but a larger one for use at two meters is preferable as the possibility of error is much less. To use the scale close one eye, and with the other look at the scale both through the prism and over it. A

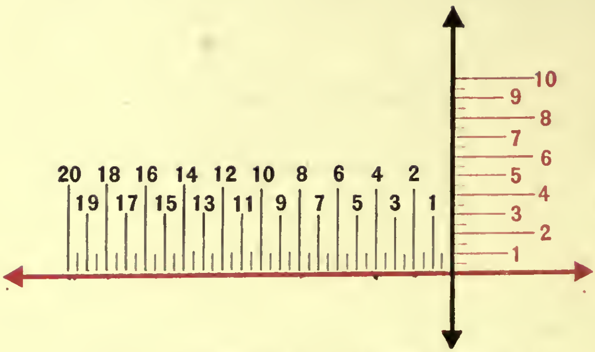

FIG. 59.—Prism scale of Dr. Lewis S. Ziegler.

comparison of these two views gives the required registration. Each field must contain either the indicator singly or the numbered gradations singly; the fields being in conjunction at the margin of the lens.

Rotate the prism until the base line seen through the prism is continuous with the base line of the scale. Always keep the plane of the prism parallel with that of the scale, and on a level with it. The index line will be displaced along the scale until the indicator stands opposite the proper numbered gradation. By moving the prism up and down along this gradation, it can be seen whether the index line accurately coincides or not.

CHAPTER V

COMBINED PRISMS

Combined Prisms.—Any two prisms of the same strength with the base of each against the edge of the other will neutralize each other and the effect will be negative. See neutralization of prisms, Chapter IV, Fig. 58.

Any two prisms of the same or different strength with the base of one to the base of the other will equal the effect of a single prism of the combined strength

FIG. 60.—Two prisms in apposition. Base and edge of one to the base and edge of the other.

of the two (Fig. 60). Any two prisms, each less than $5^{\triangledown}$, of the same strength held in apposition and with their base-apex lines at right angles to each other (Fig. 61) will equal or be equivalent to a single prism one or two units stronger than one of the prisms, with its base midway of the two bases. For instance, 5 prism-diopters base down axis 45 combined with a 5 prism-diopter base down axis 135 will equal a 7 prism-diopter base down axis 90°. This is a very close equivalent in effect and applies to pairs of prisms as high as 5 centrads or 5 prism-diopters, but when pairs of prisms as strong as 15 are used the effect is much greater and with 15$^{\nabla}$ the effect will approximate a single 21 prism-diopter.

That the reader may fully appreciate these statements, he should make these tests for himself and in this way

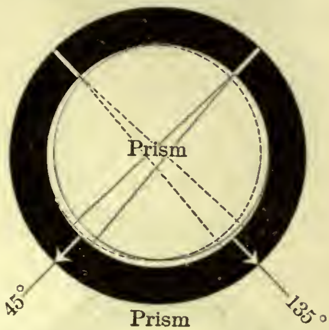

FIG. 61.—Two prisms of the same strength superimposed. One base down axis 45 and the other base down axis 135.

become familiar with the prism effects or equivalents. The following description will also be of assistance:

Fig. 62 shows a single 8 prism-diopter held about 10 inches away from and directly over the word "Prism." (Both eyes of the observer must be kept open to make this test.) The base-apex line is at axis 45° and base downward. The word "Prism" now seen through the prism appears displaced upward to the right on the base-apex line, on axis 45°. Likewise

Fig. 63 shows another prism of same strength held in the same manner over another word "Prism" and the base of the prism downward on axis 135°. It pro-

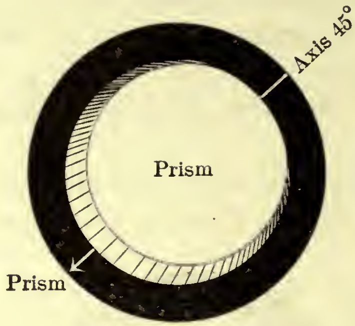

FIG. 62.

duces a similar amount of displacement of the word "Prism," upward and to the left on axis 135°. If these two prisms are now superimposed in their re-

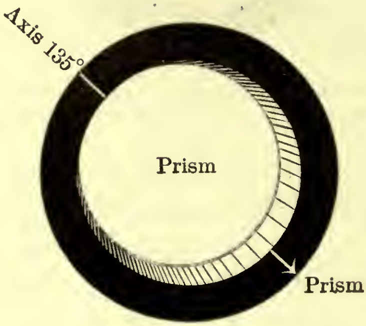

FIG. 63.

spective positions (45° and 135°) as shown in Fig. 61, and the word "Prism" as also shown in Fig. 61, is now looked at through this combination, the word "Prism" will appear displaced upward on axis 90° and the effect thus produced is equivalent to a single 11 prism base down axis 90°, Fig. 64.

As just stated and illustrated (Fig. 58), any two prisms of the same strength with the base of each to the apex of the other, neutralize each other and the effect is negative, but if these two prisms still held in opposition are now revolved in opposite directions at an equal rate of speed, the effect produced is that of a prism gradually

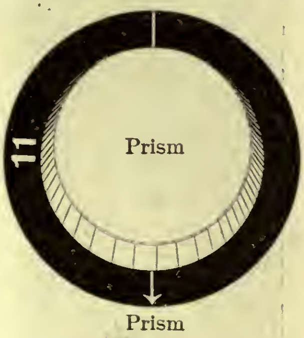

FIG. 64.

growing stronger and stronger in its effect until the bases of the two prisms become superimposed and the resulting effect will be the combined strength of the two prisms (Fig. 60)

At first thought the student will naturally imagine that such a mechanism (Fig. 61) must produce two images (diplopia) of any object looked at, but the error of this supposition will be dispelled by reference to Fig. 61 and by making the tests for himself. Sir John Herschel was the first to show the effect of combining two prisms and by rotating them in opposite directions to obtain the effect of a single prism of increasing strength up to the combined value of the two.

Crété of Paris was the first to bring forth an instrument which gave practical use to two superimposed

FIG. 65.—Front view of the revolving prisms as arranged by Crété.

prisms. It is called "Crété's Prism" or the "Prisme mobile." See Fig. 65. These two prisms are mounted in a circular cell with a straight handle. This handle contains a slot through which travels a movable button adjusted to the prisms so that on pushing the button upward or downward the prisms are made to revolve in opposite directions at an equal rate of speed. The figures on the handle opposite the gauge record the strength of the prism thus produced.

The handle of the "Crété prism and also the position of its degree markings interfere with its usefulness and make it cumbersome for every-day practice;ns. fact the instrument is rather obsolete for these reaso in The most adaptable form of Crété's prism which does away with the handle is that of Dr. S. D. Risley, known

FIG. 66.

as the "Rotary prism," Fig. 66. This apparatus which may be used in the trial-frame is composed of two superimposed prisms of 15 prism-diopters or 15 centrads each, and mounted in a 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 revolved over each other the prism strength gradually increases until the bases of the two prisms superimpose, equalling (15+15) 30 centrads. The prism strength is indicated by a pointer directed to the scale on the periphery of the cell. "Rotary prisms" are made in two strengths, one contains two 10 prisms and the other, as just described, two 15 prisms. See Chapter on Muscle Testing.

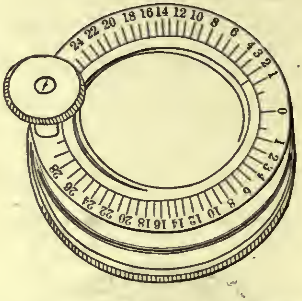

FIG. 67.—Jackson's triple prism.

Jackson's triple prism (Fig. 67) is very similar to the Crété or Risley prism. It contains three prisms, as its name implies; one of these is stationery and the other two revolve.

CHAPTER VI

COMBINING A PRISM WITH A SPHERE, CYLINDER OR SPHERO-CYLINDER

Before taking up the consideration of these combinations, the reader must be acquainted with the following:

The geometric center of a lens is a point midway of the diameters of the surface; therefore there is a geometric center for each surface and these are superimposed. As the geometric center is always con-

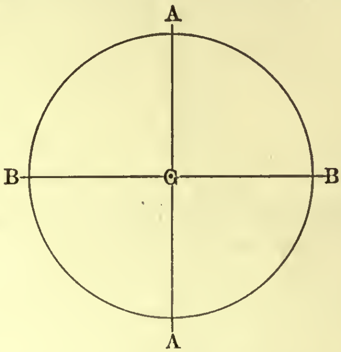

FIG. 68.—The dot in G at the point of crossing of BB with AA indicates the optic and geometric centers superimposed.

trolled by the midpoint of the diameters, it is easily located. Fig. 68 shows a circle which may be considered as the outline or contour of a lens. AA and BB are diameters. The dot in the G is the midpoint of these diameters and is therefore the geometric center. As another illustration, see Fig. 69. This is the outline of a spectacle lens; AA and BB represent the two chief diameters and the dot in the G is the midpoint of these diameters and hence is the geometric center. Also see dot on surfaces of lens pictured in Fig. 70.

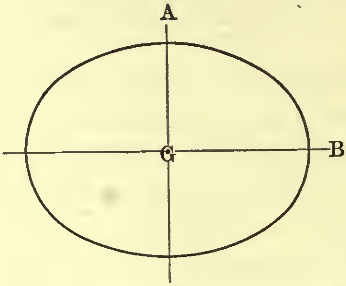

FIG. 69.—Dot in G = geometric center.

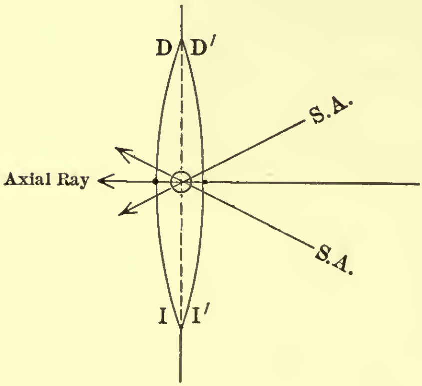

FIG. 70.—Dot in O = Optic center. Dots = Geometric centers.

Optic Center.—This term is used synonymously with nodal point, but it is not and must not be confused with the geometric center. The optic center is the point where secondary rays cross the axial ray (dot in the O, Fig. 70). Rays of light crossing the optic center in thin lenses are not considered as undergoing refraction (S A in Fig. 70). The optic center is always a fixed point and may be located at any part of the lens or at an imaginary point beyond its edge. In Fig. 70 the optic and geometric centers coincide, but in Fig. 71 they do not coincide. To summarize, the optic center is always at the thickest part of a convex lens and the thinnest part of a concave lens.

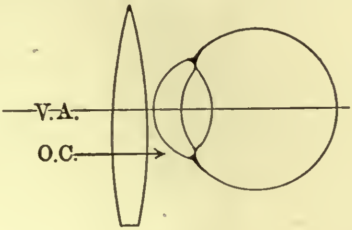

FIG. 71.

True Center of a Lens.—A lens is said to be centered when the optic and geometric centers coincide or are both on the visual axis (Figs. 70 and 72).

When the optic and geometric centers do not coincide then such a lens has a prism effect or combination, hence (Fig. 71)

(1) The nearer the optic and geometric centers coincide with or approximate the axial ray the less the prismatic effect.

(2) The further apart the optic and geometric centers the greater the prismatic effect (Fig. 71).

(3) In weak lenses or lenses with long radii of curva-

ture, a slight lateral displacement of the optic center produces but little prismatic effect.

(4) In strong lenses or those with short radii of curvature, a slight lateral displacement of the optic center from the geometric center will produce considerable prismatic effect.

Or 3 and 4 may be restated briefly; *i.e.*, a strong lens requires less lateral displacement of the optic center from the geometric center than a weak lens to obtain the same amount of prismatic effect in each.

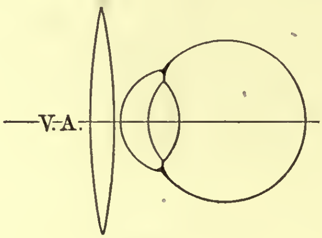

FIG. 72.

Unless otherwise prescribed, every lens placed before the patient's eye is supposed to have the optic and geometric centers coincide with the visual axis of the eye (Fig. 72), then there will not be any prismatic effect. If there is any departure from this correct position for the lens and the eye together, then a prismatic effect is produced and its amount is in proportion to the displacement or separation and the strength of the lens in use (Fig. 71).

Decentering (Decentring) a Lens.—This may be described as having the optic center of a lens laterally displaced from the geometric center, so that the eye looking through such a lens sees through the geometric center but not the optic center (Fig. 71). In other words the geometric center is on the visual axis but the optic center is to one side (Fig. 71).

A decentered lens may therefore be described as one whose optic and geometric centers do not coincide (Figs. 71, 75, 76, 77 and 78).

When ordering a prism in combination with a lens the prescriber may write his prescription out in full

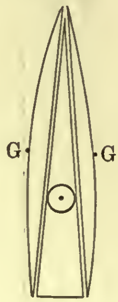

FIG. 73.—Dots at GG = Geometric centers. Dot in O = Optic center of this combination.

or he may specify that the lens is to be decentered. For instance +4 sphere ⬭ 4^{Δ} base down axis 90°. This is equivalent to a plano +2 sphere[1] on each surface of the 4 prism (Fig. 73).

The optician would, however, take a + 4 sphere (in the rough[2] as he calls it) and grind or polish the other surface at an angle as indicated by the straight dotted line. See Fig. 74. The angle at which he

[1] It might be well to mention that the optician carries spheric lenses in stock that are round or circular in contour and cylinders that are square.

[2] In "the rough" means that one surface is not polished or finished.

grinds the second surface must be in keeping with the prismatic effect which the prescription calls for.

In place of the above formula the prescriber could have ordered +4 sphere decentered 10 millimeters downward axis 90°. For this prescription the optician would take the +4 sphere and mark with a dot the true center (dot 1 in Fig. 75) and also mark the shape of the lens he is to cut out and in place of cutting it as

FIG. 74.—Plano-convex sphere in the rough. Straight dotted line for a plano-sphero-prism. Curved dotted line for meniscus sphero-prism.

indicated by the dotted line, follows the continuous line and in this way leaves the optic center 10 millimeters downward or below the geometric center at 2. In profile (Fig. 76) this +4 spheric lens shows the prism thus manufactured by decentering.

The rule for decentering lenses to obtain a certain amount of prismatic effect is as follows:

"For every centimeter (10 millimeters) of decentering there will be produced as many centrads or prism-diopters as there are diopters **in the meridian** which is decentered." In the example just given (+4 sphere ⊂ 4^{Δ} base downward axis 90°) it must first of all be remembered that this is a 4 diopter lens and secondly if the optic center is placed 10 millimeters away from the geometric center the effect will be a +4 sphere ⊂ 4 prisms; in other words, as previously mentioned, it

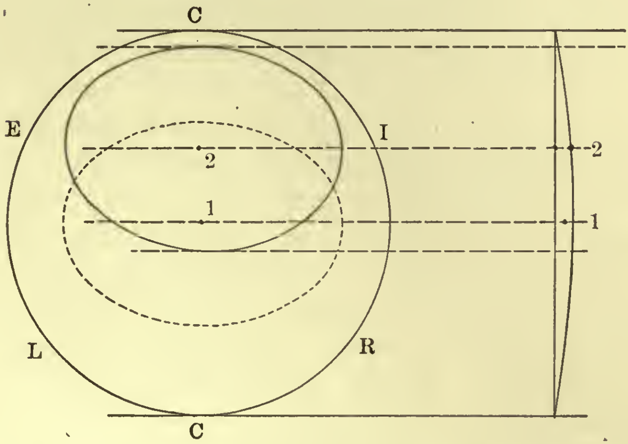

FIG. 75. FIG. 76.

FIG. 75—CIRCLE = plano-convex lens in the rough. I = optic and geometric centers superimposed. At 2 the geometric center is above.

FIG. 76.—Profile of Fig. 75 showing geometric center at 2 and optic center at 1.

will be +4 sphere decentered 10 millimeters downward axis 90° (Figs. 75 and 76). According to the same rule if the +4 sphere had been decentered 5 millimeters the effect would have been 2 prisms, if it had been decentered 2 1/2 millimeters the effect would have been 1 prism, if it had been decentered 15 millimeters the effect would have been 6 prisms. Likewise if the denominator of the sphere had been a minus in place of a plus, the effect would have been the same, also if a plus or minus 1, 2, 3, 5, 6, 7, 8, etc., was decentered 10 millimeters, the prismatic effect would be 1, 2, 3, 5, 6, 7, 8, etc., centrads or prism-diopters respectively. If the sphere is plus or minus 0.25, 0.50 or 0.75 and is decentered 10 millimeters the prismatic effect is 1/4, 1/2, and 3/4 of a centrad or prism-diopter respectively. Another rule for decentering is to multiply the number of prisms in the prescription by 10 and divide the amount by the number of diopters **in the meridian** which is to be decentered and the quotient will be the number of millimeters for decentering. In the above example, +4 sphere ⊂ 4$^{\Delta}$ base downward axis 90°, the number of prisms is 4 and multiplying 4 by 10 equals 40, dividing this amount by 4 (the number of the diopters in the meridian of 90°) and the quotient is 10 millimeters, namely +4 sphere decentered 10 millimeters downward axis 90°.

Combining a prism with a cylinder (plus or minus) requires extra consideration, as it depends in which meridian the base-apex line of the prism is to be placed and which meridian is to be decentered. The reader must remember that a cylinder does not refract rays of light in the meridian corresponding to its axis. Fig. 77 shows a +4 cylinder axis 90°. Opposite to axis 90° (that is in the 180 meridian), the strength of the cylinder is +4, but on axis 90° there is no curve to the glass, and there is therefore no refraction in the 90° meridian. Outlining the spectacle lens on the surface of the cylinder as indicated by the figure 1 in Fig. 77, there would not be any prismatic effect produced if this lens was thus cut out of the cylinder, but if the lens outlined below was cut out, then the prismatic effect would be 4 centrads or prism-diopters because the geometric center would then be 10 milli-

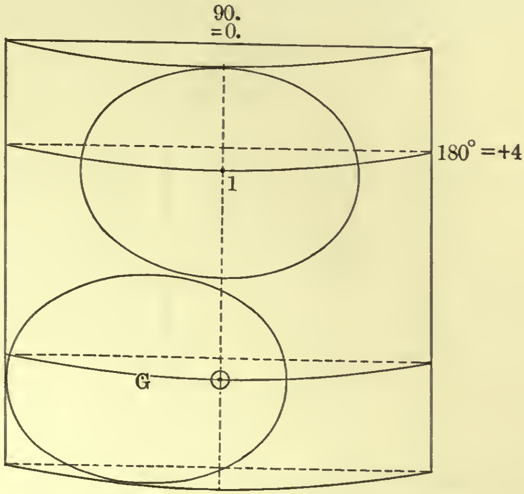

Fig. 77.

meters to one side of the axis. Namely, +4 cyl. axis 90 ⬭ 4^{Δ} base in axis 180° is equal to a +4 cyl. axis 90° decentered 10 millimeters in, on axis 180°.

From the above statements, the following may be deducted:

(1) A cylinder *per se* cannot be decentered on its axis.

(2) Decentering a cylinder one centimeter in the meridian at right angles to its axis will produce the effect of as many prism-diopters or centrads as there are diopters in the cylinder. Plus or minus 1, 2, 3, 4, 5, or 6 cylinder axis 90°, decentered 10 millimeters on the meridian of 180° will give the effect of 1, 2, 3, 4, 5, and 6 prism-diopters or centrads respectively. The

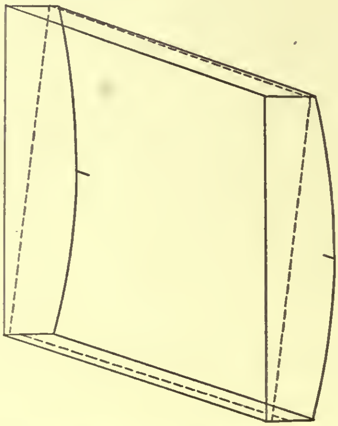

FIG. 78.—Cylinder in the rough marked with dotted lines ready to be ground to get the prism combination.

same rule applies to 0.25, 0.50 and 0.75 cylinder axis 90°. The equivalent of +4 cyl. axis 180 ○ 4$^{\Delta}$ base down is a 4$^{\Delta}$ base down axis 90° with a +4 cyl. axis 180 superimposed or as in Fig. 78 the optician will take a +4 cyl. axis 180° in the rough and grind the other surface plane (see dotted line same Fig) and at an angle which would produce the desired prismatic effect—in this instance 4.

Combining a Prism with a Plus or Minus Cylinder which has its Axis Obliquely placed to the Base-apex Line of the Prism

For instance, +4 cylinder axis 45 ⊂ 2$^{\Delta}$ base in, axis 180. This is equivalent to a 2$^{\Delta}$ base in and a +4 cylinder axis 45 superimposed or the optician takes the +4 cylinder in the rough and grinds the

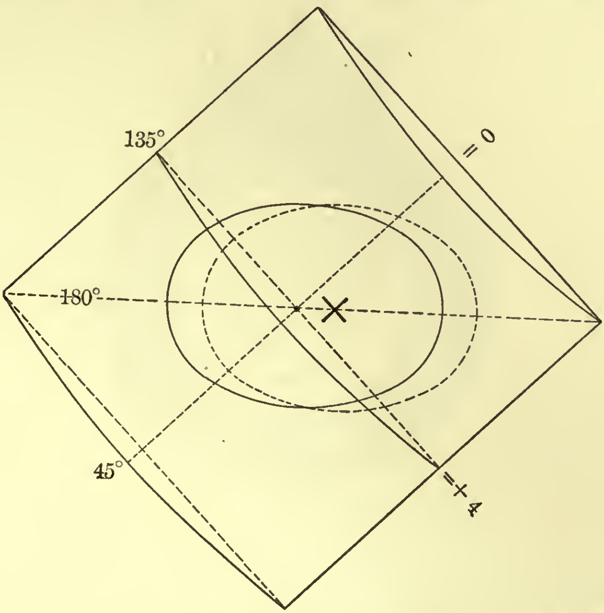

Fig. 79.—Cylinder in the rough marked with dotted line and an X ready to be cut thus producing a decentered cylinder.

opposite surface plane and at an angle to give the desired prismatic effect. In this formula for the purpose of decentering it is necessary to know the dioptric strength of the +4 cylinder in the 180 meridian when the axis of the cylinder is at 45°. Fig. 79 shows such a cylinder with its axis at 45°. The meridians of 90°, 180° and 135° are also shown. If the spectacle lens indicated by the continuous line was cut out of the cylinder there would not be any prismatic effect produced as the geometric center and cylinder axis coincide and it would simply be a + 4 cyl. axis 45°. But if the spectacle lens was cut out as indi-

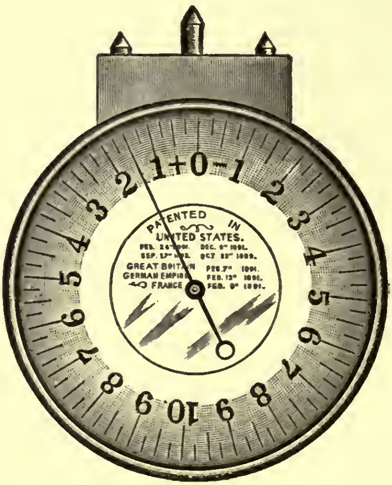

FIG. 80.—Geneva lens measure.

cated by the dotted line then there would be a $2^{\triangle}$ base in axis 180 in combination with the cylinder. This cylinder was decentered 10 millimeters. The method of finding out the strength of any cylinder in any meridian is to apply the Geneva Lens measure (Fig. 80) to the meridian to be decentered.

In other words, a +4 cyl. axis 45° has the strength of 2 diopters in the 180 meridian and decentering a 2 diopter lens 10 millimeters gives the effect of 2 prisms.

Combining a Prism with a Sphero-cylinder of Same Sign

In the following example +1.00 ⌔ +3.00 cyl. axis 90 ⌔ 1△ base out, axis 180°. This is equivalent to a +1.00 sphere on one surface of the 1 prism base out axis 180 and a +3.00 cyl. axis 90° on the other surface. Or if decentered all that is necessary to remember is that in the 180 meridian where the decentering is to be done, there are 4 diopters, 1 for the sphere and 3 for the cylinder, and to get the effect of a 1 prism in 4 diopters the sphero-cylinder must be decentered 2 1/2 millimeters; namely, + 1.00 sphere ⌔ +3.00 cyl. axis 90° decentered 2 1/2 millimeters outward, axis 180°.

If this sphero-cylinder had been decentered in the same meridian 5, 7 1/2 or 10 millimeters, the prismatic effect would have been 2, 3 and 4 prisms respectively. This applies of course to the 180 meridian, but if the decentering had been done in the vertical meridian then the calculations would be entirely different, for it will be observed that in the meridian of 90° there is only 1 diopter. If the sphero-cylinder to be decentered contains a plus sphere with a minus cylinder, the prescriber must remember that one neutralizes the other to a certain extent and he must calculate accordingly, for example, in −1, sphere ⌔ +3.00 cyl. Axis 90° ⌔ 2▽ base out, axis 180°, this sphero-cylinder would have to be decentered 10 millimeters as follows: -1 sphere ⊂ + 3. cyl. axis 90° decentered 10 millimeters outward axis 180°. Finally a decentered lens differs in no respect optically from a lens which contains a prism.

If for any reason, there is a desire to order prisms which will give rays of light a deviation of 1 degree, then it will be necessary to decenter the lens 17 1/2 millimeters (11/16 of one inch) for each degree.

A very important fact to remember in the ordering of lenses to be decentered is that many lenses are not of sufficient width or strength to permit of decentering, especially if the lens is weak and the prism is strong. For instance the following: +0.50 sph. ⊂ 4^{∇} base up. This should be made by taking a +0.50 sphere in the rough and cutting off the second surface at the angle which would produce the 4^{∇} base up (Fig. 74). If the prescriber wrote this formula for decentering as follows: +0.50 sph. decentered 80 millimeters (8 centimeters) upward axis 90 he would find that such a prescription would display great ignorance and invite suspicious criticism of the prescriber's knowledge. Weak lenses do not come large enough for any such purpose.

The following tables by Dr. Jackson and Dr. Wallace are self-explanatory:

JACKSON: DECENTERING OF LENSES FOR PRISMATIC EFFECTS, WITH GLASS HAVING AN INDEX OF REFRACTION OF ABOUT 1.54[1]

Power of lens in diopters	To obtain 1° prism	To obtain 2° prism	To obtain 3° prism	To obtain 4° prism	To obtain 5° prism	To obtain 6° prism	To obtain 8° prism	To obtain 10° prism
	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.	Decenter mm.
1 D.,	9.4	18.8	28.3	37.7	47.2	56.5	75.8	95.2
2	4.7	9.4	14.1	18.8	23.6	28.2	37.9	47.6
3	3.1	6.3	9.4	12.6	15.7	18.8	25.3	31.7
4	2.3	4.7	7.1	9.4	11.8	14.1	18.9	23.8
5	1.9	3.8	5.7	7.5	9.4	11.3	15.2	19.
6	1.6	3.1	4.7	6.3	7.9	9.4	12.6	15.9
7	1.3	2.7	4.	5.4	6.7	8.1	10.8	13.5
8	1.2	2.3	3.5	4.7	5.9	7.1	9.5	11.9
9	1.	2.1	3.1	4.2	5.2	6.3	8.4	10.5
10	.9	1.9	2.8	3.8	4.7	5.6	7.6	9.5
11	.9	1.7	2.6	3.5	4.3	5.1	6.9	8.7
12	.8	1.6	2.4	3.1	3.9	4.7	6.3	7.9
13	.7	1.4	2.2	2.9	3.6	4.3	5.8	7.3
14	.7	1.3	2.	2.7	3.4	4.	5.4	6.8
15	.6	1.3	1.9	2.5	3.1	3.8	5.1	6.3
16	.6	1.2	1.8	2.4	3.	3.5	4.7	6.
17	.6	1.1	1.7	2.2	2.1	3.4	4.5	5.6
18	.5	1.	1.6	2.1	2.6	3.1	4.2	5.3
19	.5	1.	1.5	2.	2.5	3.	4.	5.
20	.5	.9	1.4	1.9	2.4	2.8	3.8	4.8

[1] *Transactions* of the American Ophthalmological Society.

Equivalent Numbers of Prisms—Jackson[1]

The first column gives the number of each prism according to the new system, indicating its power of causing deviation in the rays of light passing through it expressed in *centrads*. The second column gives the same deviating power expressed in *prism diopters*. The third column gives the refracting angle of the prism (its number by the old system), which will cause this same deviation, when the prism has one surface perpendicular to the rays, and the glass has an index of refraction of 1.54.

Deviation in centrads	Deviation in prism diopters	Refracting angle in degrees	Deviation in centrads	Deviation in prism diopters	Refracting angle in degrees	Deviation in centrads	Deviation in prism diopters	Refracting angle in degrees
1	1.	1.06	9	9.02	9.39	17	17.16	16.98
2	2.	2.12	10	10.03	10.39	18	18.19	17.85
3	3.	3.18	11	11.03	11.37	19	19.23	18.68
4	4.	4.23	12	12.04	12.34	20	20.26	19.45
5	5.	5.28	13	13.06	13.29	25	25.53	23.42
6	6.01	6.32	14	14.08	14.23	30	30.93	26.81
7	7.01	7.35	15	15.11	15.16	40	42.38	32.18
8	8.02	8.38	16	16.14	16.08	50	54.62	36.03

[1] Dr. Edward Jackson, *Ophthalmic Review.*

Dr. James Wallace's[1]

Table Giving the Degree of the Prism and the Angle of Rotation to Produce the Effect of Two Prisms With Their Bases at Right Angles

Prisms required	Deg. of prism	Ang. of rotation	Prisms required	Deg. of prism	Ang. of rotation	Prisms required	Deg. of prism	Ang. of rotation	Prisms required	Deg. of prism	Ang. of rotation	Prisms required	Deg. of prism	Ang. of rotation
	°	° ′		°	° ′		°	° ′		°	° ′		°	° ′
1x1	1.4	45	1x2	2.2	26.34	1x3	3.2	18.26	1x4	4.1	14.02	1x5	5.1	11.19
2x1	2.2	63.26	2x2	2.8	45	2x3	3.6	33.42	2x4	4.5	26.34	2x5	5.4	21.48
3x1	3.2	71.34	3x2	3.6	56.18	3x3	4.2	45	3x4	5	36.02	3x5	5.8	30.58
4x1	4.1	75.58	4x2	4.5	63.26	4x3	5	53.08	4x4	5.7	45	4x5	6.4	38.40
5x1	5.1	78.41	5x2	5.4	68.12	5x3	5.8	59.02	5x4	6.4	51.20	5x5	7	45
6x1	6.1	80.32	6x2	6.3	71.33	6x3	6.7	63.26	6x4	7.2	56.18	6x5	7.8	50.11
7x1	7.1	81.52	7x2	7.3	74. 3	7x3	7.6	66.47	7x4	8	60.14	7x5	8.6	54.27
8x1	8	82.51	8x2	8.2	75.57	8x3	8.5	69.26	8x4	8.9	63.25	8x5	9.4	57.59
9x1	9	83.39	9x2	9.2	77.27	9x3	9.5	71.33	9x4	9.8	66.01	9x5	10.3	60.56
10x1	10	84.17	10x2	10.2	78.18	10x3	10.4	73.09	10x4	10.8	68.10	10x5	11.2	63.25
1x6	6.1	9.28	1x7	7.1	8.8	1x8	8	7.09	1x9	9	6.21	1x10	10	5.43
2x6	6.3	18.27	2x7	7.3	15.57	2x8	8.2	14.03	2x9	9.2	12.33	2x10	10.2	11.42
3x6	6.7	26.34	3x7	7.6	23.13	3x8	8.5	20.34	3x9	9.5	18.27	3x10	10.4	16.51
4x6	7.2	33.42	4x7	8	29.46	4x8	8.9	26.35	4x9	9.8	23.59	4x10	10.8	21.50
5x6	7.8	39.49	5x7	8.6	35.33	5x8	9.4	32. 1	5x9	10.3	29.04	5x10	11.2	26.35
6x6	8.4	45	6x7	9.2	40.37	6x8	10	36.53	6x9	10.8	33.42	6x10	11.7	30.59
7x6	9.2	49.23	7x7	9.9	45	7x8	10.6	41.11	7x9	11.4	37.44	7x10	12.3	35.01
8x6	10	53. 7	8x7	10.6	48.49	8x8	11.3	45	8x9	12.1	41.39	8x10	12.8	38.40
9x6	10.8	56.18	9x7	11.4	52. 6	9x8	12.1	40.21	9x9	12.8	45	9x10	13.5	42
10x6	11.7	59. 1	10x7	12.3	54.59	10x8	12.8	51.20	10x9	13.5	48	10x10	14.1	45

If the base of a prism is rotated 36° 53′ from the vertical meridan, it is 53° 7′ from the horizontal meridian. The prismatic effect in the vertical meridian, 36° 53′ from the base of the prism, is 3/10 of the prism. The prismatic effect in the horizontal meridian, 53° 7′ from the base of the prism, is 6/10 the value of the prism. The base of the prism is rotated a smaller arc for the larger effect and *vice versa*. The direction of the base is the direction of the perpendicular to the base.

[1] Oculist's Vade Mecum.

CHAPTER VII

USES OF PRISMS IN OPHTHALMOLOGY

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, and 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. Another way to detect "deceivers" is to place the trial-frame on the patient's face with a blank on the "blind" eye, nothing is placed in front of the seeing eye; the examiner then slowly passes a square prism of 10 or 12 centrads base down, axis 90° before the seeing eye as the patient observes the card of test letters across the room. As the prism base bisects the patient's pupil horizontally the eye immediately sees two test cards, etc.; then the examiner suddenly and gracefully removes the blank from the "blind" eye with his other hand and at the same time passes the prism over the entire pupil of the good eye. The patient, still admitting diplopia, proves his conspicuous inexactness for veracity. This latter test does not merit the writer's consideration as much as the former test, although it is well to bear in mind both of these

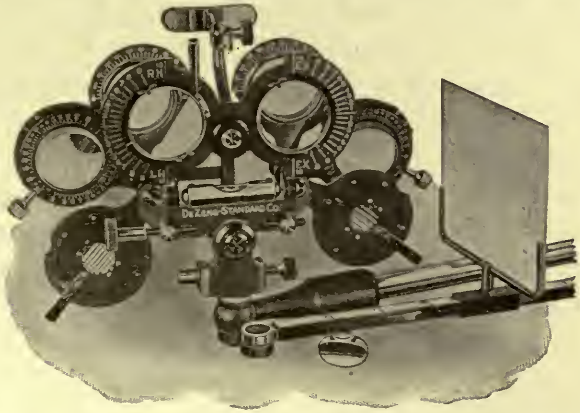

FIG. 81.—Phorometer. This apparatus contains two eye-pieces for trial lenses; two rotary prisms; a Stevens phorometer; two Maddox multiple rods (one for each eye, one at axis 90, and the other at axis 180); also a spirit level, etc.

prism tests in case the patient has been previously examined by either one of them.

To ascertain the power of Adduction (Prism convergence).

Abduction (Prism divergence) and Sursumduction.

In making these tests the patient should be comfortably seated facing a point of steady white light on a plane dark surface situated at a distance of 6 meters; this light should be on a level with the eyes or slightly below the level. A suitable trial-frame should rest easily on the patient's nose and ears, although a phorometer (Fig. 81) is recommended in place of the trial-frame.

Adduction.—To test adduction, prisms with their bases inward are placed before one or both eyes (preferably before one eye).[1] Begin with a weak prism and gradually increase the strength of the prism until the patient states that he sees two distinct lights. For example, if with 19 centrads, base out before the left eye, two lights are seen in the horizontal plane and with 18 centrads only one light, then 18 centrads represents the maximum prism convergence for these eyes.

Abduction.—This test is pursued as in testing for adduction, but the prism is placed base inward, beginning with a weak prism and gradually increasing the strength until the patient states that he sees two distinct lights. For example, if with 7 centrads, base in, before the left eye two lights are seen in the horizontal plane, and with 6 centrads only one light, then 6 centrads represents the maximum prism divergence.

Sursumduction.—This is the power of uniting or fusing the image of the light of one eye with the image of the same light seen by the other eye through a prism base up or down axis 90°. For example, if a 3 1/2 centrad prism is placed base up axis 90° before either eye[1] and diplopia results and persists, and then a 3 centrad is substituted and there is no diplopia, then the maximum amount of sursumduction is said to be 3 centrads.

[1] The writer is in the habit of placing the prism before the left eye in making these estimates.

The writer strongly recommends the use of the rotary prism, which will greatly facilitate making the above tests, and those referred to later.

The following nomenclature of *muscular anomalies* suggested by Dr. George T. Stevens of New York is in popular use:

Orthophoria is perfect binocular fixation, also spoken of as equipoise, binocular equilibrium or parallelism. With a thorough understanding of the three conditions just described and which most authorities consider as standard (adduction being three times as great as abduction, and sursumduction equalling 2 1/2 or 3 centrads), the reader may now appreciate any departure from these standard conditions.

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 axis to deviate inward.

Esotropia, a deviation of the visual axis inward.

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

Exotropia, a deviation of the visual axis 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 upward and outward.

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

As the title of this work does not call for any extended discussion on the subject of the extra-ocular muscles, the writer therefore limits himself to the consideration of prisms as applied to making tests for muscular anomalies or for their treatment. For a full consideration of the extra-ocular muscles the reader is referred to the author's work on "Refraction and How to Refract."

Tests for Heterophoria and Heterotropia.—There are many of these tests and each has more or less value. Like the many tests for astigmatism they should be understood and then the reader may decide for himself to use one or more of them as they appeal to his judgment.

Von Graefe Equilibrium Test.—Fig. 82, A. This test is a black dot one inch in diameter at the middle of a straight line 12 inches long passing through it, drawn on a white card and hung on the wall 6 meters from the patient's eyes, the dot being on a level with the eyes. This card should be hung in a bright light or illuminated by reflected light. As the patient gazes at this dot and line a 7 centrad prism is placed base down axis 90° before the left eye. This produces an image of the line and dot upward which belongs to the left eye (B in Fig. 82), the lower image belongs to the right eye. If the upper dot is directly above the lower dot and the black lines are superimposed, running through both dots then there is no lateral deviation (Fig. 82, B).

Esophoria.—If, however, the upper dot and line appear to the left (Fig. 82, C) then there is *esophoria* and the amount of the esophoria is represented by the strength of prism placed base outward before the

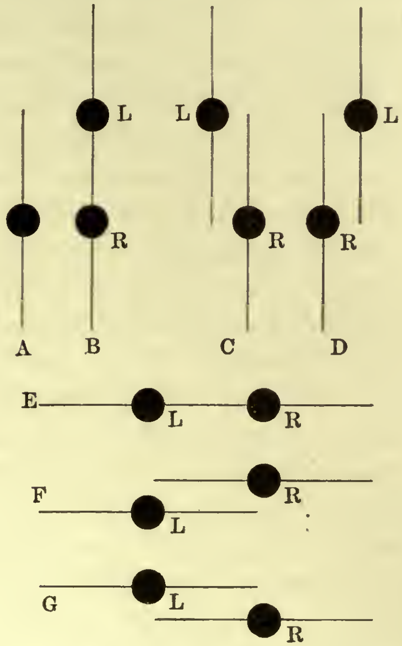

FIG. 82.—Von Graefe line and dot test. A = Line and dot. B = No lateral deviation. C = Esophoria. D = Exophoria. E = No verticle deviation. F = Left hyperphoria. G = Right hyperphoria. L = Image of left eye. R = Image of right eye.

right eye (or the left) which will put the upper dot directly above the lower one as Fig. 82, B.

Exophoria.—If the upper dot and line appear to the right (Fig. 82, D) then there is *exophoria* and the amount of the exophoria is represented by the strength of prism placed base inward before the right eye[1] (or the left) which will put the upper dot directly above the lower one.

Hyperphoria.—Place a 10 centrad prism base in axis 180° before the left eye, and have the line and dot placed horizontally. If the eyes see two dots on one line (Fig. 82, E) then there is no vertical deviation. If the right dot and line appear higher than the left line and dot then there is left hyperphoria (Fig. 82, F). If the right dot and line appear lower than the left line and dot then there is right hyperphoria (Fig. 82, G).

Prism Tests.—Place a 7 centrad prism in the trial-frame or phorometer base down axis 90° before the left eye as the two eyes look at the point of light as described under Adduction. This prism produces vertical diplopia. The upper light naturally belongs to the left eye under these conditions, and if it is directly above the other, then there is no lateral deviation.

Esophoria.—If the upper light is to the left of the lower, then the condition is one of esophoria and its amount is equal to the strength of the prism placed base outward before the right eye which will bring one light directly above the other.

Exophoria.—If the upper light is to the right of

[1] The reader's careful attention is called to the writer's method of making the foregoing test as it is similar to the tests which are to be described; namely, that the right eye is free or unencumbered to fix the object or white light; and the right eye is thus reserved for the use of the correcting prism. Furthermore, the amount of the esophoria is estimated by the prism base out; exophoria by the prism base in; left hyperphoria by the prism base up before the right eye and right hyperphoria by the prism base down before the right eye. Finally, in place of any lengthy description of esophoria, exophoria and hyperphoria as each test is described, the reader is referred to the respective illustrations.

the lower, then the condition is one of exophoria and its amount is equal to the strength of the prism placed base in before the right eye which will bring one light directly above the other.

Hyperphoria.—Place a 10 centrad prism base in axis 180° before the left eye, then the left light belongs to the left eye. If the two lights then appear in the horizontal meridian there is no vertical deviation. If the left light is lower than the right then there is left hyperphoria. If the left light is higher than the right then there is right hyperphoria.

The amount of the left hyperphoria is represented by the strength of the prism placed base up axis 90° before the right eye which will bring these two lights exactly horizontal. The amount of the right hyperphoria is represented by the strength of the prism placed base down axis 90 before the right eye, which will bring these two lights exactly horizontal.

Use of Ruby Red Glass also Cobalt Blue Glass.—To avoid confusion on the part of the examiner and patient in making these tests for esophoria, exophoria and hyperphoria, as is the case when both lights are white, it is decidedly better to use a plane piece of ruby red glass or cobalt blue glass with the prism over the left eye and in this way the lights seen by the two eyes are quickly differentiated.

In making the above tests, the writer uses a 7 centrad prism, made either of cobalt blue glass or ruby red glass.

Maddox Double Prism (Fig. 83).—(Obtuse-angled prism.) This is two prisms of 6 centrads each with their bases united. Placed before the left eye so that the bases bisect the pupil horizontally, the left eye will see two images, one higher and one lower than the true light seen by the right (fixing) eye.

Maddox double prism with a piece of ruby red glass or a Maddox Double Prism made of ruby red glass. This is far more attractive and avoids the confusion incident to having the lights all of one color seen by both eyes (Figs. 84 and 85).

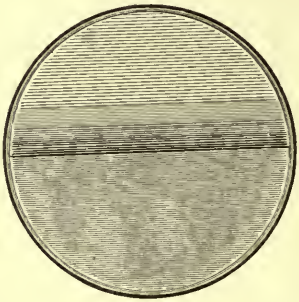

Fig. 83.—Maddox double prism.

Cobalt Blue Glass with the Maddox double prism or the Maddox Double Prism made of Cobalt Blue Glass (Figs. 86 and 87) gives the test as shown in Fig. 88.

The writer has been unable to demonstrate with his own eyes, as some authorities have done, that there is any definite streak of light connecting the two lights produced by the Maddox Double Prism of colored or colorless glass.

Cone or Quadrant or Quadrilateral Prism (Fig. 90).—This is equivalent to a pair of Maddox Double Prisms superimposed, one at axis 90 and the other at

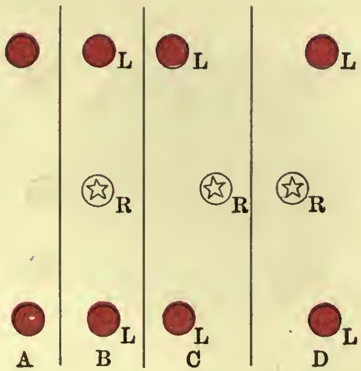

FIG. 84.—Maddox double prism of ruby red glass. A = Two images produced by double prism. B = No lateral deviation. C = Esophoria. D = Exophoria.

FIG. 85.—E = No verticle deviation. F = Left hyperphoria. G = Right hyperphoria. L = Image of left eye. R = Image of right eye.

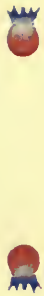

FIG. 86. FIG. 87. FIG. 88.

Maddox double prism made of cobalt blue glass. FIG. 86 is profile of Fig. 87. FIG. 88 is double image produced by Maddox double prism of cobalt blue glass.

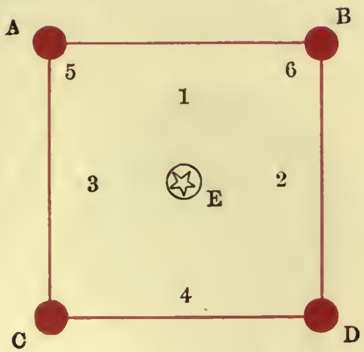

FIG. 89.—Quadrilateral prism or cone in red producing four red images connected by red streaks.[1] E = True light seen by right eye. When E is equidistant from ABCD there is no displacement, hence = Orthophoria. When E is in the direction of 1 = Left Hyperphoria; in the direction of 2 = Esophoria; in the direction of 3 = Exophoria; in the direction of 4 = Right Hyperphoria; in the direction of 5 = Left Hyperexophoria; in the direction of 6 = Left Hyperesophoria.

[1] See footnote page 84.

axis 180. Four images of the light are produced (Fig. 89), forming the corners to a square which are connected by a streak of light of the color of the glass. As this is made in colorless glass, it will be of great advantage to combine with it the plane ruby red glass or have the quadrant prism made of ruby red glass.

The Author's Double Prism, Truncated[1] (Figs. 91, 92 and 93).—The difficulty experienced by the

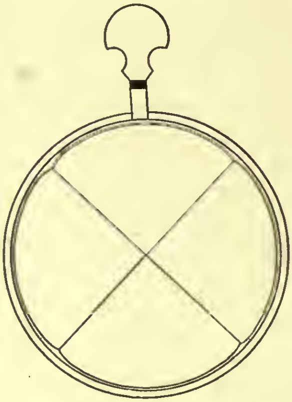

FIG. 90.—Cone or quadrant prism.

writer in the use of the obtuse-angled prism in testing for hyperphoria of small amount has been to have patients describe whether the central light seen by the right eye approached the upper or lower images as seen by the left eye. To overcome this difficulty of decision on the part of the patient, the author had the edge or top of the double prism cut off evenly leaving a flattened top 3 millimeters wide, see Fig. 91, making what he has

[1] Shown and described to the Section of Ophthalmology of the College of Physicians of Philadelphia, October 17, 1912.

FIG. 91.

FIG. 92.

FIG. 93.

Author's double prism of cobalt blue glass. Fig. 91 is profile of Fig. 92. Fig. 93 is triple images connected by a streak as seen through this double prism.

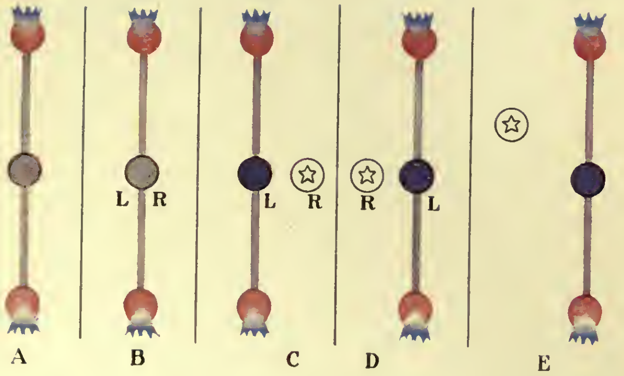

FIG. 94.—Triple images and streak produced by author's double prism in cobalt blue glass. B = No lateral deviation. C = Esophoria. D = Exophoria. E = Left Hyperexophoria.

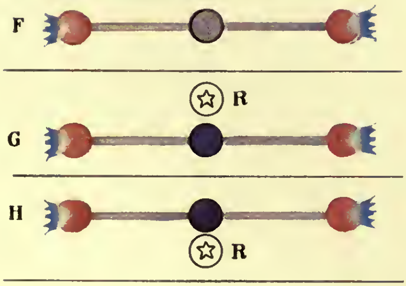

FIG. 95.—F = No verticle deviation. G = Left Hyperphoria. H = Right Hyperphoria. L = Image of left eye. R = Image of right eye.

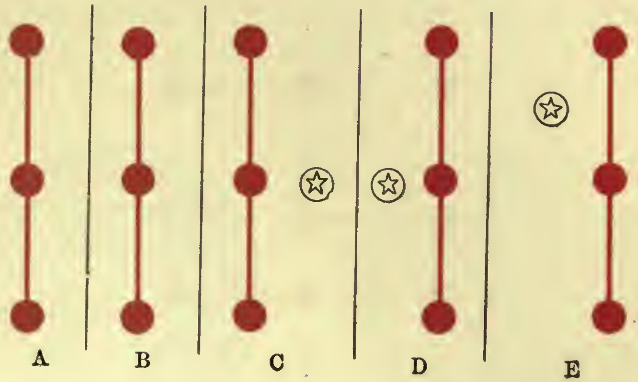

FIG. 96.—Author's double prism of ruby red. A = Three images connected by streak. B = No lateral deviation. C = Esophoria. D = Exophoria. E = Left Hyperexophoria.

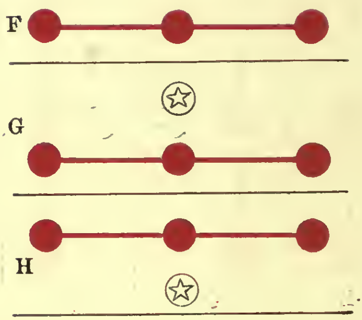

FIG. 97.—F = No verticle deviation. G = Left Hyperphoria. H = Right Hyperphoria.

chosen to call a truncated prism.[1] This is made either of ruby red glass, cobalt blue glass or colorless glass. With this form of double prism placed before the eye the observer immediately sees a central true light, and an image above and an image below, equidistant from it, if the truncated prism has been accurately ground. These three lights are seen to be connected by a band of light, Fig. 93, and the whole is distinctive from the single white light of the right eye. For the illustrative description of the tests see Figs. 94, and 95, also 96 and 97.

FIG. 98.—Maddox rod.

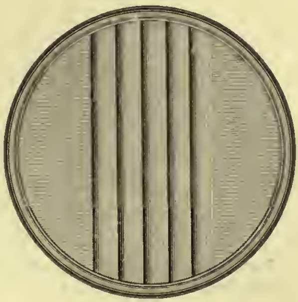

FIG. 99.

Maddox Rod.—This is a single glass rod or a series of glass rods of red or colorless glass (Figs. 98 and 99) placed in a metal cell of the trial case, and the eye looking through it at the light, will see the image of the light distorted into a streak of broken light. A strong + cylinder from the trial case may be used for 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

[1] "A cone or pyramid whose vertex is cut off parallel to the base by a plane."

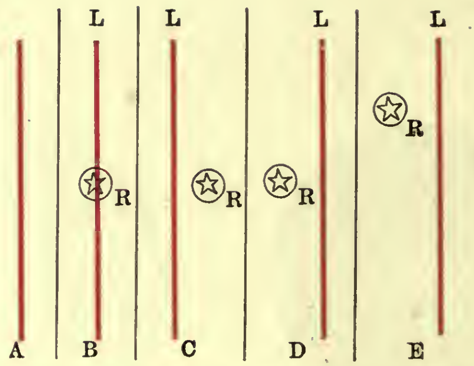

FIG. 100.—A = Image of Maddox single rod in red. B = No lateral deviation. C = Esophoria. D = Exophoria. E = Left Hyperexophoria. R = Image of right eye. L = Image of left eye.

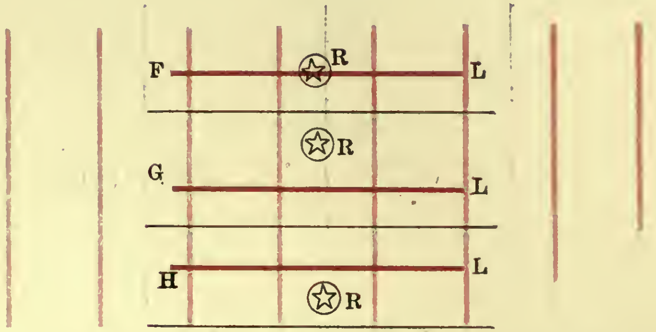

FIG. 101.—F = No verticle deviation. G = Left Hyperphoria. H = Righ Hyperphoria. L = Image of left eye. R = Image of right eye.

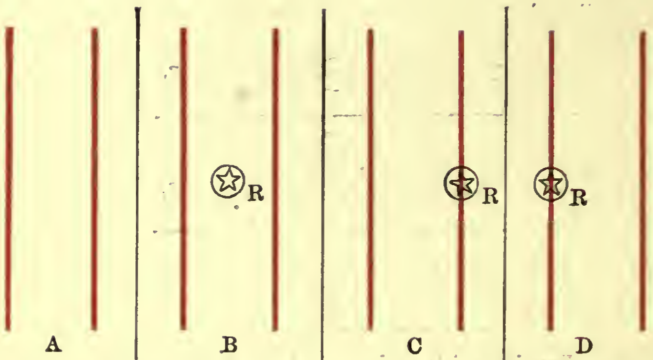

FIG. 102.—A = Double images produced by Maddox double prism in red with Maddox rod. B = No lateral deviation. C = Esophoria. D = Exophoria.

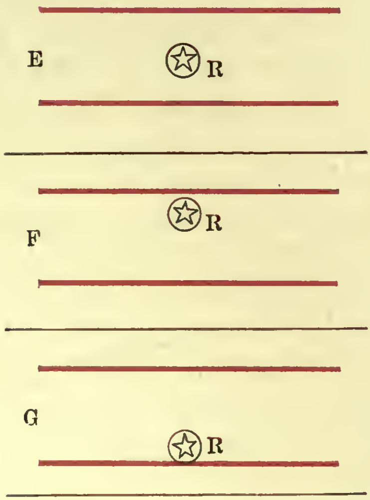

FIG. 103.—E = No verticle deviation. F = Left Hyperphoria G = Right Hyperphoria. R = Image of right eye.

meridian to that in which the axis is placed. See Figs. 98 and 99, also Figs. 100 and 101.

Maddox Double Prism and Rod Combined.—This produces two streaks of light (Fig. 102, A) white or red as the operator may choose. See illustrations in Figs. 101, 102 and 103. This combination like the double prism by itself is not as satisfactory a test for esophoria or exophoria as it is for hyperphoria. In the former condition the right eye will frequently fuse its image with one of the light streaks of the left eye, *i.e.*, with the right one in esophoria and the left one in exophoria (Fig. 102, C and D).

Convex Spherical.—Using a +15 diopter sphere before the left eye a very much blurred image is seen by this eye, and the position of the image of the right eye relative to this blurred image gives the diagnosis of the muscular inbalance. If the image of the right eye centers on the blurred image then the condition is one of orthophoria; if to the right or left or above or below the blurred image, then it will be esophoria, exophoria, right hyperphoria or left hyperphoria respectively. However, the writer is not partial to this test, as it is most difficult for the average patient to maintain exact fixation with his left eye.

Tangent Scale and Maddox Rod.—This tangent scale[1] of Prentice (Fig. 57) with a central light as a fixing object and a Maddox rod before the left eye furnishes an ideal test as the record of the amount of the deviation can be stated by the patient. Each line of displacement of the streak is equivalent

[1] Archives of Ophthalmology, Vol. XIX, No. 1, pages 64 and 68.

to one centrad or prism-diopter. For example, if the patient states that the streak is situated vertically on the zero line there is no lateral deviation, if the streak is situated horizontally on the zero line there is no vertical deviation; if the streak is to the left or right or above or below the zero line then esophoria, exophoria, and right or left hyperphoria are present and to the amount as indicated by the position of the streak whether on line numbered 1, 2, 3, etc. If the streak is between two lines then there is also a fraction of a centrad or prism-diopter of deviation.

Another way to use the tangent squares (Fig. 57) is to place a 7 centrad prism base down axis 90° before the left eye and in this way produce an upper image of the chart. If the upper image is displaced directly upward with the vertically numbered lines coinciding then there is no lateral deviation. If the upper image appears to the left the amount of the esophoria is quickly diagnosed and likewise the amount of exophoria if the upper image is to the right. A 10 centrad prism base in axis 180 before the left eye would diagnose the presence of left or right hyperphoria and also the amount of each.

Cyclophoria.—(Insufficiency of the oblique muscles.) This test is usually made at thirteen or eighteen inches from the patient's eyes. A narrow straight black line is placed horizontally on a white card, as the fixing object at the distance indicated. A Maddox Double Prism is placed before the left eye so that the bases bisect the pupil horizontally and this eye then sees two parallel horizontal lines if its oblique muscles are in a standard condition. The right eye sees but one line between the two lines seen by the left eye. The right eye is the one being tested and the position of the middle line furnishes the diagnosis. If the left eye is to be tested then the Maddox Double Prism must be placed before the right eye (Fig. 104).

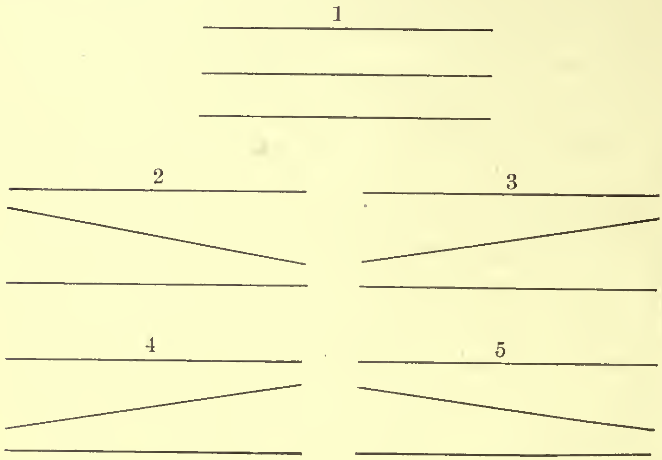

FIG. 104.—Tests for insufficiency of the oblique muscles. 1 = Orthophoria or equilibrium of the obliques. 2 = Insufficiency of left superior oblique. 3 = Insufficiency of right superior oblique. 4 = Insufficiency of the left inferior oblique. 5 = Insufficiency of the right inferior oblique.

Cyclophoria and its varieties may also be diagnosed by using two Maddox rods; one at axis 90° before one eye and the other at axis 180° before the other eye and a point of light as the fixing object at 6 meters. If orthophoria is present the two streaks produced by the two rods will naturally form a cross; but if cyclophoria is present, then one of the streaks will show a tilting or inclination from an otherwise true position of being horizontal or vertical; indicating at once therefore which eye is at fault or has the oblique insufficiency. Whenever the writer is suspicious of the existence of cyclophoria, he is partial to the use of a colorless rod before one eye and a red rod before the other eye, but each must be placed with its axis exactly horizontal. If the two streaks appear parallel or are superimposed, there is no oblique insufficiency, but if one streak dips, so to speak, then cyclophoria is present and corresponds to the eye having the corresponding rod; the inclination or dip furnishing a prompt diagnosis of the muscle at fault. In making either of these tests extreme care must be exercised to see that the phorometer or trial-frame and patient's eyes are true to the horizontal meridian. **Hyperesophoria and Hyperexophoria** may be diagnosed by any of these tests and are easily recognized as shown in the tests figured in 89 and 94.

While the foregoing tests are used for heterophoria or latent squint, yet they are also used for testing heterotropia or manifest squint. It is not necessary therefore to describe the tests for heterotropia except to say that when heterotropia is of very high degree and one eye has defective sight, it may be necessary to begin the test with a red glass and strong prism before the poor seeing eye so as to engage its attention.

Other tests for heterophoria and heterotropia are made with the use of apparatus and the following have been selected from several as most worthy of consideration.

Steven's Phorometer (see Fig. 81).—This is composed of two 5 centrad prisms each mounted in a separate large cell with cogged edges; one prism is mounted before each eye and these are connected by a small cogged wheel. A convenient handle on the right cell when pushed to either side makes both prisms revolve at the same rate of speed. The marking on the cell to which the prism pointer is directed indicates the degree and variety of heterophoria. The reader will appreciate the fact that this apparatus is ideal, but its usefulness is limited to errors of 10 centrads. If the operator wishes to use the Steven's phorometer to test errors higher than 10 centrads he must place an additional prism from the trial-case next to one of the patient's eyes. To avoid confusion it might be well to state that these two prisms of the Steven's phorometer never occupy the same position at the same time. They may both be base in or both base out, or one base up while the other is base down. They never reach a point where one is base in and the other base out, or both bases down or both bases up at the same time.

The apparatus is used as both eyes are looking at the point of light.

Dr. E. A. Prince's Phorometer (Fig. 105).—This instrument with its convenient handle is for the patient to hold before either eye as directed. A 4 centrad prism and a maddox rod are enclosed in a metal case. A milled head screw on one side permits the patient or operator to revolve the prism. The patient is told to fix with both eyes on a point of light at 6 meters. If the streak is vertical and to one side of the light, the prism is revolved until the streak and light appear to unite. The scale records the amount and character of the lateral deviation. To test hyperphoria, the apparatus must be taken off of the handle and replaced with the rod vertical so as to produce a horizontal streak and then revolve the prism until the streak and

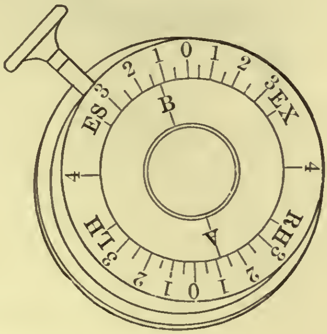

FIG. 105.

light appear to unite. Unfortunately this apparatus is limited in its usefulness to 4 centrads. The Prince phorometer is admirable, however, for testing the insufficiency of some private patients away from the office.

The Meister Phorometer (Fig. 106).—This apparatus, with its folding handle, spirit level and adjustable pair of 15 centrad prisms and adjustable Maddox multiple red rod is a veritable "Multum in Parvo". The writer takes great pleasure in giving it his cordial endorsement, for with its strong prisms it will do as much and more than the Stevens and Prince Phorometers combined.

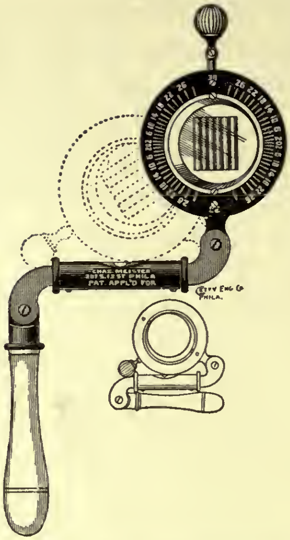

FIG. 106.—Meister's Phorometer.

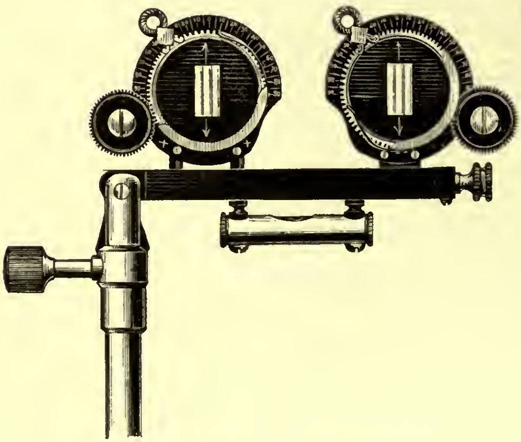

FIG. 107.—Savage's cyclophorometer.

Savage's Cyclophorometer (Fig. 107).—This instrument is used for detecting and measuring cyclophoria—a tendency of the vertical axes of the eyes to lose parallelism with the median plane of the head.

The instrument consists of the equivalent of a two-cell trial-frame with revolving cells mounted so the pupillary distance may be varied by a set screw at the end of the supporting bar. The arm carrying the cells is provided with a leveling attachment and a spirit level.

In examining for cyclophoria a multiple Maddox rod is placed in each of the revolving cells and a 5-degree prism, base up, behind one of them. The patient sees two horizontal lines of light, which should be parallel and the ends even. The latter can be regulated by varying the pupillary distance. If the lines are not parallel they may be made so by rotating either Maddox rod, the kind (plus and minus) and degree of the error being shown on the scale.

Cyclo-duction, the intrinsic power of each oblique muscle or of both superior or of both inferior obliques may also be measured.

Savage's Monocular Phorometer (Fig. 108).—This instrument is designed for the determination and measurement of insufficiencies of the various ocular muscles and is based on the principle that the image in one eye throughout every test shall be undisturbed.

It consists principally of a rotary variable prism correctly marked in degrees and lettered to show the various conditions of muscular imbalance, such as exophoria, esophoria, hyperphoria, etc. On each side of the rotary prism are cells, in one of which, toward the patient's face, is to be placed the displacing prism for causing diplopia. These prisms are carefully mounted in square cells for securing accurate position at either 90 degrees or 180 degrees. The instrument is supplied with a spirit-level and a leveling-screw.

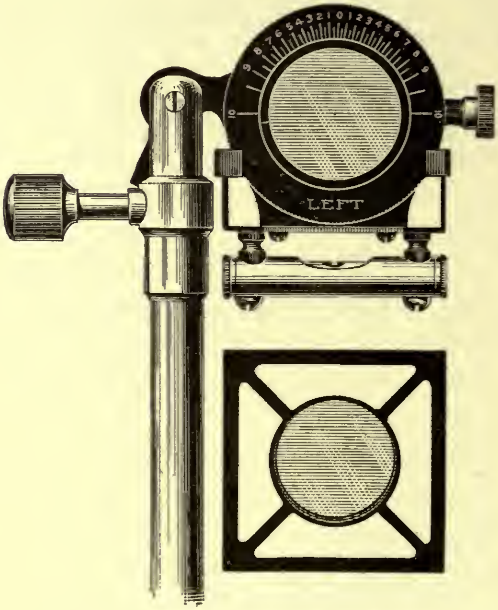

FIG. 108.—Savage's monocular phorometer.

The prism is reversible for either eye.

While most of the apparatus and descriptions just mentioned are for testing the muscular conditions at 6 meters, it is necessary to test muscular anomalies at a close range, *i.e.*, at 13 inches (33 centimeters) as this is the average reading and working distance with the eyes at close occupations.

Convergence.—Con, "together," and vergere, "to turn"; literally turning together. 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 in a state of repose. The angle which the visual line makes in turning from infinity (∞) or six meters to a near point is called the angle of convergence, and the angle which

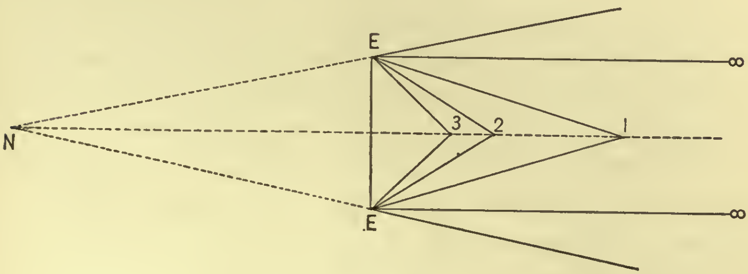

FIG. 109.

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 I in Fig. 109.)

If the visual line meets the median plane at 1/2 meter, it has then two meter angles of convergence; at 1/4 meter, four meter angles of convergence, etc., or five meter angles means that the eye is converging to a point 1/5 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 interpupillary distance. In children this distance is about 50 mm., whereas in adults it is, on the average, 60 or 64 mm.

If the average distance between pupils in the adult is 64 millimeters, then one meter angle equals a deviation for one eye of 32 millimeters. As the eyes converge closer than one meter, the meter angle increases correspondingly, the number of meter angles is, therefore, the inverse of the distance expressed in meters. As one meter angle equals a deviation of 32 millimeters, this equals or is equivalent to 3.2 centrads. One centrad deviates a ray of light .57295° and 3.2 centrads would therefore equal a deviation of 1° 50′. Knowing the prismatic effect or equivalent of converging to a point at 1 meter, then at 3 meter angles the effect would be three times as great or 9.6 centrads or 5° 30′.

The reverse of this is equivalent therefore to placing a 9.6 centrads base in axis 180° before each eye and the eyes would see an object at 33 centimeters as if it were located at infinity. In other words when a pair of standard eyes with standard muscles turn from looking at a distance of 6 meters to fix on an object at 33 centimeters, these eyes have developed a power of convergence equivalent to 19 or 20 centrads.

Any departure from this standard unit of convergence produces muscular inbalance of the varieties already described.

Tests for Muscular Inbalance at 33 Centimeters. —Have the patient look at a small black dot with a fine black line 2 or 3 inches long running perpendicularly through it, at a distance of about 13 inches. This is known as the line-and-dot test of von Graefe for near testing, and on a larger scale is described in the previous tests at 6 meters. A prism of seven or eight centrads is placed, with its base down, in front of the left eye. If the patient sees two dots exactly one above the other on one line there is not supposed to be any lateral insufficiency. If, however, there are two lines and two dots, and the upper dot and line is on the left then there is esophoria for near. The amount of the esophoria is represented by the strength of the prism, placed base outward before the right eye, which will bring the two dots exactly on one line. If the upper dot and line are to the right, then there is exophoria for near, and the amount of the exophoria is represented by the strength of the prism placed base inward over the right 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 to be placed exactly horizontal. At the middle of the horizontal line draw a heavy black line, 1/2 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 spaces, each 3 1/3 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" (Fig. 110).

To use this method, a prism of 8 centrads is placed base down before the left eye; this doubles the scale vertically; the upper scale belongs to the left 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 to the word "exophoria," then there will be approximately 9 centrads of "exophoria" at this distance of 13 inches, the distance at which this scale is intended to be used.

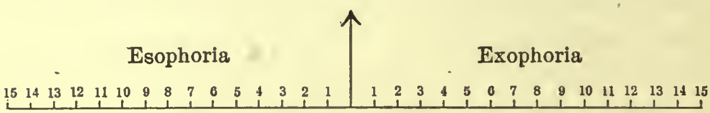

FIG. 110.—Scale for testing lateral insufficiency at 13 inches.

To Test for Hyperphoria at 33 Centimeters.—Place a 10 centrad prism base in before the left eye as the right eye fixes the line and dot of von Graefe as in the former test, except that the line is placed horizontally. If there are two dots on the horizontal line, then there is no vertical deviation, but if there are two dots and two lines one above the other then there is a vertical deviation. If a prism base down before the right eye brings the two lines together, then there is right hyperphoria; if the prism base up before the right eye brings the two lines together, then there is left hyperphoria.

The large black square and small white millimeter square in its center as suggested by Dr. Jackson makes an excellent test for muscular imbalance at 33 centimeters (Fig. 111). The small white square is made to appear double with a 10 centrad prism base down before the left eye.

The small Greek cross (Fig. 112) suggested by Dr. S. L. Ziegler answers the same purpose as the Jackson

FIG. 111.—Dr. E. Jackson's test for muscular insufficiencies at 33 centimeters.

FIG. 112.—Dr. S. L. Ziegler's Greek cross as a near test object.

squares. Other authorities are parital to a printed word like DIOPTER, for instance; this is made to appear double with a 10 centrad prism base down before the left eye. If the letters appear directly above each other, D over D, I over I, etc., then there is no lateral deviation, etc.

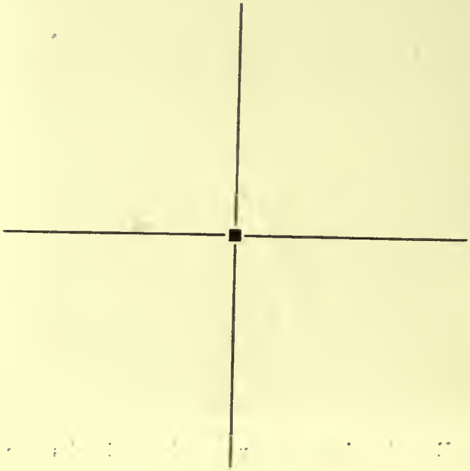

FIG. 113.—Place a 10 centrad prism base down before left eye, if upper cross appears to the left, the condition is esophoria; if to the right, the condition is exophoria. Next place a 10 or 12 centrad base in over left eye, if the left cross is below, then there is left hyperphoria, if above, then there is right hyperphoria.

The writer, however, is partial to the Maddox Scale shown in Fig. 110. The Narrow Lined Cross with central dot is also popular and is not without merit (Fig. 113).

CHAPTER VIII

PRISM TREATMENT FOR HETEROPHORIA AND HETEROTROPIA[1]

As ametropia is the most common cause of insufficiency (and of squint), 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 muscular imbalance should receive careful attention, and the condition of insufficiency be studied from every point of view.

The prescribing of prisms, as a fixed rule, for permanent use, which neutralize an insufficiency, except in vertical errors, or for old people (see Exophoria) is often a serious mistake, as in most instances prisms often do more harm than good by increasing instead of diminishing the insufficiency.

Remarks.—Patients with heterophoria cannot all be prescribed for alike with the expectation of equally good results in every instance and the writer from personal experience divides these cases into two classes:

Class 1 embraces those who are not presbyopic and can use one pair of glasses for all purposes of distant and near vision.

[1] As the treatment of the extra-ocular muscles other than by prisms has been fully explained in the Author's work, "Refraction and How to Refract," the reader is referred to that volume.

Class 2 embraces those who are presbyopic or those who require two corrections, one for distant vision and another for near work, or bifocals.

Exophoria.—(Fig. 114). 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 a latent insufficiency.

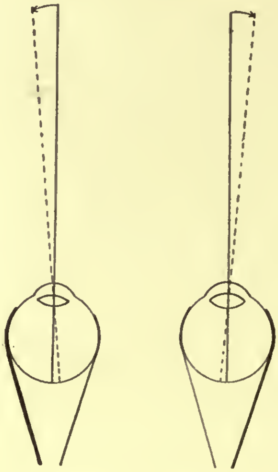

FIG. 114.—Tendency of visual axes outward.

The normal ratio of adduction to abduction (three to one) should be taken into consideration in every instance before coming to any definite 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 innervation and to do this a certain amount of systematic exercise known as ocular gymnastics must be employed. That success may result from ocular gymnastics means perseverance on the part of the patient and the exercises systematically executed. There are two methods of procedure to strengthen innervation in cases of exophoria:

Adduction Exercise.—1. Have the patient "fix" with both eyes the point of a pencil, or the end of his finger held at arm's length and slowly draw it to a point 5 or 3 inches from the bridge of his nose. If diplopia results while doing this, the exercise should cease, and be repeated at once from the original distance. This is a very convenient exercise and should be practised for five or ten minutes after meals; never before a meal, as some patients become nauseated if the stomach is empty. This mode of exercise to developed adduction, while equivalent to the use of prisms, is much better in every way than by prism exercises; in fact, the writer has long since abandoned exercises with prisms for cases of exophoria.

Prism Exercise.—2. 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 (2 or 3 centrads), bases out, in the trial-frame are placed in front of his eyes.

Then he is told to walk slowly backward across the room, 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 this first practice a pair of 5 or 10 centrads 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 by careful fixation), then raise the prisms (gazing at the light), and slowly count 20 or 30 again. This exercise is repeated three times a day after meals and a number of times at each practice. A prescription is then given for such a pair of square prisms with a convenient frame to wear over the patient's glasses, and with these the patient continues the exercises at home. 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 again ordered. This practice with stronger and stronger prisms is renewed weekly or bimonthly 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 innervation power of adduction to three or four times the strength of abduction; for when the exercises are stopped, some of the adduction power 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 for patients who must have prompt, though temporary, relief. When ordering prisms as a temporary expedient, it is best to prescribe them in the form of "hook fronts," so that they may be thrown aside at any time. What has just been stated in regard to treatment exercises applies particularly to patients in Class 1.

Treatment of Class 2.—Patients in this class, as just stated, are usually presbyopic and therefore require two corrections. Presbyopes with exophoria have reached a stage in life when it is difficult or almost impossible to put new life into old structures, and it does seem as if the extra-ocular muscles like the ciliary muscle were no exception to this statement; and this fact becomes more and more evident as the patient passes beyond fifty years of age. Developing adducting power by practising fixation at 33 centimeters may accomplish a great deal of good in some young presbyopes, but taking a presbyope of fifty or fifty-five or sixty years of age and trying to develop adduction with fixation or prism exercise is, in almost every instance and with few exceptions, a waste of time and patience. Presbyopes do not take kindly to such treatment and, in the writer's experience, patients so treated soon seek assistance elsewhere.

In hyperphoria the full prismatic correction (except in cases of presbyopia) is seldom ordered, only about two-thirds or three-fourths of the amount is prescribed and, if of high degree, this amount is usually divided between the two eyes, base down before one, and base up before the other.

Testing the muscular condition at 33 centimeters with the presbyopic near correction before the patient's eyes, there should be about ten[1] centrads of exophoria normally at this distance, but if there happens to be 12, 14 or 16 centrads of exophoria then the presbyope is uncomfortable and complains correspondingly when using the eyes at near work for any length of time. The prism treatment for exophoria at the working distance in presbyopes is to add or prescribe prisms bases in to be made in the near correction. The amount of the prism to be so ordered is usually divided between the two eyes. As 10 centrads of exophoria is considered normal for this distance of 33 centimeters as just mentioned, then the amount of prism prescribed will be practically the amount shown in excess of the normal 10 centrads. For example, a patient at fifty years of age selects for each eye plus one sphere periscopic and has a vision of $\frac{VI}{VI}$ in each eye with this correction and *does not reveal any insufficiency at six meters*, but with the near correction added (plus 2 sphere is added for near), then at 33 centimeters there is found to be 16 centrads of exophoria. After using these glasses for a few days at home the patient returns complaining that at close work the eyes pain, feel sore to the touch, and there develops occipital headache, smarting of the lids, and blurred vision. The exophoria in this instance at 33 centimeters is 6 centrads in excess of the normal amount. Ordering this amount (six centrads) divided between

[1] Some authorities say five.

the two eyes, the patient will receive one of the following prescriptions:

℞. O. D. +1.00. S. D. Periscopic.
O. S. +1.00. S. D. Periscopic.
SIG.—For distance.

Also,

℞. O. D. +3.00. S. D. ⊂ 3 centrads. Base in, axis 180°.
O. S. +3.00. S. D. ⊂ 3 centrads. Base in, axis 180°.
SIG.—For near only.

Or,

℞. O. D. +3.00. S. D. decentered in 10 mm.
O. S. +3.00. S. D. decentered in 10 mm.
SIG.—For near only.

Or,

℞. O. D. +1.00. S. D. Periscopic.
O. S. +1.00. S. D. Periscopic.
SIG.—For distance.

Cement on to lower part of the above for near.

℞ O. D. +2.00. S. D. ⊂ 3 centrads. Base in, axis 180°.
O. S. +2.00. S. D. ⊂ 3 centrads. Base in, axis 180°.
SIG.—Make bifocals.

If another patient had two or three centrads of exophoria *at 6 meters.* with the same correction (1.00 S. D. Periscopic in each eye) it would not be wise to give any distance correction, but allow him to use his relative hyperopia and at the same time to prescribe the fixation exercises if he becomes uncomfortable in the use of his eyes *at a distance.*

Esophoria (Fig. 115).—As esophoria is a tendency of the visual axes to deviate inward, it will be found that some patients with this form of insufficiency, when of two or three or four centrads, suffer very little, as a rule, 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, as well as in some cases of exophoria, but it is not so apt to cause discomfort if the full ametropic correction is worn constantly. In other words, if a hyperope with esophoria does not wear his distance correction and

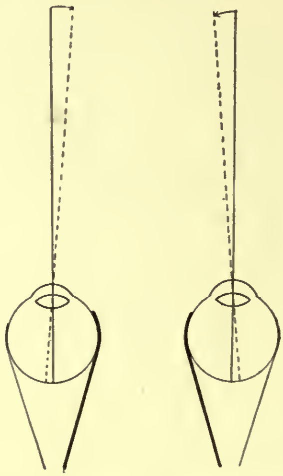

FIG. 115.—Tendency of visual axes inward.

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 full 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.* Prism exercises (prisms, base in) for esophoria do not always benefit, and are occasionally a waste of time; yet they should be tried thoroughly if the case appears to demand it.

When the patient has several centrads of esophoria for distance he must use his full distance correction and this usually corrects any former discomfort in the use of his eyes for distance; but he may continue to have discomfort at any near work, such discomfort as ocular pains, occipital headache, pains running into the neck and sometimes felt in the shoulders. Such patients do not have any comfort from their eyes when reading or writing or at any close work which requires the eyes **to move** instead of remaining fixed. For instance, a sewing woman will come with the story that she can sew with comfort with her glasses on, but that she cannot read with comfort and she cannot understand why. A stenographer who runs the typewriter during the day suffers from the symptoms just described, yet she can sit and sew in the evening and not get a headache. The trouble lies in weak abducting power. The question of treatment in such cases is not to weaken adduction but to strengthen abduction. The writer's method of treatment, which he believes to be original, is to practise abduction or turning outward of each eye while its fellow is covered. This is illustrated in Fig. 116. The patient is told to fix his head in one position and not to turn it while practising, as follows: to cover the eye with a card as shown in the illustration and in such manner that the covered eye cannot see what the other eye is doing; then, holding the index-finger point on a level with the eye, the finger is gradually made to describe a quarter circle or more to the same side as the eye being exercised; the eye fixes the point of the finger to the limit of external rotation. First one eye and then the other eye is exercised in this way for five or ten minutes after each meal. Marked improvement will follow this treatment in a few days, and the writer can testify to some remarkable results by this very simple method

FIG. 116.

of strengthening abduction. Occasionally this practice alone will not suffice and the patient will also have to use prism exercises (prisms, bases in).

Hyperphoria.—Having prescribed the ametropic correction, an attempt should be made to develop the innervation of 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 with the ametropic correction for constant use. See Presbyopia.

Hyperesophoria and Hyperexophoria.—The hyperphoria as previously stated and directed is to be corrected by the necessary prism which is to be combined with the ametropic correction and the remaining esophoria or exophoria to have any required treatment as described under these headings.

Heterotropia ("Cross-eye," strabismus, squint or manifest squint).—This is a condition of the eyes in which the amount of turning of the eye is so great that it cannot (always) be overcome by the effort of the patient; and, in fact, inspection often shows the manifest condition. Or heterotropia may be defined as the condition in which the visual axis of one eye is positively 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.

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, cannot 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, prisms should not be ordered. 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 in which the amblyopia is becoming established, or when there is a strong muscle deviating the eye. If the squint is due to

FIG. 117.

amblyopia exanopsia, then the vision may be improved in one of two ways. 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. 117), 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. 118.) 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°; 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

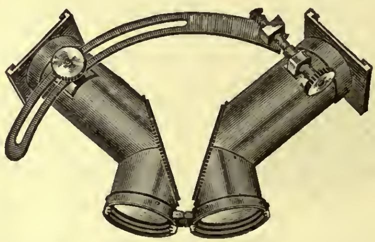

FIG. 118.—Worth's Amblyoscope. (Reduced size.)

60°, or a divergence of the visual axes of 30°. When the adjusting screw is used an additional movement of 10° is obtained.

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 (in patients under seven years of age) 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 should not be prescribed for the correction of heterotropia.

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, cannot, as a rule, be cured by any form of treatment, but may be benefitted by the prescribing of a prism to be referred to later.

It may be stated as a good rule to follow that *no case of squint 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.

Final Summary.—From the descriptions just detailed it will be observed that prisms are seldom prescribed and the careful refractionist will not order prisms with freedom or impunity. There are five conditions, however, which warrant the prescribing of prisms as follows:

Hyperphoria.—As previously stated, the patient with hyperphoria will usually accept and wear a prism which corrects about three-fourths of the amount of the hyperphoria, and this amount may be divided between the two eyes depending, of course, upon the strength of the prism and also upon the strength of the correcting lenses. If the amount is one or two centrads which is to be prescribed, this may all be placed before one eye if the lens for the other eye is a strong or compound one, for instance, if the prescription is as follows:

O. D. +2.00 ⊂ +1.00 cyl. axis 60°
O. S. +1.00

and the prism is a 2 base down before the right eye, it would be well to place the prism base up before the left eye making it +1.00 ⊂ 2▽ base up axis 90° and in this way equalize somewhat the weight and thickness of the lenses for the two eyes. In this instance it would have made a very expensive, cumbersome and heavy lens for the right eye, if the prism had been added to it, namely,

O. D. +2.00 ⊂ +1.00 cyl. axis 60 ⊂ 2△. Base down axis 90°.

In other words the prescriber must use some judgment in the matter as to which eye is to receive the prism or whether to put the entire prism before one eye or divide it between the two.

Ordering a Prism after a Tenotomy.—When a tenotomy has been performed for the relief of an insufficiency or manifest squint, and there still remains an annoying imbalance, a prism that assists the weak innervation may be prescribed for constant use made up in the lens which corrects the refractive error. For instance, if the tendon of the left internal rectus has been divided on account of a squint and after the tenotomy there remains possibly 3, 4 or 5 centrads of esophoria; the patient may have a 3, 4 or 5 centrad prism ordered with the ametropic correction, the base of the prism to be placed base out axis 180° over the left external rectus. It might be well to remember when prescribing prisms after a tenotomy that the base of the prism is to be placed over the weak muscle.

Ordering Prisms in Presbyopia.—This has already been explained in great part on page 119. However, the prescriber should be on his guard and never prescribe too strong a prism in the reading or near glasses, a prism in other words that would produce annoying metamorphopsia. The way to guard against this is to place the prisms (bases in) over the near correction and let the patient read the paper or look at a plane or flat surface, such as the top of a table or a desk and note whether the paper or table or desk appears conspicuously convex, *i.e.*, raised in the middle. If slightly so, then the appearance of convexity will gradually disappear after wearing the glasses, but if this condition is extreme, then the strength of the prisms must be reduced. Prisms, bases in, at close work may produce the convex effect just described and prisms, bases out, for esophoria may produce the opposite or concave effect.

Prisms for Cosmetic Purposes.—When an eye squints or is turned by reason of injury or disease (corneal opacities), or very poor vision or a palsy, and is not a suitable one for surgical intervention, the wearing of a prism over such an eye may give it a more sightly appearance, thus making it appear nearer the normal position than it actually is.

Prisms for Cyclophoria.—Cyclophoria is not a common condition. It is the least common of the heterophorias and yet it does exist and when present it should be prescribed for in full with a correcting prism, using either one of the three tests for cyclophoria already described in Chapter VII.

It is hoped that the reader will not confuse hyperesophoria and hyperexophoria with cyclophoria. The descriptions under these headings should guard him against any such error in diagnosis.

A prism at an oblique axis while it may temporarily neutralize an hyperesophoria or hyperexophoria does not necessarily signify that cyclophoria exists. Hyperesophoria and hyperexophoria are to receive the necessary prism for the hyperphoria only, *i.e.*, prism base up or down, axis 90. (See Hyperesophoria.) The writer does not advocate prisms at oblique axes except in cyclophoria and cyclotropia.

When the diagnosis is made then the amount of the cyclophoria is estimated by the strength of the prism which is necessary to make the lines parallel as shown in Fig. 104. The base of this prism may be up or down and at an "off axis," and before the eye which has the cyclophoria. The prism is to be combined with the prescription glasses for constant use.

Cyclotropia is to be prescribed for in the same way as cyclophoria. Cyclotropia is a very rare condition. The writer never saw but one such patient and he required the following:

O. D. $+2.75 \bigcirc +0.50$ cyl. axis 15°
O. S. $+2.75 \bigcirc 2^{\Delta}$. Base down axis 30°.

These glasses the patient is wearing with great comfort and satisfaction:

Summary:—Cases of hyperopia with 2 or 3 centrads of esophoria for distance and near vision are usually made comfortable for all purposes with a full correction of the refractive error. By 'full correction' is meant the cycloplegic correction less 0.25 sphere.

Cases of hyperopia with orthophoria for infinity and possibly 2 or 3 centrads of exophoria for near should receive 0.50 or 0.75 less than the full cycloplegic correction to be worn constantly.

Cases of hyperopia with exophoria of 3 or 4 centrads for distance should receive a partial correction of the hyperopia and be instructed in convergent exercises. When the exophoria disappears and orthophoria or esophoria is present the hyperopia should receive further correction. The writer's experience while it may differ from others, does not warrant him in advising a prism in these cases.

Cases of myopia with exophoria should receive the full static correction if the eyes are apparently free from fundus changes.

Cases of myopia with esophoria should receive an under correction, or be prescribed for as if they were presbyopes, *i.e.*, one correction for distance and another for near.

Hyperphoria associated with any of the above mentioned cases should receive the necessary prismatic correction, see page 129.

CHAPTER IX

GENERAL REMARKS ON PRISMS AND THE PRISMATIC EFFECT OF LENSES

That muscle over which the base of a prism is placed is put at rest to the extent of the power of the prism so used; or the prism may be said to act as a sedative to the muscle over which its base is situated. That muscle over which the edge of a prism is placed is put into action to the extent of the power of the prism so used, the prism may be said to act as a stimulant to the muscle over which its edge is situated.

Prisms with their bases in or bases out could be worn if the eyes would remain fixed, but on account of accommodation and convergence prisms for the relief of esophoria and exophoria in young patients cannot be tolerated. A prism with its base up or down for the correction of hyperphoria is tolerated and accepted because in these positions the accommodation and convergence do not alter the prism effect in the vertical meridian.

There are several reasons why prisms bases in or out stronger than a unit cannot be worn constantly and with comfort, but the chief reason is the resulting metamorphopsia or distortion which appears when the patient's eyes are turned laterally from the center of the lenses.

Illustrations which give some idea of distortion may be seen in Figs. 39, 40, 41 and 42.

Another reason why prisms which correct esophoria and exophoria cannot be worn constantly, is that by stimulation they soon increase the amount of the esophoria or exophoria and it is therefore very bad treatment to prescribe prisms in these cases, except in the instances mentioned in the text.

It seems hardly necessary to explain to the reader that (1) a convex sphere is equivalent to prisms with their bases at the center of the sphere; (2) that a concave sphere is equivalent to prisms with their edges at the center of the sphere; (3) that a convex cylinder is equivalent to prisms with their bases at the axis of the cylinder and (4) a concave cylinder is equivalent to prisms with their edges at the axis of the cylinder; *i.e.*, (a) on the axis of a cylinder there is no prismatic effect and (b) at the true center of a sphere there is no prismatic effect.

Strong convex spheres worn before both eyes, by an adult for the first time (as he looks through the true centers of these lenses), produce the effect of making a flat surface appear convex or raised in the middle and as the eyes look downward through the lenses (below the true centers) at the floor, it appears as if it were further away than it actually is or further away than it did without the lenses; giving the patient the sensation of having suddenly grown taller, *i.e.*, the sense of "distance" with these lenses, has been more or less disturbed. If the convex spheres are each + 3 and the patient glances through them 10 millimeters below the centers, he has the effect of seeing through a pair of 3 prisms bases upward. If he looks through these same lenses 10 millimeters above the centers an object appears shorter than it actually is, or if the patient tips his head far enough over and looks through the lenses above the centers at the floor, the floor seems closer than it is normally and the patient has the sensation of having grown shorter in stature.

Such complaints are not uncommon and are due entirely to the prismatic effect of the lenses.

Strong concave spheres worn before both eyes, by an adult for the first time, produce the opposite effect to that of convex spheres. The pavement or flat surface appears "dished" or hollowed out. If the spheres are −3 and the patient looks downward through them 10 millimeters from the centers, he has the equivalent of seeing through a pair of 3 prisms bases down; the floor or pavement appears raised or closer than without the lenses, the patient feels as if he had suddenly grown shorter and the sense of distance is correspondingly disturbed. If he looks through these lenses 10 millimeters above the centers, he has the sensation of feeling taller, for now the prismatic effect is equivalent to prisms bases up and distant objects appear elongated vertically (Figs. 39 and 40).

These optic illusions are also conspicuous with some patients as they turn their eyes from right to left or left to right. Some patients cannot explain exactly what the sensation may be except to say that they feel more comfortable without glasses and would rather endure poor vision than wear them. It is not always a case of "vanity."

Prismatic effect is more evident with certain varieties of spheres. Some patients cannot wear toric lenses (or menisci) for this very reason, they cannot get accustomed to toric lenses but still they can wear plano-convex lenses. The writer has seen patients who could not even wear periscopic lenses on account of the distortion, and wonder how others wear them and they cannot. Nearly all of these patients will admit that they can wear their spheres with pleasure and comfort, if they do not walk around with them on or turn their eyes from side to side and look through the edges of their lenses. In other words these patients have no trouble as long as they keep their visual axes on the line of the true centers of their lenses, but when they turn the visual axes from the true centers, then discomfort comes on and persists until the glasses are removed. Of course, and fortunately all patients are not alike in this respect, in fact, it is the very few who are thus disturbed. Finally some of the prismatic effect may be the result of poorly fitting lenses, and naturally this fact must have first consideration. However, it must be admitted, that there are different nervous sensibilities in different patients. Any observer along these lines has many opportunities of seeing individuals wearing strong lenses that are so out of adjustment that one would imagine the resulting metamorphopsia would be sufficient to produce migraine. but the truth is, very likely the individual is only seeing with one eye at a time or possibly has "nerves of steel."

A Strong Convex or Concave Sphere before One Eye and a Weak Lens of Any Variety before the Other Eye.—Adults whose eyes require such lenses also occasionally suffer from metamorphopsia before they get accustomed to their glasses, but the distortion complained of is more of the tilting variety, that is to say, in looking at a plane surface, one side seems to slope upward or downward. The pavement or floor seems raised or lowered to the right or left as the case may be. Yet again the wearers of such lenses usually have comfort as long as they do not turn their visual axes from the true centers of the lenses.

A Strong Convex or Concave Cylinder before One Eye and a Weak Lens of Any Variety before the Other Eye.—Such a pair of lenses may with some adults produce metamorphopsia similar to that experienced by patients who require a strong sphere before one eye, but if the cylinder axis is oblique, then these patients have a metamorphopsia similar to the picture shown in Figs. 41 or 42. These patients do not see picture frames as square-cornered but rather of the appearance of a rhombus.

Remarks.—Young patients (children) if required to wear correcting glasses such as first mentioned, seldom refer to any distortion but seem to adapt their vision to the glasses without difficulty.

Many patients who suffer from metamorphopsia also temporarily may have muscular imbalance, esophoria, exophoria or cyclophoria, etc., that they never knew or complained of before getting glasses, and possibly the metamorphopsia is due as much to the temporary cyclophoria as to the prismatic effect of the lenses; however, it is for the patient to persevere and wear the lenses and train his innervation, otherwise there must be a compromise in his lenses by reducing their strength and from time to time give stronger lenses up to the strength of the necessary lens to correct the ametropia. Prisms are not to be prescribed for such cases of cyclophoria or temporary hyperphoria.

With all these cases of anisometropia and heterometropia, the wise prescriber will have such patients test their vision by looking at picture frames, the door, the floor, etc., in his office before ordering the glasses and in this way make sure just how much distortion does exist and let the patient know what to expect.

Prismatic Effect in Bifocal Segments.—At the true center of a lens there is no prismatic effect, but from this center to the edge of the lens, the prismatic effect gradually increases and the stronger the lens, the greater this prismatic effect, no matter whether the lens is convex or concave. With this understanding the prescriber must bear in mind when he orders segments (scales or wafers), placed on the distant correction to make bifocals, that it is the duty of the optician to place enough prism in each segment to counteract sufficiently the prismatic effect at the edge of the lens used for distant vision so as to give the segment a mid-center of its own.

If the strength of both distance lenses is the same then the prism in each segment must be the same, but if the strength of the distance lenses is not the same, then the strength of the prism in each segment must be different.

The prescriber must be on his guard for this condition of things and the prismatic element at the edge in the distance glasses must be eliminated in part by each segment separately.

The reader can readily understand for himself that if the patient's distance glass was −9.00 sphere in the right eye, and −6.00 sphere in the left eye, and +3 segments are to be added, the optician must add more prism base up to the right segment than to the left segment, otherwise such a patient would be getting a false hyperphoria when using the segments.

It is not uncommon to hear patients complain that they have tried bifocals and could not wear them; possibly the segments were not centered.

Prismatic combinations in bifocals were described under class 2, *presbyopes*, page 119.

In conclusion and that the reader may not become confused as to the effect of prisms, the writer takes great pleasure in quoting his friend Dr. G. C. Savage who says that "when a prism base in or base out is placed before one eye, only one nerve center is excited and only one muscle is brought into a state of contraction." "When the base is placed up or down, it must excite two centers, one to elevate or depress the eye, the other to prevent torsion."

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