

## **The refraction of the eye : a manual for students / by Gustavus Hartridge.**

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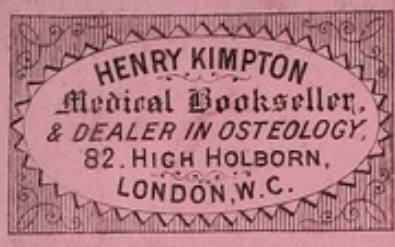
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**THE REFRACTION OF THE EYE**



THE  
REFRACTION OF THE EYE

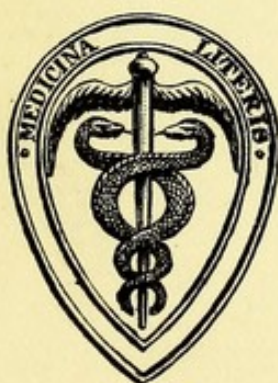
A MANUAL FOR STUDENTS

BY

GUSTAVUS HARTRIDGE, F.R.C.S.

ASSISTANT SURGEON TO THE ROYAL WESTMINSTER OPHTHALMIC HOSPITAL

WITH EIGHTY-SEVEN ILLUSTRATIONS



LONDON  
J. & A. CHURCHILL  
11, NEW BURLINGTON STREET  
1884



MY FIRST BOOK

CHAPTER I

THE FIRST

CHAPTER II



CHAPTER III

CHAPTER IV

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## P R E F A C E

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I HAVE endeavoured in the following pages to state briefly and clearly the main facts with which practitioners and students should be acquainted in order to enable them to diagnose errors of refraction accurately, and to prescribe suitable glasses for their correction.

Those who would do this with facility can only require the requisite amount of dexterity by practically working out a large number of cases of refraction. No book, nor even the knowledge gained by watching others who are thus employed, can take the place of this, the practical part of the subject.

To many of my readers the chapter on Optics may appear unnecessary. I have added it for the benefit of those whose school education did not include this subject, since its elementary details so completely underlie the whole subject of refraction, that every student should understand them thoroughly before passing on to the real subject in hand.

I have found it necessary in several instances to



repeat important matters, and this I have done to obviate the necessity of continual references to other parts of the book, as well as in some cases to impress the importance of the subject upon the student.

The woodcuts are numerous in proportion to the size of the work, but I consider that they are a very great help to the thorough understanding of the subject.

The old measurements have been purposely omitted in favour of the almost universally adopted metrical system. It is confusing to the learner to have to do with two distinct sets of measurements, and no possible good can accrue from perpetuating the old system of feet and inches.

At the end of the work I have given a list of those authors to whom I have been indebted for much valuable information; and, in conclusion, I take this opportunity of thanking my numerous friends for their help and suggestions.

G. H.

47, KENSINGTON PARK GARDENS, W.;

*Janauary*, 1884.



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Lithographic Plate between pages 108 and 109 :

1, 2, and 3. Drawn from myopic patients.

4. Copied from Atlas of Wecker and Jaeger.





### ERRATUM.

Page 194, Appendix, line 5, *should be* "lens of  $\frac{1}{2}$  a metre (= 50 cm.) is 2 D.,  $\frac{1}{10}$  of a metre (= 10 cm.) 10 D., etc."

THE FIFTH

...the ... of ...  
...the ... of ...



# THE REFRACTION OF THE EYE

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## CHAPTER I

### OPTICS

RAYs of light coming from any distant source, although actually slightly divergent, are assumed to be parallel.

The amount of divergence of rays is proportionate to the distance of the point from which they come.

A ray of light meeting with a body may be absorbed, reflected, or if it is able to pass through this body, it may be refracted.

**Reflection** takes place from any polished surface and according to two laws :

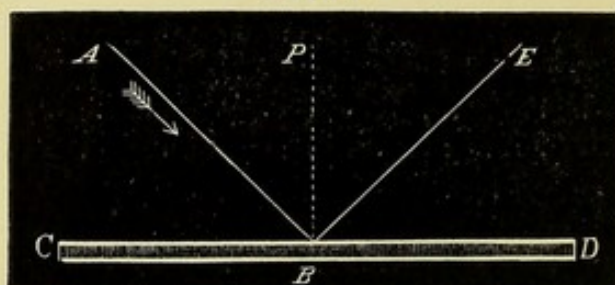
1st.—The angle of reflection is equal to the angle of incidence.

2nd.—The reflected and incident rays are both in the same plane, which is perpendicular to the reflecting surface.

Thus if  $AB$  be the ray incident at  $B$  on the mirror  $CD$ , and  $BE$  the ray reflected, the perpendicular  $PB$  will

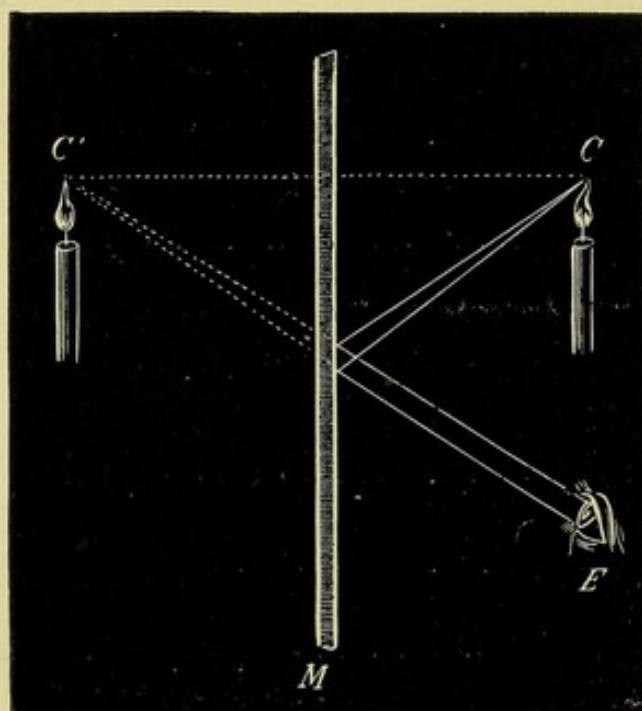
divide the angle  $ABE$  into two equal parts, the angle  $ABP$  is equal to the angle  $PBE$ ; and  $AB$ ,  $PB$  and  $EB$  lie in the same plane.

FIG. 1.



When reflection takes place from a plane surface the image is projected backwards to a distance behind the mirror, equal to the distance of the object in front of it, the image being of the same size as the object. This is called a *virtual image*.

FIG. 2.



M. The mirror. C. The candle. C'. The virtual image of the candle. E. The eye of the observer receiving rays from mirror.

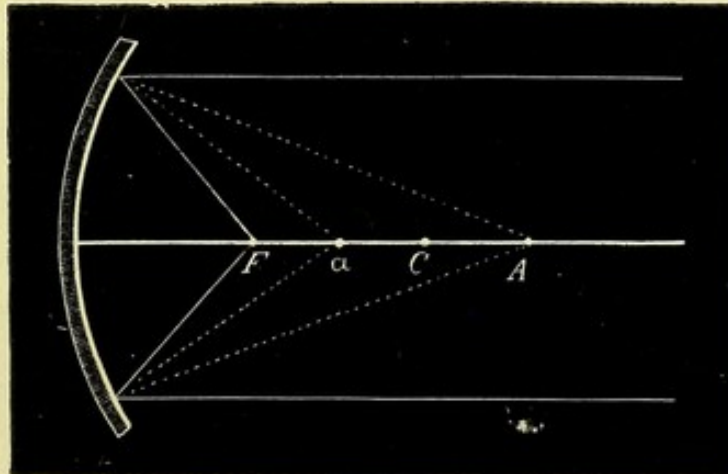


*Reflection from a Concave Surface*

A concave surface may be looked upon as made up of a number of planes inclined to each other.

Parallel rays falling on a concave mirror are reflected as convergent rays which meet on the axis at a point (F, Fig. 3), called the *principal focus*, about equally distant from the mirror and its centre c. The distance of the principal focus from the mirror is called the focal length.

FIG. 3.



If the luminous point be situated at F, then the diverging rays would be reflected as parallel to each other and to the axis.

If the point is at the centre of the concavity of the mirror (c), the rays return along the same lines so that the point is its own image.

If the point be at A the focus will be at *a*, and it will be obvious that if the point be moved to *a* its focus will be at A; these two points, therefore, A and *a*, bear a reciprocal relation to each other and are called *conjugate foci*.

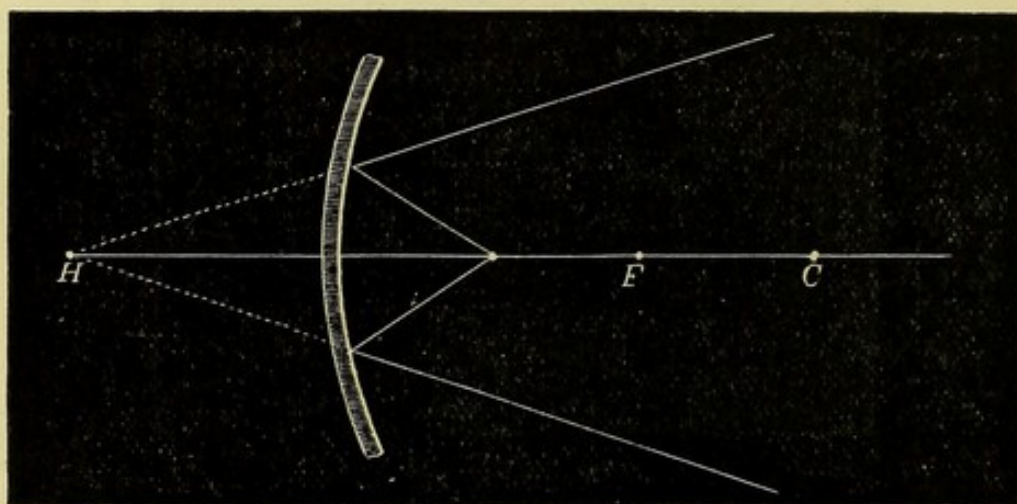


If the luminous point is beyond the centre, its conjugate focus is between the principal focus and the centre.

If between the principal focus and the centre, then the conjugate is beyond the centre ; so that the nearer the luminous point approaches the principal focus the greater is the distance at which the reflected rays meet.

If the point be nearer the mirror than  $F$ , the principal focus, the rays will be reflected as divergent and will therefore never meet ; if, however, we continue

FIG. 4.



these diverging rays backwards, they will unite at a point ( $H$ ) behind the mirror, which point is called the virtual focus, and an observer situated in the path of reflected rays will receive them as if they came from this point.

Thus it follows that—

Concave mirrors produce two kinds of images or none at all, according to the distance of the object, as may be seen by looking at oneself in a concave mirror ; at a certain distance one sees a small and inverted

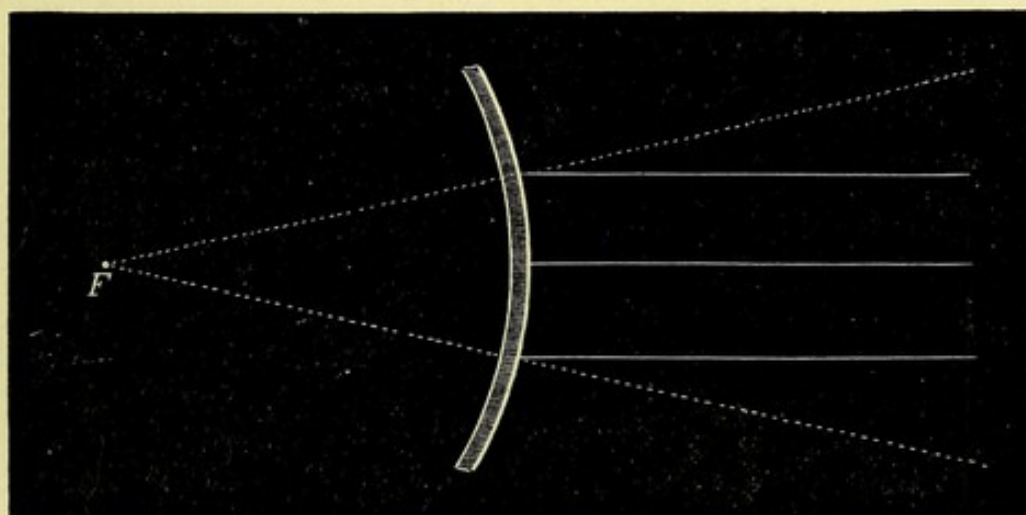


image, at a less distance the image is confused and disappears when at the focus ; still nearer the image is erect and larger, being then a virtual image.

### *Reflection from a Convex Surface*

Parallel rays falling on such a surface become diverging, hence never meet, but if the diverging rays thus formed are carried backwards by lines, then an imaginary image is formed which is called *negative*, and at a point called the *principal focus* (F).

FIG. 5.



Foci of convex mirrors are only virtual, and the image, whatever the position of the object, is always virtual, erect, and smaller than the object.

The radius of the mirror is double the principal focus.

The principal and conjugate foci are always on the same side of the mirror as the luminous point, while the virtual focus is always on the other side of the mirror.

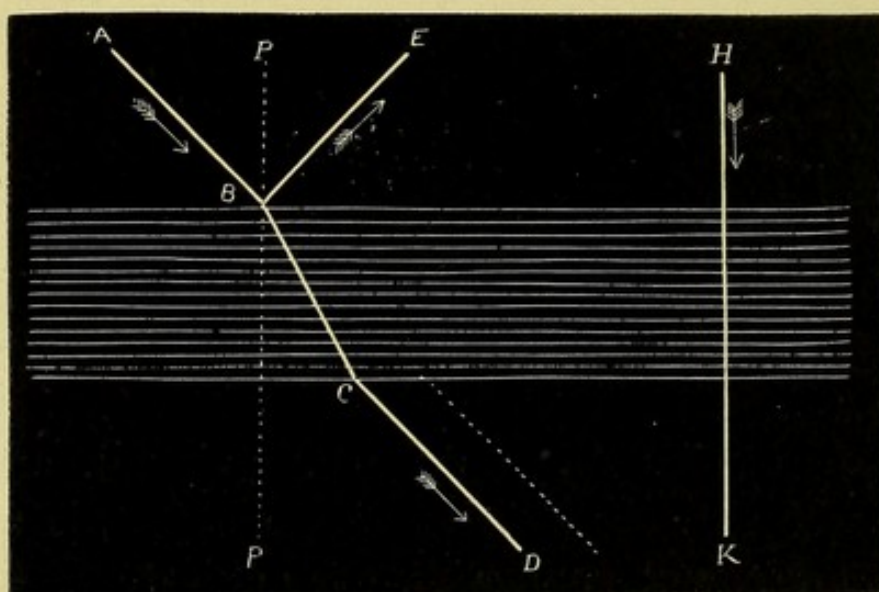


**Refraction.**—A ray of light passing through a transparent medium into another of a different density is refracted, unless the ray fall perpendicular to the surface separating the two media, when it continues its course without undergoing any refraction (Fig. 6, H K).

A ray passing from a rarer to a denser medium is refracted towards the perpendicular; as shown in Fig. 6, the ray A B is refracted at B towards the perpendicular P P.

In passing from the denser to the rarer medium the ray is refracted from the perpendicular, B D is refracted at C from P P (Fig. 6).

FIG. 6.



Reflection accompanies refraction, the ray dividing itself at the point of incidence into a refracted portion B C and a reflected portion B E.

The amount of refraction is the same for any medium at the same obliquity, and is called the index of



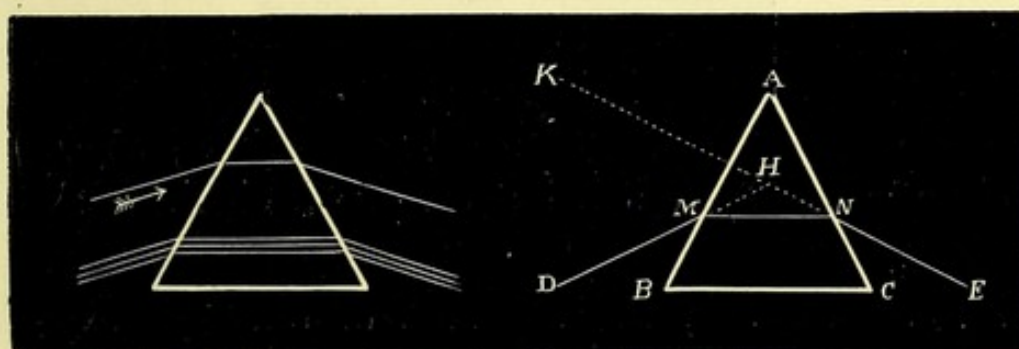
refraction ; thus from air to water it is  $\frac{4}{3}$ , from air to glass  $\frac{3}{2}$ .

If the sides of the medium are parallel, then all rays except those perpendicular to the surface which pass through without altering their course, are refracted twice, as at B and C, and continue in the same direction after leaving as before entering.

If the two sides of the refracting medium are not parallel, as in a prism, the rays cannot be perpendicular to more than one surface at a time.

FIG. 7.

FIG. 8.



Therefore every ray falling on a prism must undergo refraction, and the deviation is always towards the base of the prism.

The relative direction of the rays is unaltered (Fig. 7).

If DM (Fig. 8) be a ray falling on the prism (ABC) at M, it is bent towards the base of the prism, assuming the direction MN, on emergence it is again bent at N, an observer placed at E would receive the ray as if it came from K ; the angle KHN formed by the two lines at H is called the *angle of deviation* and is about half

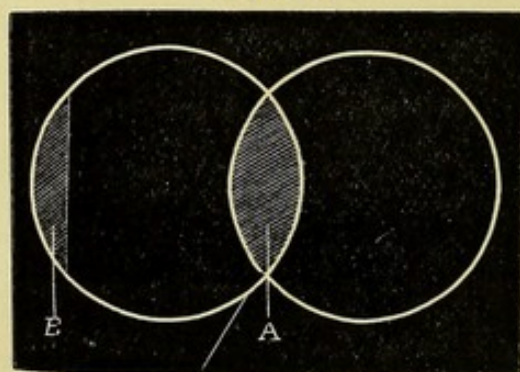


the size of the *principal angle* formed at A by the two sides of the prism.

Refraction by lenses is somewhat more complicated.

A lens is an optical contrivance consisting of a refracting medium with two opposite surfaces, one or both of which may be segments of a sphere, they

FIG. 9.



are then called spherical lenses, of which there are six varieties.

1. Plano-convex, the segment of one sphere (Fig. 9, B).
2. Biconvex, segments of two spheres (Fig. 9, A).
3. Converging concavo-convex.
4. Plano-concave.
5. Biconcave.
6. Diverging concavo-convex.

A lens may be looked upon as made up of a number of prisms with different refracting angles.

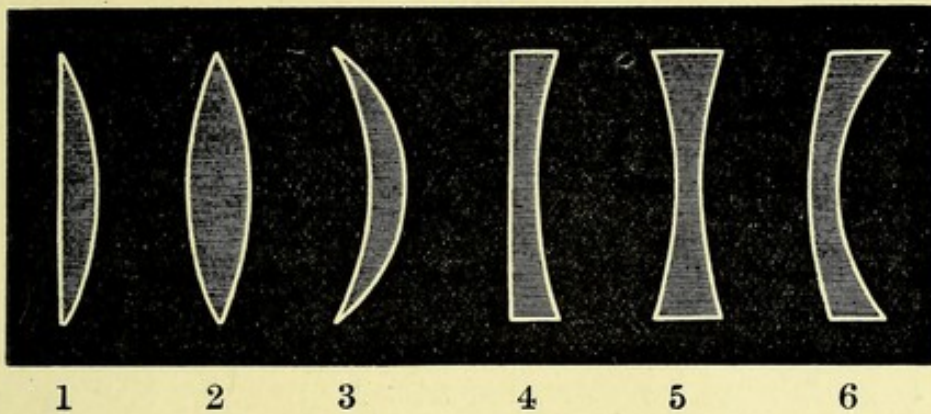
A ray passing through a lens is deviated towards the thickest part, therefore the three first lenses, which are thickest at the centre, are called *converging*, and the others, which are thickest at the borders, *diverging*.

A line passing through the centre of the lens, called



the *optical centre*, is at right angles to the surfaces of the lens ; it is termed the *principal axis*, and any ray passing through that centre is not refracted.

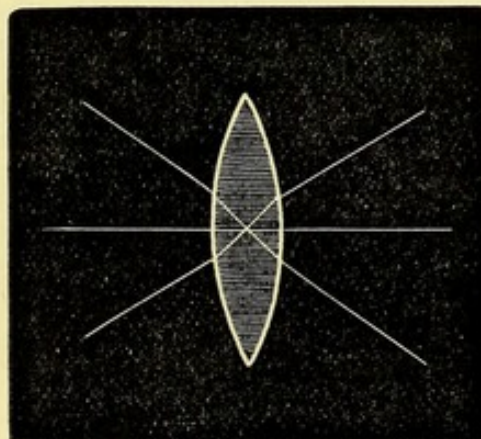
FIG. 10.



All other rays undergo more or less refraction.

Rays passing through the optical centre of a lens emerge in the same direction as they entered ; the deviation in thin lenses is so small that they are usually assumed to pass through in a straight line, and are called *secondary axes* (Fig. 11).

FIG. 11.

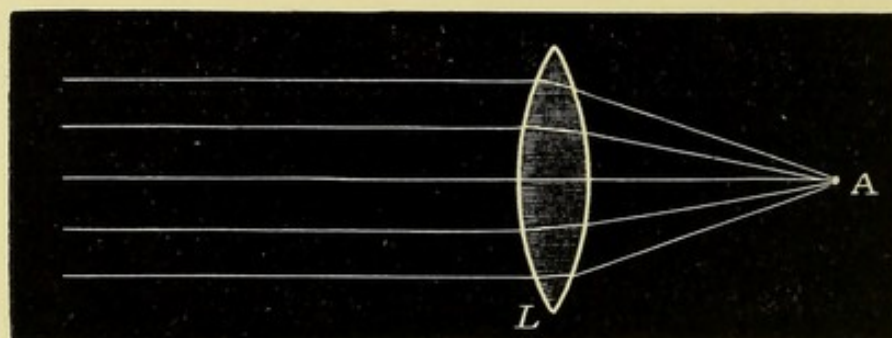


Parallel rays passing through a convex lens (L) are brought to a focus at a certain fixed point beyond the lens (A) ; this point is called the *principal focus*, and the



distance of this focus from the lens is called the focal length of the lens.

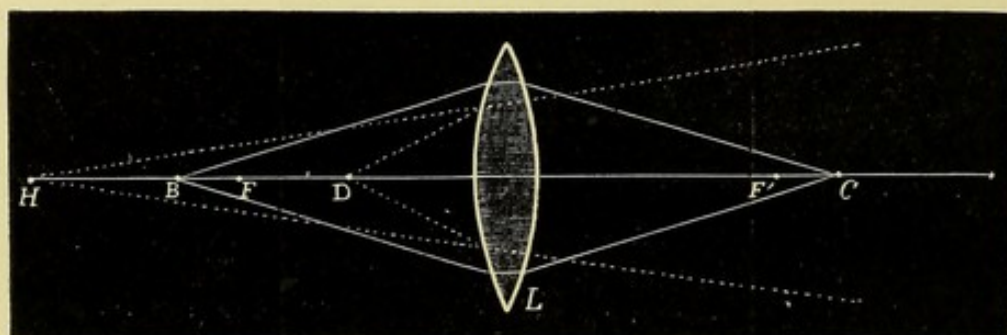
FIG. 12.



Rays from a luminous point placed at the principal focus (A) emerge as parallel after passing through the lens.

Divergent rays from a point (B) outside the principal focus (F, Fig. 13) meet at a distance beyond (F') the principal focus on the other side of the lens (L), and if the distance of the luminous point (B) is equal to twice the focal length of the lens, the rays will focus at a point (C) the same distance on the opposite side of the

FIG. 13.



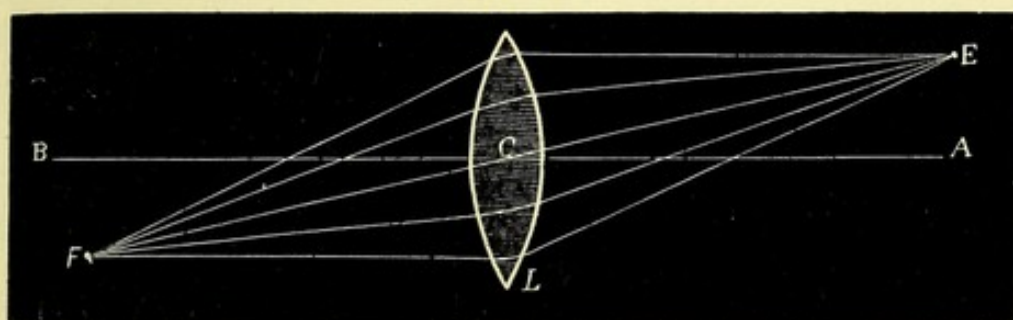
lens (L), rays coming from C would also focus at B, they are therefore called conjugate foci, for we can indifferently replace the image (C) by the object (B) and the object (B) by the image (C).



If the luminous point ( $D$ ) be between the lens and the principal focus ( $F$ ), then the rays will issue from the lens divergent, though less so than before entering; and if we prolong them backwards they will meet at a point ( $H$ ) further from the lens than the point  $D$ ,  $H$  will therefore be the virtual focus of  $D$ .

Biconvex lenses have therefore two principal foci,  $F$  and  $F'$ , one on either side, at an equal distance from the centre.

FIG. 14.



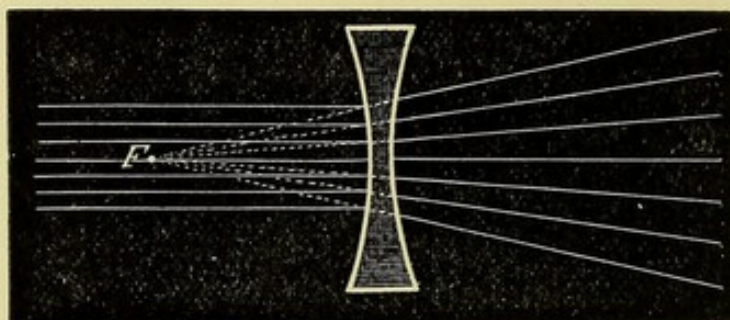
In ordinary lenses, and those in which the radii of the two surfaces are nearly equal, the principal focus closely coincides with the centre of curvature.

We have assumed the luminous point to be situated on the principal axis, supposing, however, it be to one side of it as at  $E$  (Fig. 14), then the line ( $EF$ ) passing through the optical centre ( $C$ ) of the lens ( $L$ ) is a secondary axis, and the focus of the point ( $E$ ) will be found somewhere on this line, say at  $F$ , so that what has been said respecting the focus of a luminous point on the principal axis ( $AB$ ), is equally true for points on a secondary axis, provided always that the inclination of this secondary axis is not too great, when the focus would become imperfect from much spherical aberration.



In biconcave lenses there are only virtual foci whatever the distance of the object.

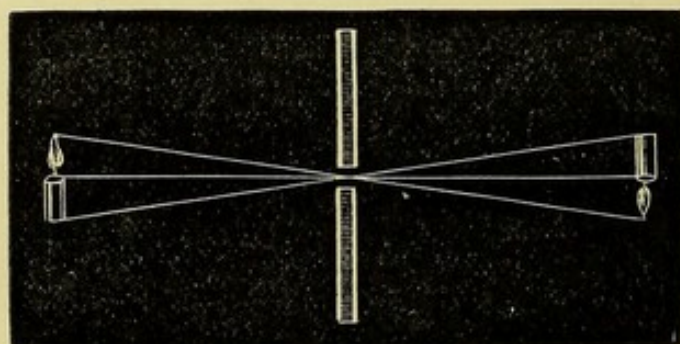
FIG. 15.



Rays of light parallel to the axis diverge after refraction, and if their direction be continued backward, they meet at a point termed the principal focus (F).

**Formation of images.**—To illustrate the formation of images the following simple experiment may be carried out: place on one side of a screen, having a small perforation, a candle, and on the other side a sheet of

FIG. 16.



white cardboard at some distance from the orifice, to receive the image formed; rays diverge from the candle in all directions, most of those falling on the

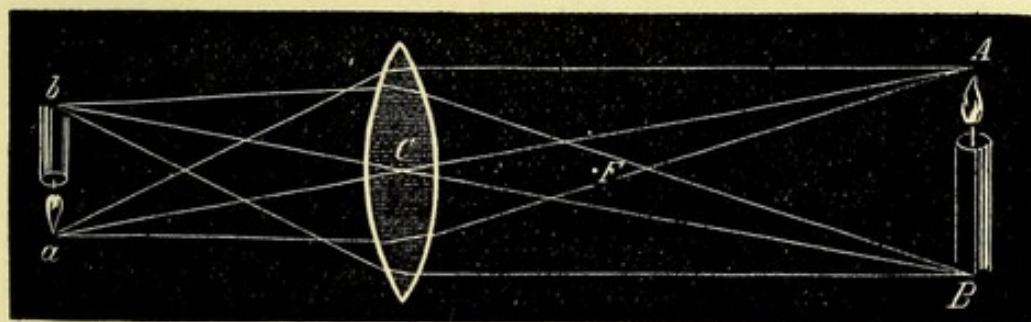


screen are intercepted by it, but some few rays pass through the perforation and form an image of the candle on the cardboard, the image being inverted because the rays cross each other at the orifice; it can further be shown that when the candle and cardboard are equally distant from the perforated screen, the candle flame and its image will be of the same size, if the cardboard be moved further from the perforation the image is enlarged, if it be moved nearer it is diminished; if we make a dozen more perforations in the screen, a dozen more images will be formed on the cardboard, if a hundred then a hundred, but if the apertures come close together then the images overlap, and instead of so many distinct images we get a general illumination of the cardboard.

The image of an object is the collection of the foci of its several points, the images formed by lenses are, as in the case of the foci, real or virtual. Images formed therefore by convex lenses may be real or virtual.

In Figure 17 let  $A B$  be a candle situated at an

FIG. 17.



Real inverted image smaller than object formed by convex lens.

infinite distance, from the extremities of  $A B$ , draw two lines passing through the optical centre ( $c$ ) of a

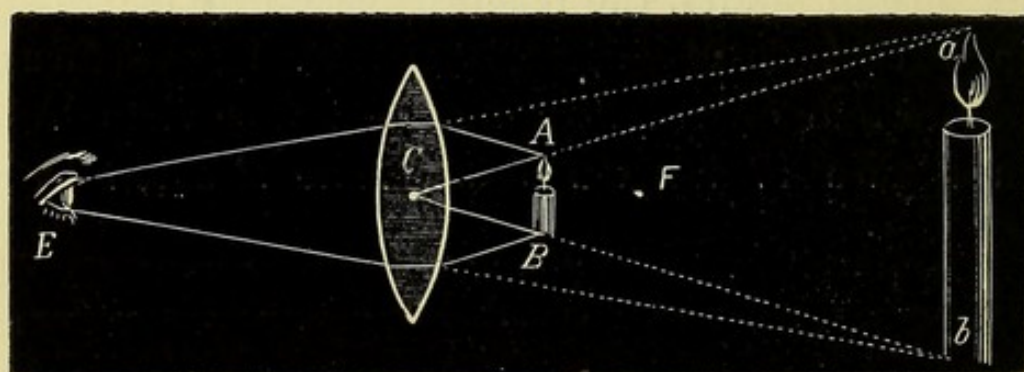


biconvex lens, the image of A will be formed somewhere on this line (termed a secondary axis), say at  $a$ , rays from B at  $b$ , so  $b a$  is a small inverted image of the candle A B, formed at the principal focus of the convex lens. Had the candle been placed at twice the focal distance of the lens, then its image would be formed at the same point on the opposite side of the lens, of the same size as the object, and inverted.

If the candle be at the principal focus (F) then the image is at an infinite distance, the rays after refraction being parallel.

If, however, the candle (A B) be nearer the lens than the focus, then the rays which diverge from the candle will, after passing through the convex lens, be still divergent so that no image is formed; an eye

FIG. 18.



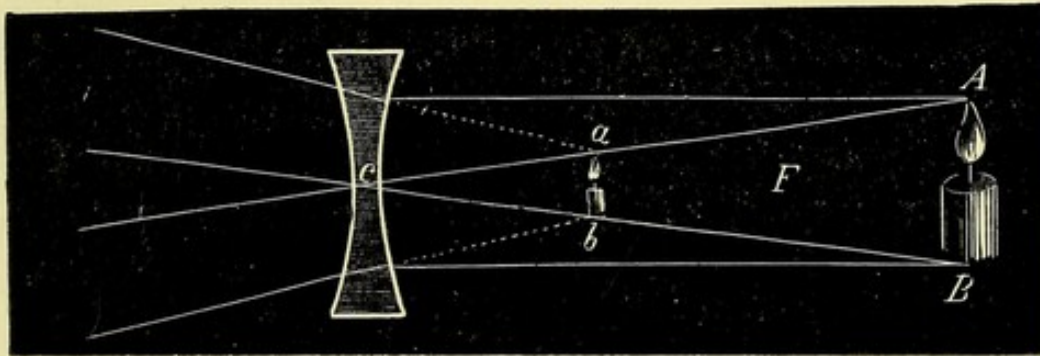
Virtual image formed by convex lens.

placed at E would receive the rays from A B as if they came from  $a b$ ,  $a b$  is therefore a virtual image of A B, erect and larger than the object, and formed on the same side of the lens as the object.

Images formed by bi-concave lenses are always virtual, erect, and smaller than the object; let A B be

a candle, and  $F$  the principal focus of a biconcave lens, draw from  $A B$  two lines through  $c$  the optical centre of lens, and lines also from  $A$  and  $B$  parallel to

FIG. 19.



Virtual image formed by concave lens.

the axis, after passing through the lens they diverge and have the appearance of coming from  $a b$ , which is therefore the virtual image of  $A B$ .



## CHAPTER II

## REFRACTION, ACCOMMODATION, CONVERGENCE

THE eye may be looked upon as an optical instrument, a sort of photographic camera, designed to produce by means of its refracting system an exact picture of surrounding objects upon the retina, the stimulation here produced is conducted by the optic nerve to the brain. Immediately behind the transparent retina is a layer of pigment, which absorbs the rays of light as soon as the image is formed; were this not so the rays would be reflected to other parts of the retina, and cause much dazzling, interfering considerably with vision, as is the case with albinos. The refracting system of the eye is so beautifully arranged that but little, if any, spherical or chromatic aberration takes place, as is the case with ordinary optical instruments.

For distinct and accurate vision the following conditions are necessary :

First, that a well-defined inverted image be formed on the layer of rods and cones at the yellow spot.

Secondly, that the impression there received be conveyed to the brain.



In a work of this character the first of these conditions alone concerns us, and for the carrying out of this—the media being transparent—three important factors call for a separate description, viz.

Refraction.

Accommodation.

Convergence.

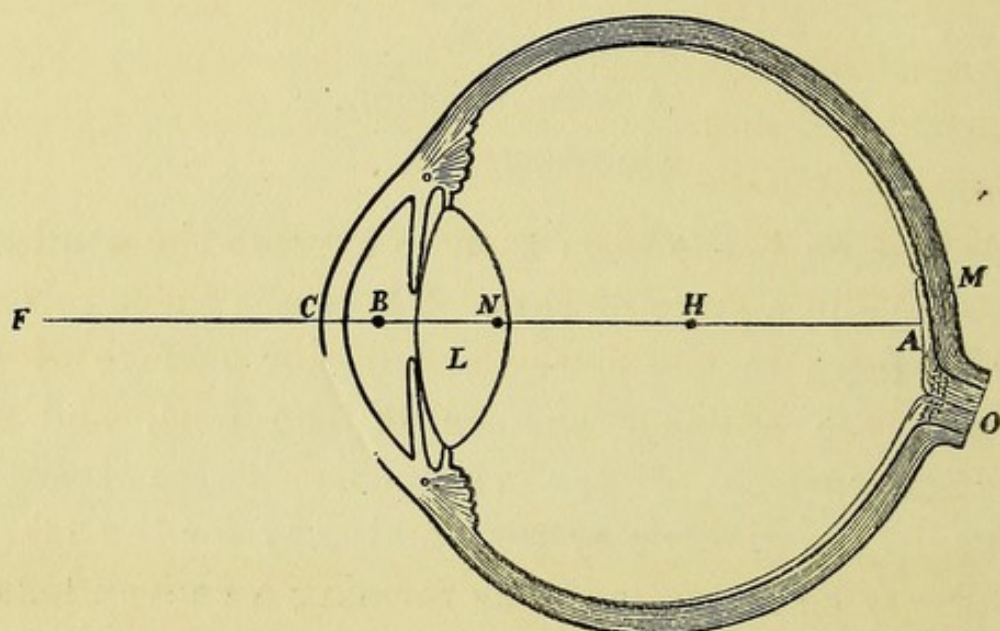
**Refraction** is the term used to express the condition of the eye in a state of rest. There are three refracting surfaces in the eye—the anterior surface of the cornea, the anterior surface of the lens, and the anterior surface of the vitreous. These together make up the dioptric system, and may for the sake of simplicity be looked upon as forming a convex lens of about 23 mm. focus. What was said about convex lenses applies equally to the eye as an optical instrument.

A ray of light falling on the cornea does not, however, follow the simple direction we might imagine when considering the eye merely as a lens of 23 mm. focus, but it must be looked upon as a compound system, composed of a spherical surface and a biconvex lens. To enable us to understand the course of a ray through the eye, it is necessary to be acquainted with the cardinal points of this compound system; too much space would be occupied to explain how the position of these points is arrived at, but it suffices to say that having first found the cardinal points of the cornea and then those of the lens, the cardinal points of the eye will be the result of these two systems



together. In the following diagram of the emmetropic eye the cardinal points of this compound

FIG. 20.



system are shown, all situated on the optic axis (F A); at B are two principal focal points, situated so close together in the anterior chamber that they may conveniently be looked upon as one point. At N are two nodal points, also close together; for simplicity we shall consider them as one point, we then have the following: C, the cornea; L, the lens; M, the macula; O, the optic nerve; F A, the optic axis; B, the principal focal point, 2 mm. behind the cornea; N, the nodal point just in front of the posterior surface of the lens, 7 mm. behind the cornea; H, the centre of rotation of the eye, 9.2 mm. in front of the retina. Rays parallel before falling on the cornea come to a focus on the retina 22.8 mm. behind the cornea. Rays

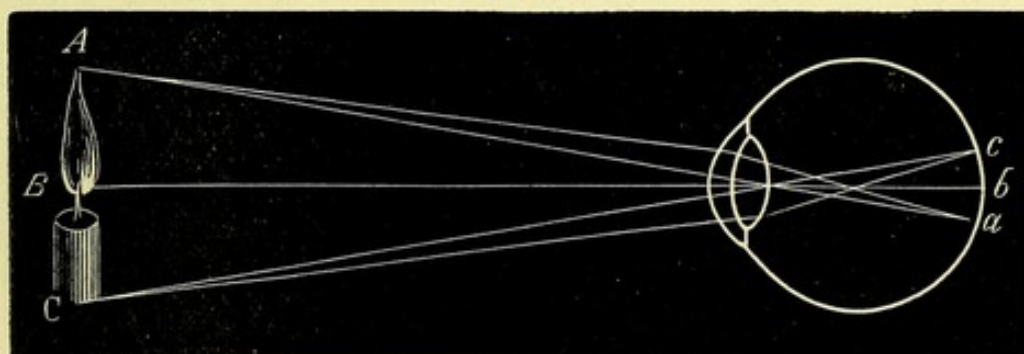


parallel in the vitreous, focus at the anterior focal point  $F$  situated 13.7 mm. in front of the cornea.

Fig. 17 shows that an image formed by a biconvex lens is an inverted one; so also is that formed by the refracting surfaces of the eye, as can easily be proved by the following figure, and it is essential that the method of formation of these inverted images be thoroughly understood.

From every point of an object  $A B C$ , proceed divergent rays. Those coming from  $A$  pass through the pupil, and being refracted by the dioptric system, come to a focus on the retina at  $a$ . Those coming

FIG. 21.



from  $B$  focus at  $b$ , and those from  $c$  at  $c$ . In the same way rays come from every point of the object as divergent rays, and are brought to a focus on the retina; the retina being exactly at the focal distance of the refracting system, a well-defined inverted image is formed.

Much has been said and written as to why images which are formed in an inverted position on the retina should be seen upright, and all sort of ingenious explanations have from time to time been



given. It is entirely a matter of education and experience, which is supplemented and corroborated by the sense of touch. We have no direct cognisance of the image on the retina, nor of the position of its different parts, but only of the stimulation of the retina produced by the image, which stimulation is conducted by the optic nerve to the brain, producing there certain molecular changes. We do not actually see the retinal image, but the object from which the rays emanate, and we refer the sensation in their direction; thus if an image is formed on the upper part of our retina, we refer the sensation downwards from which the rays must have come.

The refraction of the eye is said to be normal when parallel rays are united exactly on the layer of rods and cones of the retina; in other words, when the retina is situated exactly at the principal focal distance of the refracting system of the eye. This condition is called *emmetropia* (Εμμετρος, regular measure, ὥψ, the eye). If parallel rays are focussed behind, or in front of the retina, the term *ametropia* (α, priv., μέτρον, measure, ὥψ, the eye) is used, and of this there are two opposite varieties.

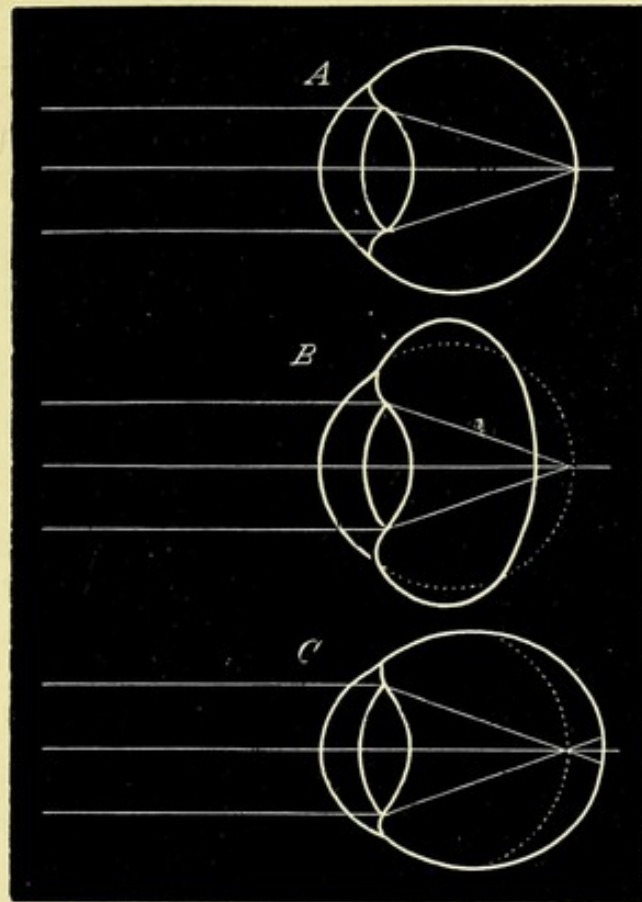
*Hypermetropia*, when the eyeball is so short, that parallel rays are brought to a focus behind the retina (Fig. 22, B).

*Myopia*, when the eyeball is too long, so that parallel rays focus in front of the retina (Fig. 22, c).

If we represent the eye by a biconvex lens and the retina by a screen, emmetropic when situated at the principal focus of the lens as E, we make it hyperme-

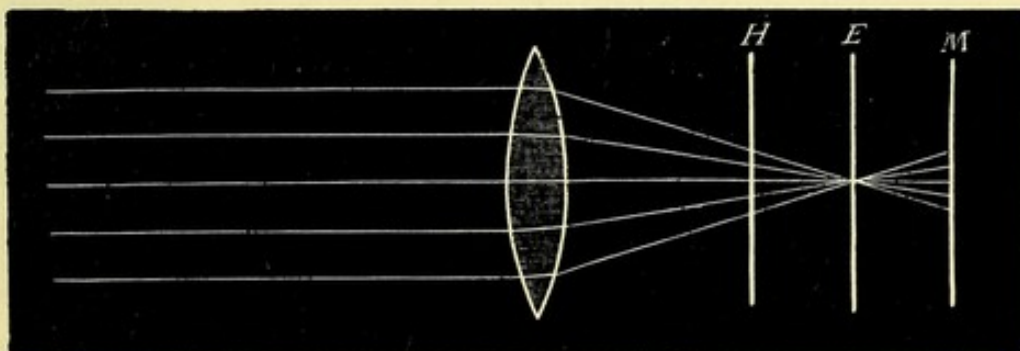


FIG. 22.



A. Emmetropic eye. B. Hypermetropic eye. C. Myopic eye.

FIG. 23.



Convex lens of 23 mm. focus. Parallel rays focus at E (emmetropia) on the screen, forming a well-defined image of object from which rays come; at H (hypermetropia) forming a diffusion patch instead of an image. M (myopia), also a diffusion patch, the rays having crossed and become divergent.



tropic (H) by bringing forward the screen, and myopic (M) by moving it further away from the lens.

In all eyes, vision ranges from the far point, which in the emmetropic eye is at infinity, to the near point.

The near point (punctum proximum) varies in the normal eye. It recedes as age advances, but should not be further off than 22 cm. (Fig. 75).

Infinity is any distance beyond 6 metres, the rays coming from a point at or beyond that distance being parallel, or almost so.

The emmetropic eye, therefore, is one whose far point, or punctum remotum, is situated at infinity. The hypermetropic eye has its punctum remotum beyond infinity, and the myopic at a finite distance.

When the near point has receded beyond 22 cm. (which usually occurs in the emmetropic eye about the age of forty-five), the eye is said to be *presbyopic*.

Generally the two eyes are similar in their refraction, though sometimes there is a very great difference. One may be hypermetropic, the other myopic; or one emmetropic, the other ametropic. *Anisometropia* is the term used when the two eyes thus vary in their refraction.

There may be differences also between the refraction in the different meridians of the same eye—*astigmatism*.

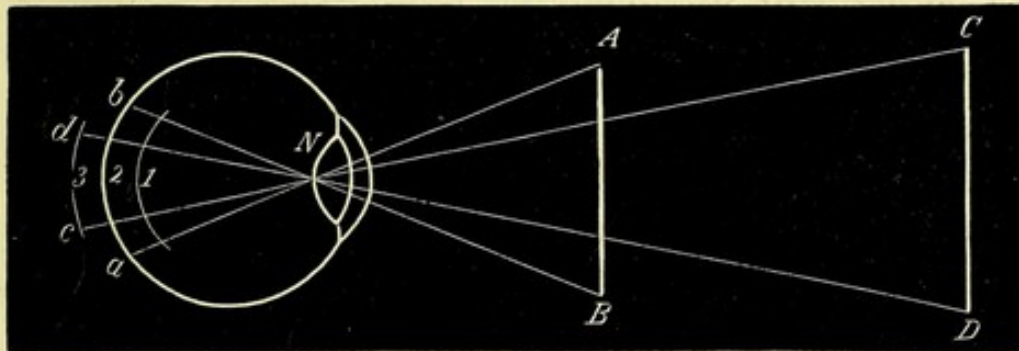
In all forms of ametropia the acuteness of vision is liable to be diminished. It also decreases slightly as age advances, without any disease.

The acuteness of vision refers always to central vision. The yellow spot is the most sensitive part of



the retina, and the sensibility diminishes rapidly towards the periphery. The acuteness is measured by the size of the visual angle, that is, the angle formed at

FIG. 24.



the posterior nodal point, which point closely coincides with the posterior surface of the lens, and is about 15 mm. in front of the yellow spot.

In Fig. 24, let  $cd$  be an object for which the eye is accommodated. The lines  $cc$ ,  $dd$ , drawn from the extremities of the object, cross at the nodal point  $N$ . The angle  $cNd$  will be the visual angle under which the object  $cd$  is seen. The size of the angle depends upon the distance of the object as well as upon its magnitude, and the size of the image thus formed will also depend upon the antero-posterior length of the eyeball.

Thus an object  $AB$  which is as large as  $cd$ , but nearer to the eye, may be seen under a larger angle, the angle  $ANB$  being greater than  $cNd$ . It is also clear that the image formed on the retina will be smaller at 1, when the antero-posterior diameter of the eye is less, as in hypermetropia, than it is at 2, as in



emmetropia, and that it will be larger in myopia, as at 3, where the eyeball is elongated. It is, therefore, easy to understand that a patient may be able to read the smallest type and still have some defect of refraction, unless the type be read at its proper distance.

It is by the unconscious comparison of things of known size that we are able to estimate the distance of objects, and not by the visual angle alone.

Objects must therefore be of a certain size, and it has been found out that to enable us to see an object distinctly it must be viewed under an angle of not less than  $1'$ .

It has been shown (Fig. 22, B), that in hypermetropia, when in a state of rest, parallel rays are brought to a focus behind the retina, so that instead of a clear, well-defined image, we get a circle of diffusion. Convex glasses possess the power of rendering parallel rays passing through them convergent, so that by placing a lens of the right strength in front of the hypermetropic eye, we bring forward its focus on to the retina.

In myopia (Fig. 22, c), where the focus is in front of the retina, we succeed by concave glasses in carrying back the focus.

These lenses are spherical, and were until recently numbered according to their focal length in inches, a glass of 1 inch focus being taken as a standard. To this plan there were several objections. The standard glass being a strong one, weaker glasses had to be expressed in fractions. Thus a glass of 4 inch focus was one fourth the strength of the standard 1 inch,



and was expressed as  $\frac{1}{4}$ . In addition to the trouble and inconvenience of working with fractions, the intervals between the lenses were most irregular, and, moreover, the inches of different countries vary. At the Ophthalmological Congress in 1872, it was decided to adopt a metrical scale of measurement. A lens of 1 metre focus was taken as the unit and was called a dioptre; a weak instead of a strong glass therefore being the unit, a lens of two dioptres is twice the strength of the former and has a focal length of half a metre. Thus each lens is numbered according to its refracting power, and not, as in the old system, according to its focal length.

The focal length of a lens is not expressed in the dioptric measurement; this can, however, always be found by dividing 100 cm. by the number of the lens; if it be 2 D. then the focal length will be 50 cm., if 10 D. then 10 cm.

The intervals between dioptres is somewhat large, so that decimals .25, .50, .75 of a dioptre were introduced; these work easily.

Convex glasses magnify and concave ones diminish the size of objects.

**Accommodation.**—In the normal eye, in a condition of complete repose, parallel rays come to a focus exactly on the rods and cones of the retina, and the object from which they come is therefore seen distinctly.

Rays from a near object proceed in a divergent direction, and come to a focus behind the retina; the object would not then be clearly seen, unless the eye



possessed within itself the power of bringing rays of different directions into union on the retina.

This power of altering the focus of the eye at will is called accommodation, and is due to an alteration in the form of the lens. That the eye possesses this power can easily be proved in many ways, apart from the conscious muscular effort; perhaps as simple a way as any to demonstrate it to oneself, is to look through a net held a short distance off, at some distant object. Either the net or the object can be seen distinctly, but not both at once. If the meshes of the net be looked at, then the distant object becomes indistinct, and on looking at the object the meshes become confused.

Accommodation, therefore, increases the refraction of the eye and adapts it to near objects. The changes which take place in the lens during accommodation are—

1st. The anterior surface becomes more convex and approaches the cornea.

2nd. The posterior surface becomes slightly more convex, but remains equally distant from the cornea.

That these changes take place may be proved in the following manner: a small candle flame, or other convenient object, being held on one side of the eye, so as to form an angle of  $30^{\circ}$  with its visual axis, an observer looking into the eye from a corresponding position on the other side, will see three images of the flame, the first upright, formed by the cornea, the second larger, upright and formed by the anterior surface of the lens, the third smaller and inverted,



formed by the posterior surface of the lens; when accommodation is put in force, images one and three remain unchanged in shape and position, image two, which is that formed by the anterior surface of the lens, becomes smaller, more distinct, and approaches image one, proving that this surface of the lens has become more convex and has approached the cornea. In an emmetropic eye adapted for infinity, it has been proved that the radius of curvature of the anterior surface of the lens is 10 mm., when accommodated for 13.5 cm. it is changed to 6 mm.

The pupil also becomes somewhat smaller, the central part advances while the peripheral part slightly recedes.

The alteration in the shape of the lens is due to the contraction of the ciliary muscle, which draws forward the ciliary body and choroid, thereby relaxing the ligament of Zinn and allowing the elasticity of the lens to come into play. This elasticity is due to the peculiar watch-spring arrangement of the lens fibres.

FIG. 25.

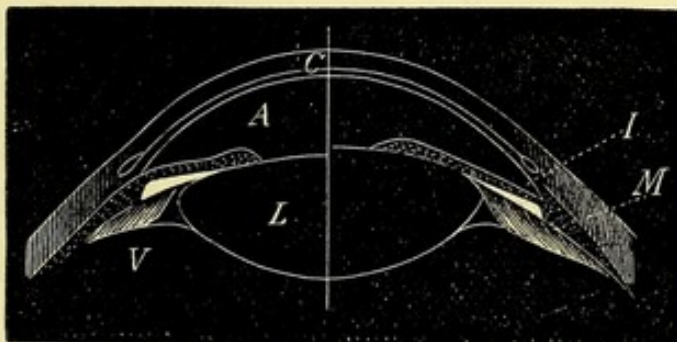


Diagram of lens, cornea, &c. The right half is represented as in a state of accommodation, the left half at rest. A. The anterior chamber. C. The cornea. L. The lens. V. The vitreous humour. I. The iris. M. Ciliary muscle.



When the ciliary muscle is relaxed, the elasticity of the capsule comes into play and compresses the lens so as to make it flatter; and when thus relaxed to its uttermost, the lens has assumed its least convexity and the eye is then adapted for its far point (*punctum remotum*).

In this condition the eye is spoken of as being in a state of complete repose.

When the ciliary muscle has contracted as much as it can, the lens has assumed its greatest convexity and its maximum amount of accommodation is now in force. This point is the nearest for which the eye can accommodate itself and is called the *punctum proximum*.

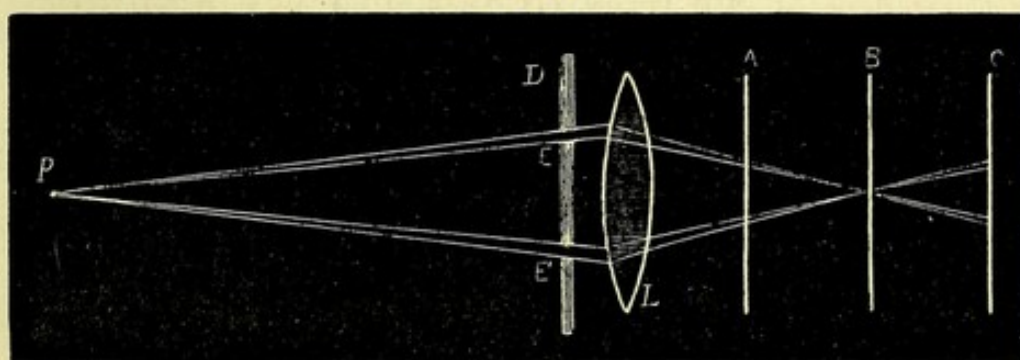
In the emmetropic eye the *punctum remotum* is situated at infinity.

The position of the *punctum proximum* can be determined in several ways; the ordinary plan is to place in the patient's hand the small test type and note the shortest distance at which he can read Sn. 1 with each eye separately; or we may measure it with the wire optometer, which consists of a steel frame crossed by thin vertical wires; this is supported in a handle to which a tape measure is attached, the tape is placed against the temple and held there while the frame is made gradually to recede from the patient's eye we are examining, stopping as soon as the wires become distinct, and reading off the number of centimetres on the measure. Another excellent plan by which to find the position of the *punctum proximum* is that of Scheiner. Close in front of the eye we wish to



examine is placed a card having two small pin holes, which must not be further apart than the diameter of the pupil, through these two holes the patient is directed to look at a pin held about one metre away (the other eye is of course excluded from vision during the experiment). The pin will be clearly and distinctly seen, it is then gradually approached to the eye, at a certain place it will become double, the point at which it ceases to appear single is the punctum proximum.

FIG. 26.



In Figure 26 the biconvex lens *L* represents the eye, *D* the perforated card, *P* the pin, *E E'*, the two sets of rays from *P*, which focus exactly at *B* the retina. If, however, the pin be brought nearer, so that the accommodation is unable to focus the two sets of rays, they will form instead of one, two images of the pin on the retina as at *A*. These will be projected outwards as crossed images.

The whole amount of accommodation that can be put in force, *i.e.* the difference between the eye in a state of complete repose and when its maximum amount of accommodation is in force, is styled the *amplitude*



of accommodation, so that the amplitude of accommodation is the distance between the punctum proximum and the punctum remotum.

A convex glass placed in front of the eye produces the same effect as accommodation, *i.e.* it increases its refraction and adapts the eye for nearer objects. We can easily understand that the lens which enables an eye to see at its near point without its accommodation, is a measure of the amplitude of accommodation, giving to rays which come from the near point a direction as if they came from the far point.

Therefore, if we wish to measure the amplitude of accommodation in emmetropes we have merely to find the nearest point at which the patient can read small print. A lens whose focal distance corresponds to this is a measure of the amplitude of accommodation. Thus, supposing 20 cm. the nearest distance at which he is able to read small print, we divide this into 100 cm. to find the focal distance of the lens ( $\frac{100}{20} = 5$  D.); in this case a lens of 5 D. is the measure we require.

Or we can measure it in an inverse manner by looking at a distant object through a concave glass; the strongest with which we can see this distant object distinctly, gives the amplitude of accommodation; the concave glass gives to parallel rays coming from the distant object such an amount of divergence as if they came from a point situated at the principal focal distance of this glass.

A hypermetrope requires some of his accommodation for distant objects; we must, therefore, in order to find the amplitude of accommodation in his case,



add on to the lens whose focal length equals the distance of the near point, that lens which enables him to see distant objects without his accommodation. Thus we will assume his near point to be 25 cm. ( $\frac{100}{25} + 4$  D.), and that he had to use 4 D. of accommodation for distant objects, then the amplitude of his accommodation would be (4 D. + 4 D.) = 8 D.

In myopes we have to subtract the glass which enables them to see clearly distant objects from that whose focal length equals the distance of the near point. Thus, to find the amplitude of accommodation in a myope of 2 D., the near point being at 10 cm., we subtract from ( $\frac{100}{10} = 10$ ) 10 D. the amount of the myopia 2 D. and the resulting 8 D. is therefore the amplitude of accommodation. Hence it is obvious that with the same amplitude of accommodation the near point is further away in hypermetropia than in emmetropia, and further in emmetropia than in myopia. Thus an emmetrope with an amplitude of accommodation of 5 D. would have his near point at ( $\frac{100}{5} = 20$ ) 20 cm., a hypermetrope of 2 D. whose amplitude equalled 5 D. would require 2 D. for distance, leaving him 3 D., which would bring his near point to ( $\frac{100}{3} = 33$ ) 33 cm.; and a myope of 2 D., who would require a concave glass of this strength to enable him to see at a distance, would have a near point of 14 cm. ( $\frac{100}{7} = 14$ ) with the same amplitude.

Accommodation is spoken of as absolute, binocular, and relative.

Absolute, is the amount of accommodation which one eye can exert when the other is excluded from



vision, *i.e.* from the punctum remotum to the punctum proximum.

Binocular, that which the two eyes can exert together, being allowed at the same time to converge.

Relative, that which the two eyes can exert together for any given convergence of the visual lines.

As age advances the elasticity of the lens diminishes, the ciliary muscle loses power, and the accommodation therefore becomes less, the near point gradually receding. These changes commence at a very early age, long before the individual has come to maturity.

FIG. 27.

Dioptres.

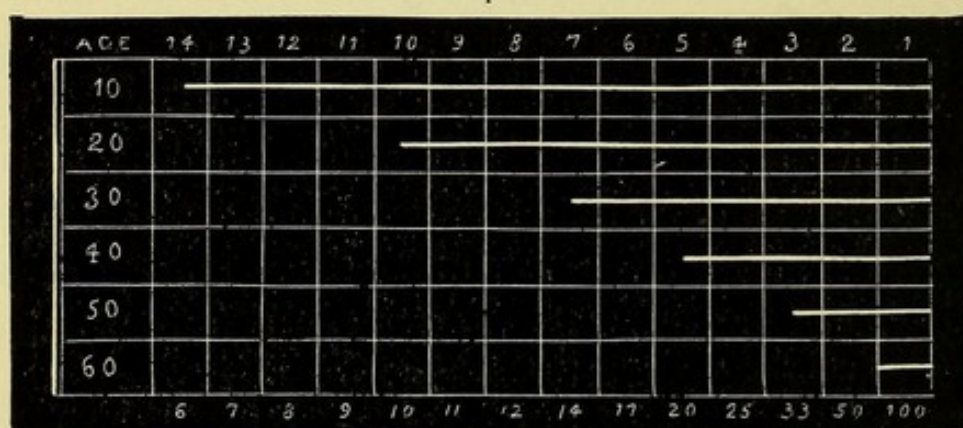


Diagram showing by the number of squares through which the thick lines pass, the amplitude of accommodation at different ages. The figures above represent the number in dioptres of accommodation; those below, the near point for each amount; and those on the left, the age of the individual (*after Donders*).

**Convergence** is the remaining element of distinct binocular vision, and with it accommodation is very intimately linked, so that usually for every increase of the convergence a certain increase in the accommodation takes place.



Convergence is the power of directing the visual axes of the two eyes to a point nearer than infinity. This is brought about by the action of the internal recti muscles.

When the eyes are completely at rest the optic axes are either parallel or more usually slightly divergent. The angle thus formed between the visual and the optic axis is called the angle  $\alpha$ , and varies according to the refraction of the eye, in emmetropia the angle is usually about  $5^\circ$ . In hypermetropia it is greater, sometimes about  $7^\circ$  or  $8^\circ$ , giving to the eyes an appearance of divergence. In myopia the angle is less, often about  $2^\circ$ , or the optic axis may, even in extreme cases, fall on the inside of the visual axis, so that no angle  $\alpha$  is formed (p. 157). In myopia, therefore, there is frequently an appearance of convergence, giving one the idea of a convergent squint, and hence the mere look of the patient's eyes with regard to their axes is not always quite reliable.

The object of convergence is the directing of the yellow spot in each eye towards the same object, so as to produce singleness of vision. Diplopia, or double vision, at once resulting when the image of an object is formed on parts of the retina which do not exactly correspond in the two eyes.

To test the power of convergence prisms are held with their bases outwards. The strongest prism which it is possible to overcome, that is, the prism which does not produce diplopia on looking through it at a distant object, is the measure of the convergence, and varies in different persons, usually



between prisms of  $20^\circ$  and  $30^\circ$ , divided between the two eyes.

In considering convergence we have not only to bear in mind the state of the internal recti muscles, but also the equilibrium produced by them and the action of their antagonists—the external recti.

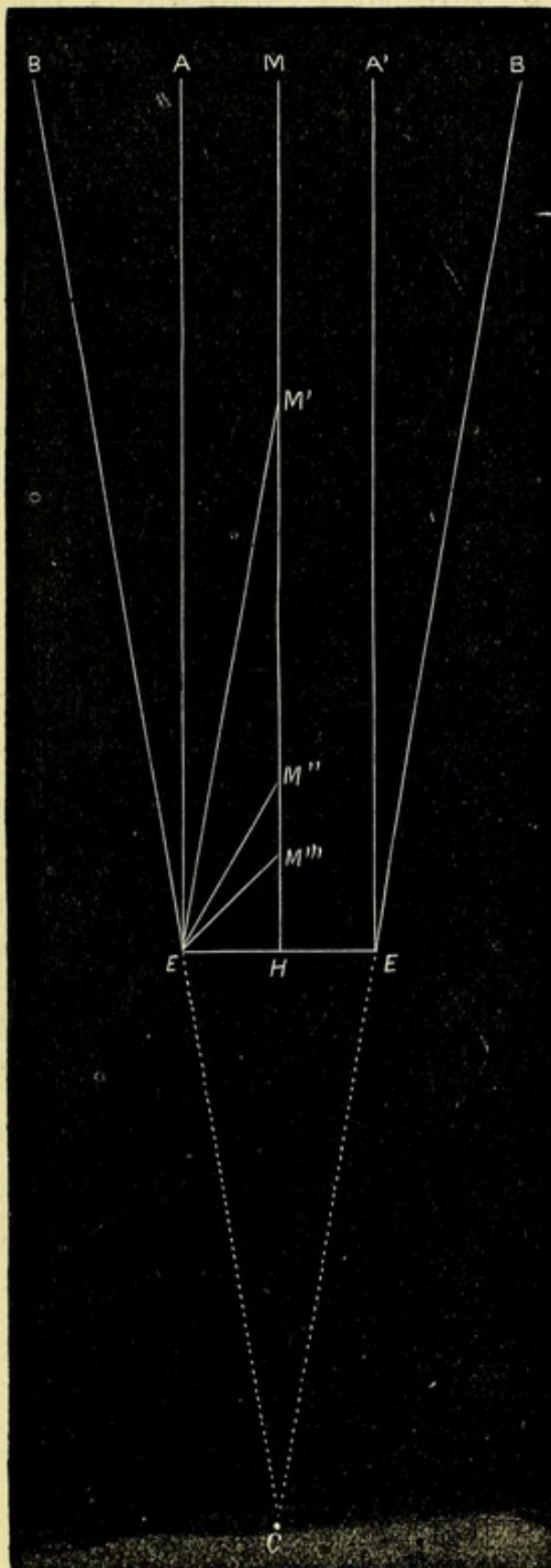
The nearer an object, the more we have to use the power of convergence and so also with the accommodation. Hence usually on converging to any particular point we also involuntarily accommodate for that point, the internal recti and ciliary muscles acting in unison.

Nagel has proposed a very simple and convenient plan by which we may express the convergence in metres, calling the angle formed by the visual and median lines as at  $M'$ , the *metrical angle*. The following is the plan, in Fig. 28:  $E, E'$  represent the centres of rotation for the two eyes;  $EHE'$  is the base line between the eyes. When the eyes are fixed on some distant object, the convergence being passive, the visual lines are parallel or almost so, as  $EA, E'A'$ , the angle of convergence is then at its minimum, and it is said to be adapted to its *punctum remotum*, this, then, being at infinity is expressed,  $C = \infty$ .\*

If the eyes be directed to an object 1 metre away, the metrical angle  $EM'H$  equals one, *i.e.*  $C = 1$ . If the object is 50 cm. off then  $C = 2$ ; if 10 cm. then ( $\frac{100}{10} = 10$ )  $C = 10$ . If the object had been beyond 1 metre (our unit), but not at infinity, say 4 metres, then  $C = \frac{1}{4}$ .

\*  $C$  is the sign for convergence, and  $\infty$  the sign for expressing infinity.



FIG. 28 (*Nagel*).



When the visual lines, instead of being parallel, diverge, then the punctum remotum is found by continuing these lines backwards till they meet at  $c$ , behind the eye, the convergence is then spoken of as *negative*.

When the eyes are directed to the nearest point at which they can see distinctly, say at  $m'''$ , the angle of convergence is at its maximum, and it is said to be adapted to its *punctum proximum*.

The distance between the punctum proximum and the punctum remotum is the *amplitude of convergence*.

As the angle of convergence is greater the nearer the object approaches the eyes, we may say that the angle of convergence is inversely proportionate to the distance of the object from the eyes.

We know also that the accommodation increases the nearer the object approaches, hence we see that both the convergence and accommodation increase and decrease together; and in recording the convergence in the manner proposed by Nagel, it will be seen on referring to the foregoing figure, that in the emmetropic eye the number which expresses the metrical angle of convergence, expresses also the state of refraction for the same point—this is a great advantage. Thus when looking at a distant object, the angle of convergence is at infinity,  $C = \infty$ , and the refraction is also at infinity,  $A = \infty$ . When the object is at 1 metre the angle of convergence = 1, and the amount of accommodation put into play = 1 D. When the object is at 25 cm. then the angle of convergence = 4, and the amount of accommodation = 4 D.

It has been found by experiment that the amplitude



of convergence is somewhat greater than the amplitude of accommodation, passing it both at its punctum remotum and its punctum proximum.

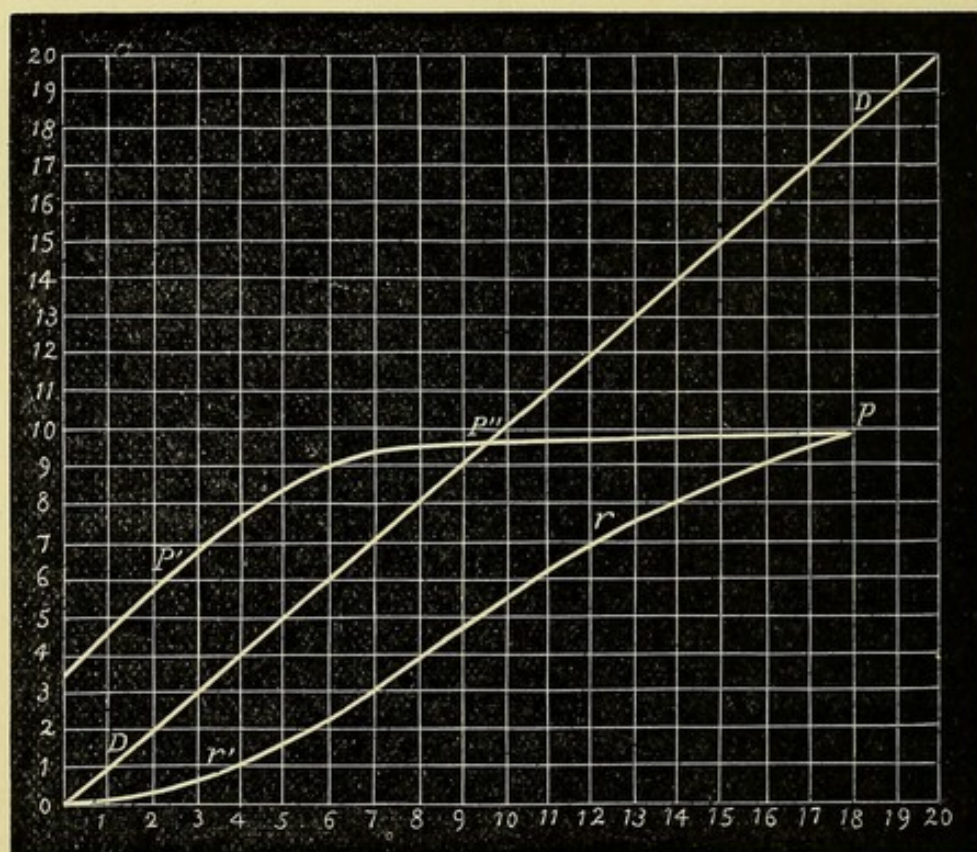
The following table from Wecker and Landolt, shows the angle of convergence in degrees for different distances of the object when the eyes are 6.4 cm. apart :

Distance of the object from the eyes.		The metrical angle.		Value expressed in degrees.
1 metre	...	1	...	1° 50'
50 cm.	...	2	...	3° 40'
33 „	...	3	...	5° 30'
25 „	...	4	...	7° 20'
20 „	...	5	...	9° 10'
16 „	...	6	...	11°
14 „	...	7	...	12° 50'
12 „	...	8	...	14° 40'
11 „	...	9	...	16° 30'
10 „	...	10	...	18° 20'
9 „	...	11	...	20° 10'
8 „	...	12	...	22°
7.5 „	...	13	..	23° 50'
7 „	...	14	...	25° 40'
6.5 „	...	15	...	27° 30'
6 „	...	16	...	29° 20'
5.5 „	...	18	...	33°
5 „	...	20	...	36° 40'

Although accommodation and convergence are thus intimately linked together, it can easily be proved that they may have a separate and independent action. If we suspend the accommodation with atropine, the convergence is not interfered with, and if by division of both internal recti for squint, the power of convergence is for the time lost, the accommodation can still be brought into play.



Again, an object at a certain distance being seen clearly without a glass, can still be seen distinctly with weak concave and convex glasses. The following diagram shows the relative amount of accommodation for different points of convergence in an emmetrope aged fifteen. The amount of accommodation in excess of the metrical angle of convergence is called *positive* and the amount below *negative*.

FIG. 29 (*Donders*).

The diagonal *D D* represents the convergence from infinity to 5 cm.; it is also a record of the accommodation. The line *P P' P''* indicates the maximum accommodation for each point of convergence, and the line *r r'* the minimum. The numbers on the right



and below the diagram are dioptries and metrical angles of convergence; thus, when the visual lines are parallel it will be seen that 3.5 D. of positive accommodation can be put into play, *i.e.* the object can still be seen distinctly with a concave glass of that strength, 3.5 D. is therefore the relative amplitude of accommodation for convergence adapted to infinity; or the metrical angle C being 5, which is a distance of 20 cm. away, the accommodation for that point would equal 5 D. The positive amount that can be put in force while angle C remains the same, would be 3 D., and the negative also 3 D., the object being seen clearly with a concave or convex glass of 3 D., therefore the relative amplitude of accommodation for C 5 is 6 D., *i.e.* from 12 to 50 cm. When the angle C = 10 or any larger angle, the accommodation that can be put in force will be seen to be entirely on the negative side.

Thus, the convergence being fixed, the amount of accommodation which can be brought into play for that particular point, is the sum of the difference between the strongest concave and convex glass employed.

The eye being accommodated for an object at a certain distance, the amount of convergence for that particular point may be measured by placing in front of the eyes prisms, bases outwards, the strongest with which the object is still seen singly is the measure of the positive part of the amplitude of convergence. Prisms, bases inwards, give us the negative part—the sum of these is the amplitude of relative convergence.



## CHAPTER III

## METHODS OF DETERMINING ERRORS OF REFRACTION

IN this and the following chapters I propose to consider some of the numerous objective and subjective methods by which errors of refraction may be diagnosed and estimated. These methods will embrace:

The objective examination of the patient.

The acuteness of vision.

The indirect and direct ophthalmoscopic examinations.

Scheiner's method.

Retinoscopy.

First with regard to the objective examination, we notice the general appearance of the patient, the form of the face and head; a flat-looking face is frequently an indication of hypermetropia, a head elongated in its antero-posterior diameter, with a long face and prominent nose, indicates myopia. If the two sides of the face are not symmetrical, or if there be some lateral displacement of the nose from the median line, astigmatism may be suspected. We should notice also the shape of the eyes themselves, if large and prominent, or small. In high degrees of astigmatism



it can often be seen that the curvature of one meridian exceeds that of the other. The distance between the eyes should also be noted, as well as the direction of their axes.

**The acuteness of vision** is of great value in estimating errors of refraction, and is the most used of all subjective methods; for, although it may be impaired by other causes, such as a loss of sensibility of the retina, a want of clearness of the retinal images by opacities in the media, &c., yet the proper adjustment of the refraction of the eye is probably the most common cause of a diminution in the acuteness of vision.

In order to measure the acuteness of vision, it has been discovered by various and numerous experiments, that the smallest distance between two points on the retina which can be perceived separately is 0.00436 mm., about the diameter of a single rod or cone, and this only at the macula and the part immediately around it, which is the most sensitive portion of the retina. In the periphery the two points must be further apart to appear distinct. Such an image as that formed at the macula corresponds to a visual angle of 1'.

The visual angle (Fig. 24) has been shown to be an angle included between two lines drawn from the two opposite edges of the object through the nodal point.

Test types have been constructed upon these principles for determining the acuteness of vision; Snellen's being those now universally used. The letters are so made that the strokes composing them are seen under



an angle of 1' and the whole letter itself under an angle of 5' when placed at their respective distances.

In order to estimate the refraction by the acuteness of vision the test object must be placed in a good light and so far away as to exclude as much as possible the accommodation, 6 metres has been found to be a sufficient distance, and rays coming from an object so far off may be assumed to be parallel, and falling on an emmetropic eye at rest would come to a focus on the retina. The smallest letter which can be seen distinctly at this distance will represent the acuteness of vision.

Snellen's type consists of rows of letters, each being marked above with the distance in metres at which it should be read. The top letter should be distinct at 60 metres, the next at 36, and each succeeding row at 24, 18, 12, 9, and 6 metres respectively.\* The patient placed at 6 metres should, without any accommodation, be able to read the bottom line with either eye. This is expressed in the form of a fraction in which the numerator is the distance at which it is read, and the denominator the number of the line. We note down the result found for each eye separately, if the bottom line is read,  $\frac{6}{6}$  expresses it, if the next  $\frac{6}{9}$ , the top  $\frac{6}{60}$ , &c.

If our patient, however, be not able even to see

\* The set of test type at the end of the book has an additional line to those generally used and is marked 5, so that a greater amount of visual acuteness than the normal  $\frac{6}{6}$  can be estimated, and is, of course, recorded  $\frac{6}{5}$ . This set of type is also convenient for those who prefer working at five metres.



the large letter at the top, we allow him to approach the board, telling him to stop as soon as the letter becomes visible. Supposing he stop at 2 metres from the board we express that as  $\frac{2}{60}$ , if he be able to read it at no distance, we see how far off he can count fingers. If not able to do this, a lower degree of visual acuteness is found out by determining the ability to distinguish different sorts of light, as to colour, &c. This is called "qualitative perception of light," whereas a still lower degree is to distinguish the difference between light and darkness, this is "quantitative perception of light."

Although the capability of reading the bottom line at six metres is the average of acuteness at different ages, yet it is not the maximum, since many young people will be found who are able to read line six at 7 metres, in which case their acuteness is  $\frac{7}{6}$ .

When the acuteness of vision is not up to the normal, the patient frequently has some error of refraction.

If he is able, however, to read with each eye separately  $\frac{6}{6}$  we assume the absence of myopia or astigmatism, although he may be using some accommodation, which might enable him to read  $\frac{6}{8}$ , even if hypermetropic. This we decide by holding weak convex glasses in front of each eye separately, when if he still be able to read  $\frac{6}{6}$  he has hypermetropia. The *strongest* convex glass with which  $\frac{6}{6}$  can still be read, will be the measure of the manifest hypermetropia (Hm.). But if the weakest convex glass make  $\frac{6}{6}$  indistinct, we judge the eye to be emmetropic, or per-



haps, to speak more correctly, we may say that the patient has no manifest hypermetropia.

Supposing that our patient, instead of reading  $\frac{6}{6}$ , is only able to read say the third line,  $\frac{6}{24}$ , and that this becomes blurred with a weak convex glass, we place in his hands the near type. If he can read the smallest (Snellen 1), though at a nearer point than the distance for which it is marked, we note the *greatest* distance at which he is able to read it. Let us suppose this to be 25 cm., he has then most likely myopia of 4 D., because 25 cm. is probably his far point. In this case a glass -4 D would give to rays coming from a distant point the same amount of divergence as if they came from 25 cm. ( $\frac{100}{25} = 4$ ).

We try the patient at the distant type with - 4 D. If he now read  $\frac{6}{6}$  the myopia is confirmed, and the weakest glass with which he reads it, is the measure of his myopia. If the myopia be of high degree, then probably no glass will enable him to read  $\frac{6}{6}$ , and we note the glass with which he gets the greatest acuteness of vision.

If our patient be able to read only  $\frac{6}{24}$ , and we are unable either by positive or negative glasses to bring up his vision to  $\frac{6}{6}$ , there may be some astigmatism present, presupposing of course that there is no other cause for bad vision.

We find out the spherical glass with which he is able to see best, then rotate in front of it a weak convex cylindrical glass. No improvement occurring we do the same with a weak concave cylinder, finding thereby the glass and the particular axis which gives



the best result. It is absolutely necessary that the eye be thoroughly under the influence of atropine in order to enable us to arrive at definite results by this method. With practice one is able in this way to work out simple cases of astigmatism accurately and quickly.

The object in view is always to bring up the vision of each eye, as nearly to the normal standard of  $\frac{6}{6}$  as possible. Frequently, however, we have to be satisfied with  $\frac{6}{9}$  or  $\frac{6}{12}$ .

If the patient read  $\frac{6}{6}$ , but be unable to read the near type except it be held at a further distance than that for which it is marked, he has presbyopia. If, however, he be much younger than forty-five, the age at which presbyopia usually commences in the emmetropic, it is probably a case of paralysis of the accommodation.

When trying the patient at the distant type it is often convenient to have two sets on the opposite sides of the same board, so that it may be reversed when the patient gets too accustomed to the letters on one side.

The near type is chiefly used to estimate the accommodation by finding out the far and near point at which any particular line is read—Snellen and Jaeger's are the types most commonly in use, many preferring Jaeger's, owing to the letters being of the ordinary shapes. It must, however, be remembered that sentences are an inferior test to letters, many people recognising the words by their general appearance, whereas they would be unable to see distinctly each letter of which the sentence was composed.



As convex glasses magnify, and concave glasses diminish the size of objects, it follows that these, when placed before the eye, will exercise some influence on the size of the retinal image. Now the hypermetropic eye sees objects smaller, and the myopic eye larger than the emmetrope, and Landolt says that if glasses which are to correct the ametropia be placed "13 mm. in front of the cornea, the retinal image of the ametropes should be of the same size as that of the emmetrope."

Before leaving this subject of the acuteness of vision the following directions may be given :

1st. The test type must be in a good light.

2nd. Commence with the right eye, or that which has the best vision, covering up the other with an opaque disc placed in a spectacle frame, and do not be contented to allow the patient to close one eye, as he may not do so completely, or he will probably unconsciously slightly diminish the palpebral aperture of the eye under examination, whereby the circles of diffusion may be somewhat diminished and so give misleading results. Neither should he close the eye with his hand, he may look between the fingers, or exercise some pressure, however slight, on the eyeball, which may interfere temporarily with the function of the retina and so cause delay.

3rd. Having noticed what each eye sees without glasses, always begin the examination with *convex* ones, so as to avoid calling the accommodation into action.

4th. Having noted the result found for each eye

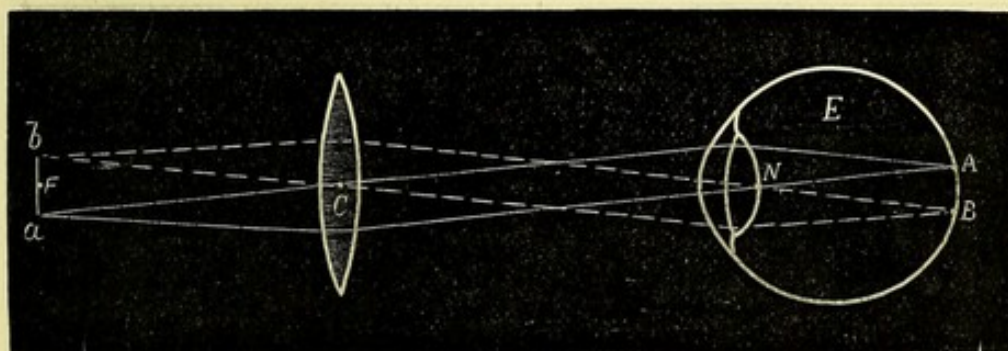


separately, we try the two together, the binocular visual acuteness being usually slightly greater than that for one eye.

**The Ophthalmoscope** furnishes us with several methods for determining the refraction of the eyes.

By the **indirect method** we obtain an inverted image of the disc by means of a biconvex lens placed in front of the eye. In emmetropia (Fig. 30) rays coming from

FIG. 30.



A emerge from the eye parallel, and are focussed by the biconvex lens at *a*, and rays coming from B are focussed at *b*, so also with rays coming from every part of A B, forming an inverted image of A B at *b a*, situated in the air at the principal focus of the biconvex lens.

In hypermetropia (Fig. 31) the rays from A emerge divergent, so also of course those from B; if these rays are continued backwards, they will meet behind the eye (at the punctum remotum) and there form an enlarged inverted image (*a β*) of A B; it is of this imaginary projected image that we obtain by the help of the biconvex lens a final inverted image (*b a*) situated in front of the lens beyond its principal focus. In



myopia (Fig. 32) the rays from A and B emerge from the eye convergent, forming an inverted aerial image

FIG. 31.

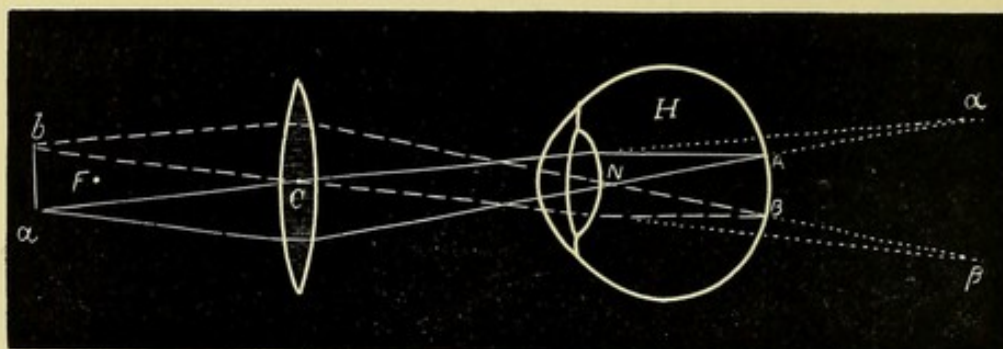
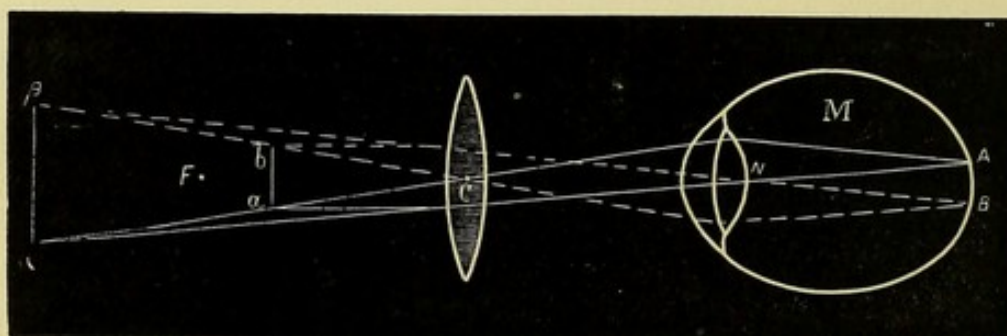


FIG. 32.



in front of the eye at  $\beta a$ , its punctum remotum. It is of this image we obtain with a biconvex lens placed between it and the eye, a final image ( $b a$ ) situated within the focus of the biconvex lens.

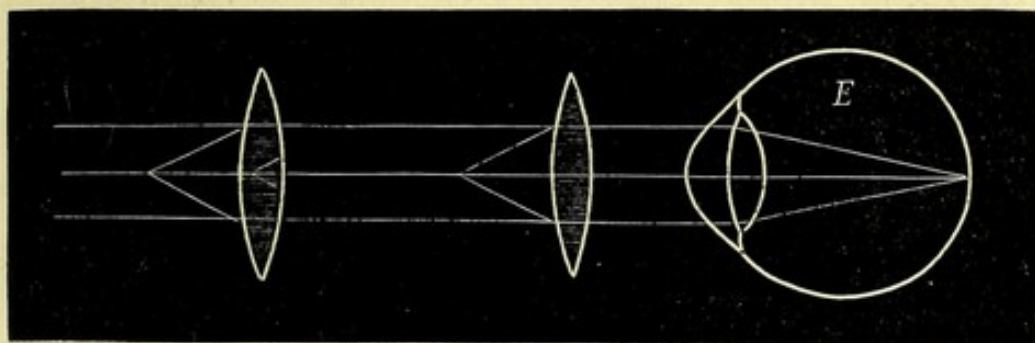
With this method we are able to detect the form of ametropia, by the changes which take place in the size and shape of the optic disc, always remembering that the inverted image of the disc, produced by a convex lens at a certain fixed distance from the cornea, is larger in hypermetropia and smaller in myopia than in emmetropia. The lens should be held close to the patient's eye, and as it is gradually withdrawn, the



aërial image of the disc being steadily kept in view the while, the rapidity with which any increase or decrease takes place in the size of this image, gives us an indication of the amount of the refractive error.

If no change take place in the size of the image on thus withdrawing the objective, the case is one of emmetropia, because rays issue from such an eye parallel, and the image formed by the object glass will always be situated at its principal focus, no matter at what distance the glass is from the observed eye (Fig. 33). As the relative distances of the image and the object from the lens is the same, the size of the image will also be the same.

FIG. 33.



E, Emmetropic eye. Rays issuing parallel, image formed at the principal focus of lens, no matter at what distance the lens is from the eye.

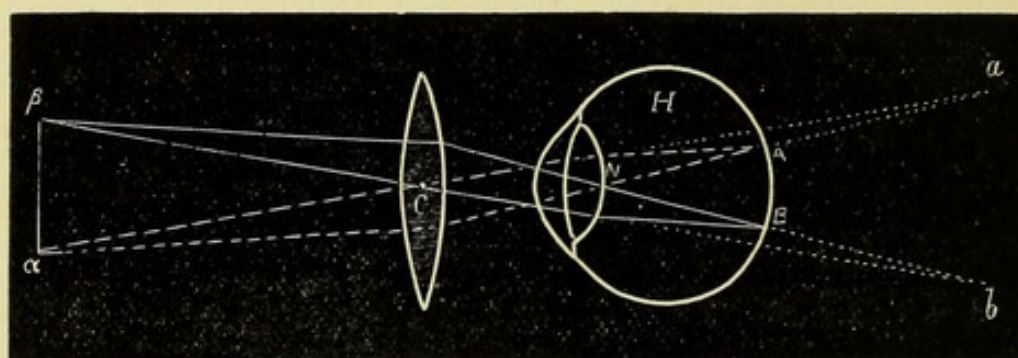
If diminution take place in the size of the image, the case is one of hypermetropia, and the greater the diminution the higher is the hypermetropia.

This change in size may be explained by remembering that in hypermetropia the image of the disc is projected backwards (Fig. 36), and it is of this projected image we obtain a final image with the help of

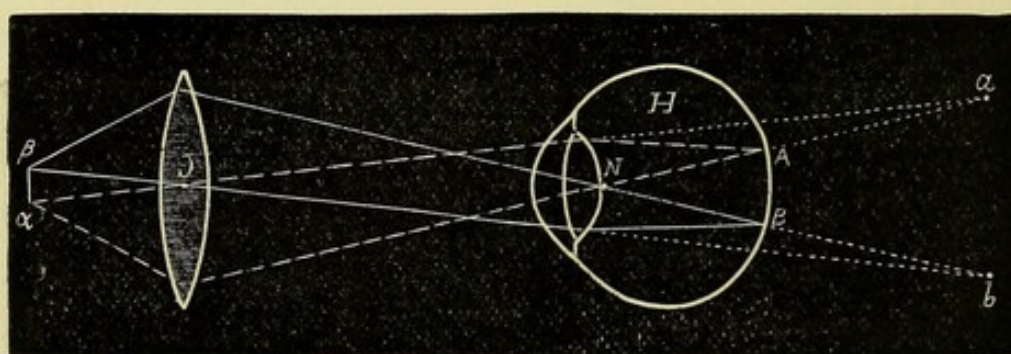


the objective. The two diagrams show images formed by the object glass when held at 4 cm. and at 12 cm. from the cornea, the latter image being the smaller.

FIG. 34.



Lens at 4 cm.



Lens at 12 cm.

H. Hypermetropic eye. C. The centre of the lens. A B. Image on retina.  $a b$ . Projected image.  $\beta a$ . The final image formed by the objective.

The following explains this :

The ratio of  $a \beta$  to  $a b$  varies directly as the length  $c a$ , and inversely as the length  $c a$ ; on withdrawing the lens  $c$  from the observed eye,  $c a$  diminishes and  $c a$  increases; therefore the ratio of  $a \beta$  to  $a b$  diminishes, *i.e.* the size of the image diminishes.

If the image become larger on withdrawing the



object-glass the case is one of myopia, the greater the increase of the image the higher the myopia.

This increase in the size of the image can also be explained with the help of mathematics, remembering that in myopia an inverted image is formed in front of the eye (Fig. 37), and it is of this we obtain an image, with a convex glass placed between the eye and the inverted image, which we must regard as the object, the object and its image being both on the same side of the lens.

In astigmatism the disc, instead of appearing round, is frequently oval. If one meridian decrease while the other remain stationary as the objective is withdrawn, it is a case of simple hypermetropic astigmatism. If the whole disc decrease in size, one meridian diminishing more than the other, it is compound hypermetropic astigmatism, the meridian being most hypermetropic which diminishes most.

Increase in one meridian, the other remaining stationary, indicates simple myopic astigmatism.

Increase in disc, but one meridian more so than the other, indicates compound myopic astigmatism, that meridian being most myopic which increases most.

If one meridian increase while the other decrease, mixed astigmatism is our diagnosis.

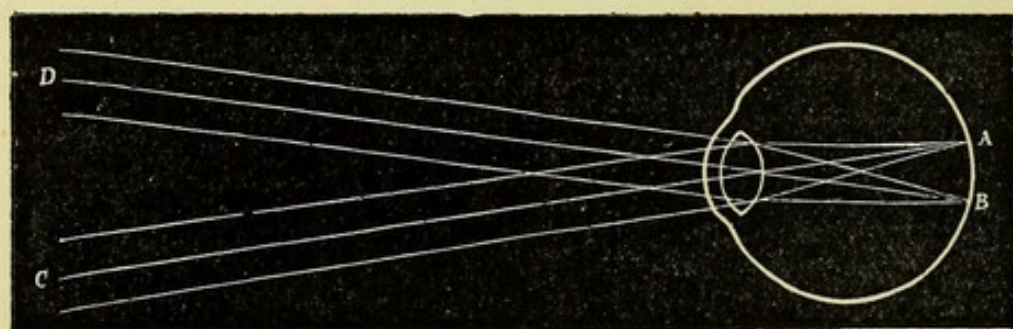
By the **direct examination** we obtain much more important information, not only of a qualitative but also of a quantitative character.

The observer first of all corrects any ametropia that may exist in his own eye. If he be able to see the disc or some of the vessels with the mirror alone at a



distance from the patient, the case is one of hypermetropia or myopia. The explanation of this is that in emmetropia (Fig. 35) the rays which come from the two extremities of the disc (A B) emerge as two sets of parallel rays in the same direction as the rays A C,

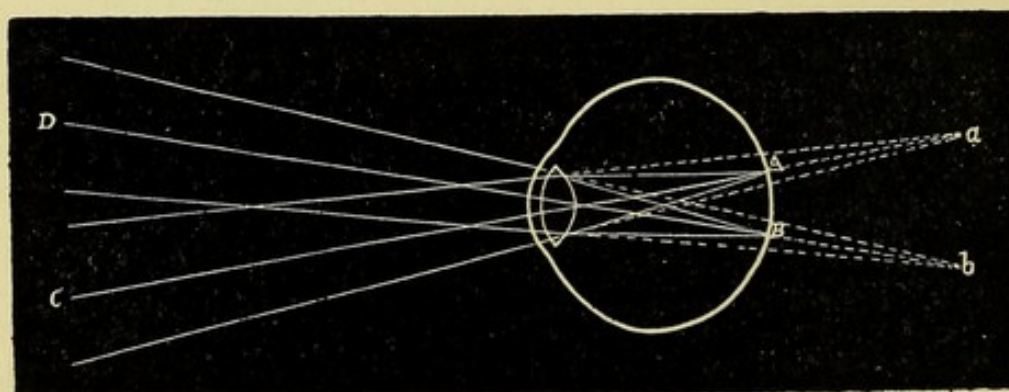
FIG. 35.



B D, which, having passed through the nodal point, undergo no refraction. These two sets of rays soon diverge, leaving a space between them, so that an observer, unless he be quite close to the observed eye, is unable to bring these rays to a focus on his retina; and therefore, at a distance from the eye the observer sees only a diffused and blurred image.

In hypermetropia (Fig. 36) the rays from the two

FIG. 36.





points A B, emerge from the eye in two sets of diverging rays in the same direction as the rays A C, B D, which undergo no refraction. These diverging rays have the appearance of coming from two points (*a b*) behind the eye, where an erect imaginary image is formed (*a b*).

The more the rays diverge on exit, the sooner they will meet when prolonged backwards; and hence, the greater the hypermetropia the nearer will the image be to the nodal point.

The observer at a distance sees a clear, erect image, which is formed behind the eye.

In myopia (Fig. 37), the rays from the two points (A B) emerge as two converging sets of rays, which meet at *a b* on their secondary axes, thus forming an inverted

FIG. 37.

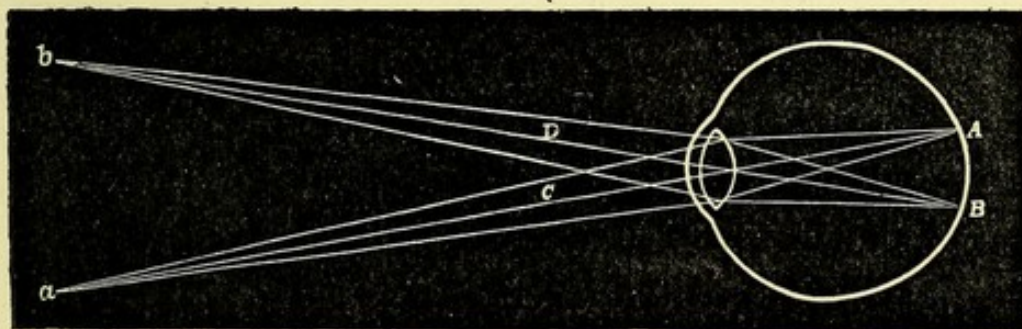


image in front of the eye. This image can be distinctly seen by the observer if he be at a sufficient distance from the point, and accommodating for the particular spot at which the aerial image is formed, and the higher the myopia the nearer to the eye will this image be formed. If the observer now move his head from side to side, and the vessels of the disc are seen to move in the same direction, the case would be



one of hypermetropia, the image formed being an erect one.

Had the vessels moved in the opposite direction to the observer's head, the case would be one of myopia, the image being an inverted one formed in the air in front of the eye.

If the vessels of one meridian only are visible, then we have a case of astigmatism, hypermetropic if moving in the same, and myopic if moving in the opposite direction to the observer's head, that meridian being ametropic which is at right angles to the vessels seen.

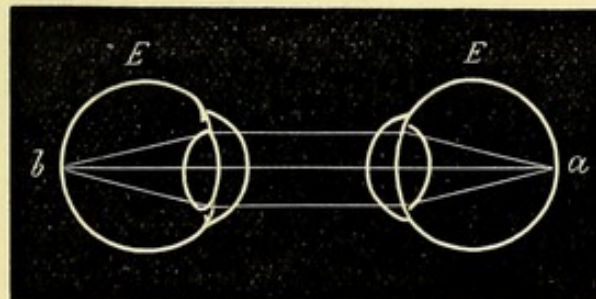
In mixed astigmatism the vessels of one meridian move against the observer's movements, and those of the other meridian with them ; this is difficult to see.

Thus we have obtained an indication of the form of ametropia. We may, however, estimate the amount of error by means of a refracting ophthalmoscope, of which there are many. Mr. Couper has lately shown at the Ophthalmoscopical Society a very long instrument, containing seventy-two lenses, with most ingenious movements, the advantage claimed being that one never looks through two lenses at once, thereby reducing the thickness of the instrument and allowing us to approach nearer the cornea than can be done with other ophthalmoscopes.

In endeavouring thus to estimate the refraction, it is essential that the accommodation of both the patient and observer be suspended. The observer places both himself and the lamp on the same side as the eye he is about to examine, then with



the mirror close to the patient's eye, so that the ophthalmoscope may occupy as nearly as possible the position of the spectacle glass, he looks for the disc. We really wish to estimate the refraction at the macula, but to this there are several obstacles: the light falling on this, the most sensitive part of the retina, has a very dazzling, unpleasant effect for the patient and causes the pupil to contract vigorously, the reflex from the cornea and the lens is exactly in the line of vision, and further, there are no convenient vessels in this part which we may fix as test objects, whereas the disc is but little sensible to light, and the vessels of this part, as well as the margins of the disc itself, are very convenient for our purpose; and although occasionally the refraction of the macula and disc are not exactly the same, still practically it is sufficiently accurate to take that of the latter. Having relaxed the patient's accommodation by making the examination in a dark room and directing him to look with the eye not under examination into space, or, what is

FIG. 38. (*Landolt.*)

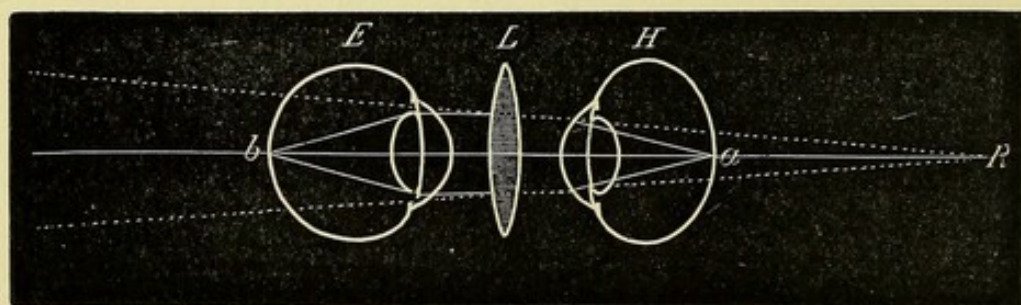
better, having paralysed it by atropine, then, if the observer's own accommodation be suspended, and the image appear quite clear and distinct, the case is



one of emmetropia. This we know, because rays coming from an emmetropic eye (fig. 38, E) in a state of repose, issue parallel according to the law of conjugate foci, and the observing eye receiving these rays will, if emmetropic with its accommodation suspended (which often requires great practice), be adapted for parallel rays, so that a clear image of *a* in the observed eye will be formed at *b* on the retina of the observing eye.

Supposing the image does not appear clear and distinct without an effort of accommodation, then we turn the wheel of the ophthalmoscope so as to bring forward convex glasses in front of the observing eye. The *strongest* positive glass with which we are able to get a perfectly clear image is a measure of the hypermetropia, because rays coming from *a* (Fig. 39) in the

FIG. 39. (Landolt.)



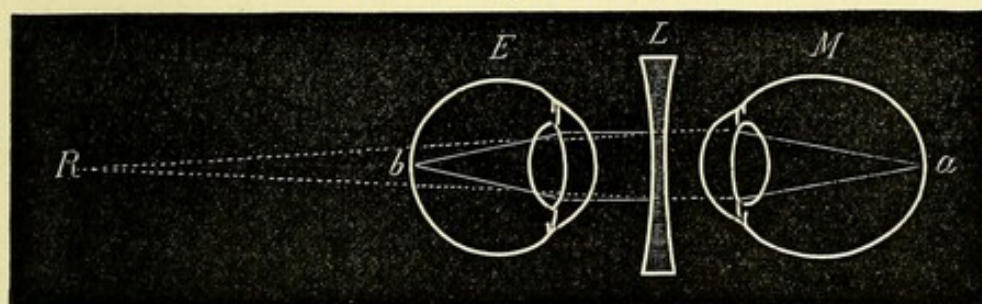
hypermetropic eye (H) issue in a diverging direction, as though coming from R, the punctum remotum behind the eye. The convex lens (L) renders them parallel and they then focus at *b* on the retina of the observing emmetropic eye (E).

If the convex glass, instead of rendering the image



more distinct, had the opposite effect, we must turn the wheel of the ophthalmoscope in the other direction, thus bringing forward the concave glasses. The *weakness* with which we can see the details of the fundus is a measure of the myopia, because any stronger glass merely brings into play the accommodation of the observer. Rays from *a* (Fig. 40) leave the myopic eye (*M*) so

FIG. 40. (*Landolt.*)



converging that they would meet at (*R*) the punctum remotum. The concave lens (*L*) renders them parallel before falling on the relaxed eye (*E*) of the observer.

If the ophthalmoscope is not held very close to the eye, we must deduct from the focal distance of the lens the distance between the cornea and the instrument in hypermetropia, adding them together in myopia.

If astigmatism exist, the plan is to find the glass which enables the vertical vessels and lateral sides of the disc to be seen distinctly, and then the glass with which the vessels at right angles are best seen.

Suppose the vertical vessels and lateral sides of the disc appear distinct without any glass, then the horizontal meridian, *i.e.* the meridian at right angles to the vessels clearly seen, is emmetropic; and suppose, also, that the horizontal vessels with the upper and



lower borders of the disc require a convex or concave glass to render them clear and distinct, then the vertical meridian is hypermetropic or myopic, and the case is one of simple hypermetropic or myopic astigmatism.

If both the vertical and horizontal vessels require convex glasses, but a stronger one for the horizontal than for the vertical, then the case is one of compound hypermetropic astigmatism, the vertical meridian being most hypermetropic.

If both meridians had required concave glasses, but of different strengths, then the case would be one of compound myopic astigmatism.

If the vertical vessels and the lateral sides of the disc require a convex glass to render them distinct, while the horizontal vessels require a concave glass, the case is one of mixed astigmatism, the horizontal meridian being hypermetropic, the vertical meridian myopic.

The essential point to remember, is that the glass with which the vessels in one direction are seen, is a measure of the refraction of the meridian at right angles to them.

The estimation of the refraction by the direct ophthalmoscopic examination requires very great practice, Some observers are able to estimate the amount of error within half a dioptré, and in cases of astigmatism to find out the chief meridians accurately; they profess to be able to do this without subjecting the patient to the inconvenience of having their accommodation paralysed with atropine, which in many



cases must be of great advantage. In my hands, however, this method of examination gives less satisfactory results than retinoscopy; especially is this so in cases of myopia of high degree. I am inclined to think the reason is that the direct, requires much greater practice than any other method of examination; probably many observers can never relax their accommodation so completely as to give satisfactory results.

The comparison of the direct and indirect methods of examination is also very useful in astigmatism. If, for instance, the disc is elongated horizontally in the erect and oval vertically in the inverted image, we know that the curvature of the cornea is greater in the horizontal than in the vertical meridian (see Figs. 71 and 72).

The observer must always remember, when using the direct ophthalmoscopic method for the estimation of errors of refraction, to correct any ametropia that he may have, either by wearing spectacles or by having a suitable glass in a clip behind his ophthalmoscope; he is then in the position of an emmetrope, but, if he prefer it, he may subtract the amount of his own hypermetropia or myopia from the glass with which he sees clearly the patient's disc. Thus, if the observer have 2 D. of hypermetropia and require + 3 D. to see the fundus clearly ( $3 \text{ D.} - 2 \text{ D.} = 1 \text{ D.}$ ), the patient would have 1 D. of hypermetropia; had he required  $- 2 \text{ D.}$  then ( $- 2 \text{ D.} + (- 2 \text{ D.}) = - 4 \text{ D.}$ ) the observed would have myopia of 4 D.

The same with the myopic observer, if his myopia amount to 3 D., then he will require  $- 3 \text{ D.}$  to



see clearly the emmetropic fundus ; if he see well without a glass, then the eye under examination has 3 D. of hypermetropia ; if he require a + 2 D., then the hypermetropia will be 5 D., and so on.

**Scheiner's method.**—Although this plan for detecting ametropia is now but little used, it is necessary the student should understand the principles upon which it is based. A diaphragm having two small perforations is placed in front of the eye we wish to examine ; the perforations must be so near together that rays passing through them will enter the pupil (Fig. 26). The patient is directed to look at a small flame 6 metres off ; rays emanate from this flame in all directions, some fall on the diaphragm, the greater number are thus cut off, but a few rays pass through the two openings, and if the eye be adapted for the flame, *i.e.* if it is emmetropic, these two sets of rays will meet exactly on the retina, forming there an image of the flame (B, Fig. 26) ; if, however, the eye be hypermetropic (with suspended accommodation) then the two sets of rays will reach the retina before meeting, each set forming an image of the flame (A, Fig. 26). The greater the hypermetropia the further apart will the images be formed ; these are projected outwards as crossed images, and the patient sees two images of the flame. That convex glass (from our trial box) which, held behind the diaphragm, causes the flame to be seen singly is a measure of the hypermetropia. If the eye be myopic, then the two sets of rays will have crossed and are diverging when they reach the retina, where two

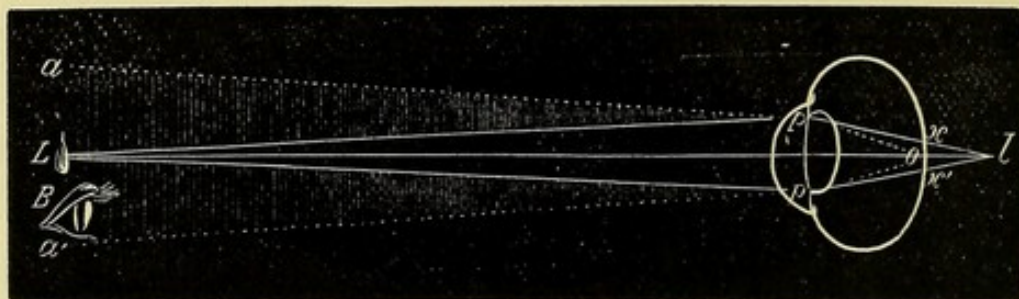


images of the flame are therefore formed (c, Fig. 26). These images are crossed again as they are projected outwards, and having twice crossed, the result is homonymous images. To find the amount of myopia we have only to find the concave glass which, behind the diaphragm, brings the two images into one. To enable us to tell if the images are crossed or homonymous, it is usual to have in front of one of the perforations a piece of coloured glass. We will suppose the diaphragm held so that the two openings are horizontal, that to the patient's right having in front of it a piece of red glass; if only one flame is seen the case is one of emmetropia, if two images of it appear, one white the other red, with the red to the left of the other, the images are crossed and the case is one of hypermetropia. If the red appeared on the right then the case is one of myopia. The further apart the images are, the greater is the ametropia.

Ametropia may also be easily recognised in the following manner, as was recently pointed out to me by Mr. W. Odillo Maher, house surgeon at Moorfields. The fundus being illuminated by a mirror about 1 metre from the patient, if the eye be emmetropic the rays of light will return parallel to one another and a red reflex can only be obtained when the observing eye is in the path of these rays, that is, behind the perforation of the mirror. If hypermetropic the returning rays will diverge (Fig. 41), and the observer will notice as he moves his eye (B) from behind the mirror at L, and at right angles to the visual axis of the patient, who should fix on the centre

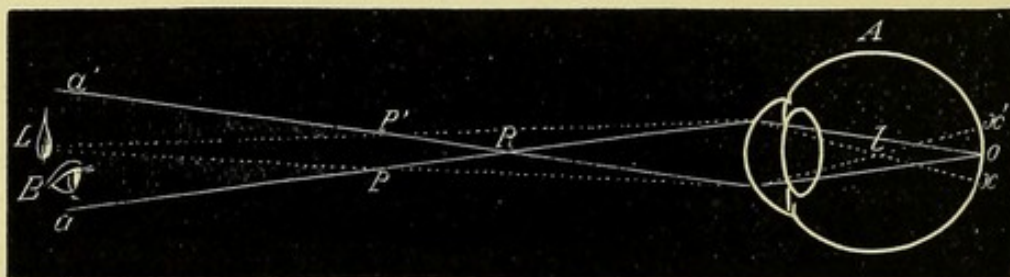


FIG. 41.



of this mirror, that the last ray of light ( $a' p'$ ) is seen, or, in other words, the red reflex disappears on the same side of the pupil as that to which the observer moves his head. If myopic the rays will converge, cross at  $R$ , and diverge (Fig. 42); when the error is

FIG. 42.



1 D. or more the last ray of light is seen, or the red reflex disappears on the opposite side of the pupil. A single trial of this will prove its correctness.

Mr Maher endeavoured to estimate the amount of myopia or hypermetropia by measuring the distance between the perforation of the mirror and the point at which the last ray was seen; at present the varying size of the pupil is the obstacle.

The ophthalmometer of Javal and Schiötz and Tweedy's optometer can, I think, be more conveniently considered when treating of astigmatism.



## CHAPTER IV

## RETINOSCOPY

RETINOSCOPY is a method of determining the refraction of the eye, and of correcting any error that may exist, by means of ordinary trial glasses, without help from the patients themselves—a matter of no small importance in children and persons of weak intellect, as will be readily acknowledged by those who have to do with large numbers of hospital patients.

We are also able to estimate the refraction in amblyopic eyes caused by squint, tobacco, alcohol, &c.

Retinoscopy is carried out by means of a concave ophthalmoscopic mirror alone. Twenty years since, Mr Bowman noticed that it was possible to discover astigmatism, and find out its chief meridians, by employing the mirror of the ophthalmoscope. Mr Macnamara has shown me a number of concave mirrors of different focal lengths, which he used years ago in India, employing them much in the same way as we do the concave mirror in the method retinoscopy.

The first systematic description of it, however, was by Dr Cuignet, of Lille, who gave to it the name "Keratotomy," thinking, as he did, that the shadows



which he saw and described were formed on the cornea. This has since been clearly proved not to be the case. Monsieur Parent, who has also worked and written on the subject, proposed the name Retinoscopy, and although a better term, not suggesting, as keratoscopy does, a false theory, it is not sufficiently definite, as all other ophthalmoscopic examinations of the retina, whether direct or indirect, might equally be described by the same name; perhaps Umbrascopy would have been a better term, though the introduction of fresh names is to be deprecated unless quite satisfactory. Landolt has recently proposed the name Pupilloscopy. Several English surgeons have also written on this subject.

The method of employing retinoscopy is so simple that a few practical trials will suffice to make it understood, although, of course, as in all other manipulations, some little practice is required in giving to the mirror the necessary movements, and enabling one to appreciate what is seen.

Atropine is not always absolutely essential; still, when we have to examine young people and children its use is most certainly advisable. In the first place, the consequent dilatation of the pupil renders our examination so much easier; and secondly, atropine helps us to a more definite conclusion by thoroughly paralysing the accommodation; for although the examination takes place in a dark room, and with the patient looking into distance, it must be remembered that there is often (especially in the case of children) some accommodation, due to the normal tone of the



ciliary muscle, or to a condition of spasm common in hypermetropia and myopia—it also enables us easily to detect small degrees of astigmatism which frequently exist, and, but for this method, would probably escape notice. In mixed astigmatism the time that is saved by this plan is enormous.

To examine the patient, then, we dilate his pupils, and seat him in a dark room, with a lamp placed over his head, so far back that it throws no direct rays upon his face, and consequently requires no moving during the examination of either eye. Then the observer—having previously corrected any ametropia that may exist in his own eye—takes up a position about 120 cm. in front of the patient, and directing him to look at the perforation in the mirror, which should be a concave one and of 22 cm. focus, he will be enabled to reflect the light along the visual axis.

If atropine has not been used, this procedure will cause the pupil so to contract that it will be difficult to see the shadows, and in that case the observer must make the patient look a little inwards, so that the light may be reflected along the optic axis—thus we obtain the ordinary red fundus reflex. If we now rotate the mirror slightly from side to side on its vertical axis, we see a shadow come out from behind the pupil, moving horizontally across the illuminated part. The edge of this shadow may be linear or somewhat crescentic. Its direction will vary, being either vertical, or it may be oblique if astigmatism exist. The shadow moves either in the same or the



opposite direction to the mirror, so that when the latter is tilted to the right, the shadow may come from the left, or *vice versâ*.

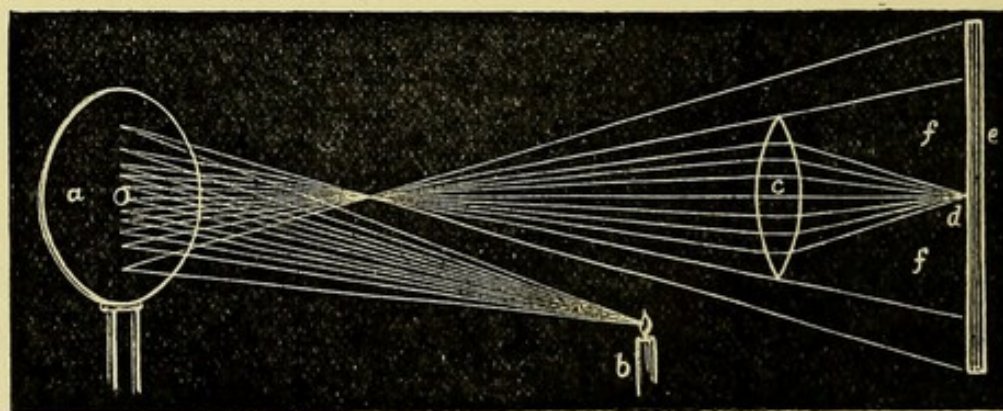
On the behaviour of these shadows the method retinoscopy depends.

Thus, assuming the shadow's edge to be vertical, if it move with the mirror, the case is one of myopia; but if it move against or in the opposite direction to the mirror, it is either one of hypermetropia, emmetropia, or low myopia.

What is this shadow whose edge we see? How and where is it formed? and what influences its movements and clearness?

To enable us to answer these questions we will place before a screen a convex lens, at such a distance from it that converging rays from a concave mirror, having crossed and become diverging, are brought to an exact focus, and there is then formed a very small, erect, well-defined image on the screen of the lamp

FIG. 43.



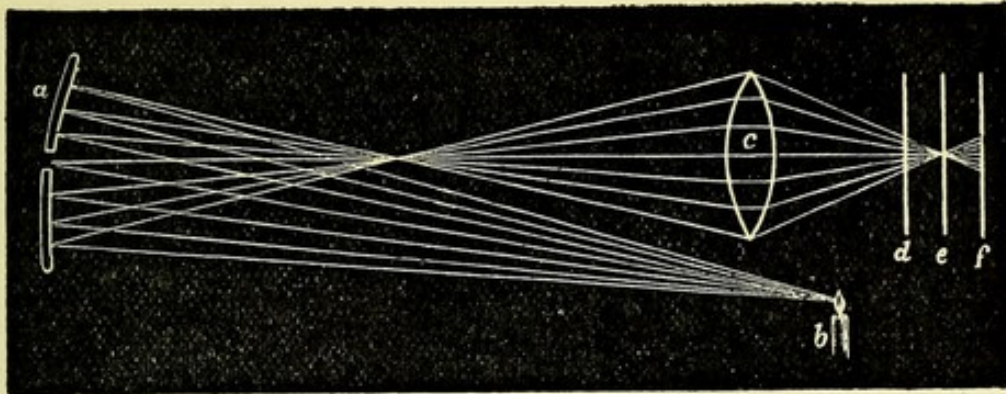
*a.* The concave mirror. *b.* The candle. *c.* The lens. *e.* The screen.  
*d.* Small image of candle found on screen. *f.* Dense shadow around.



from which the concave mirror received its rays ; erect because it has suffered two inversions.

This image of the lamp is surrounded by a sharply defined and dense shadow.

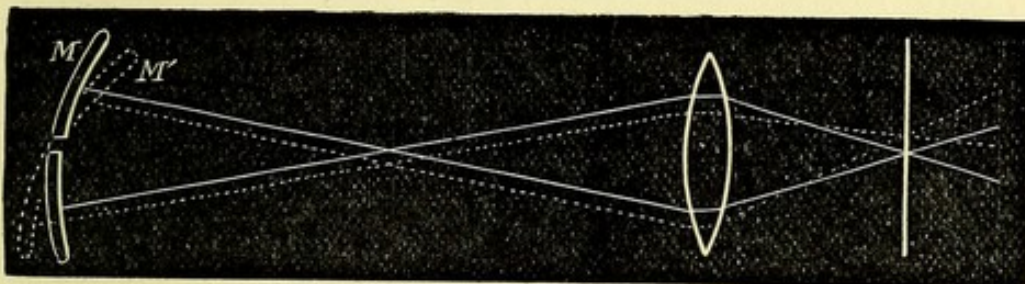
FIG. 44.



At *e* a small image of the candle is found ; at *d, f*, circles of diffusion.

If we move the lens near to or farther from the screen, the area of light becomes larger, and the illumination feebler, owing to the circles of diffusion on the screen.

FIG. 45.



*M.* The mirror. *M'*. The mirror after rotation. The extremities of the dotted line have moved in the opposite direction to the rotation of the mirror.

The mirror being rotated on its vertical axis, the image of the candle, with the surrounding shadow,



will always be found to move in the opposite direction to the mirror, whatever be the distance of the lens from the screen.

This is exactly what takes place in the eye, of which our screen and lens are a representation.

It may therefore be stated that the illumination and shadows which we see, are an enlarged image of the lamp with the surrounding shadow, brought more or less to a focus on the retina according to the refraction of the eye. They always move against the mirror, but as these movements are seen through the transparent media of the eye, and thereby undergo refraction, the "apparent" may differ from the "real" movements. The image we see of the lamp, and its surrounding shadows, are formed as all other images are formed.

In emmetropia the image is formed at infinity, so that the observer at a distance sees it only diffused and blurred (Fig 35).

In hypermetropia it is formed behind the eye (Fig. 36), the higher the hypermetropia, the nearer will the image be to the nodal point.

The observer, at a distance, sees a clear, erect image, which is formed behind the eye.

In myopia an inverted image is formed in the air in front of the eye, which can be clearly seen by the observer, if he be at a sufficient distance from it, so as to be able to accommodate for the particular spot at which the aërial image is formed (Fig. 37).

We have already seen that the real movements of the shadows on the retina are against the mirror.



In hypermetropia the final image of the candle and its surrounding shadow produced by the concave mirror is an erect one, formed behind the eye, and as it is viewed through the dioptric system of the eye, it therefore moves against the mirror.

In myopia the final image is an inverted one, projected forwards. This, therefore, moves with the mirror, it having undergone one more inversion.

To this rule, that in myopia the image moves with the mirror, there are two exceptions :

1st. If the observer be nearer the patient than his far point, but not within the focal distance of the mirror, the image will move against the mirror. This is frequently the case in low degrees of myopia, where the patient's far point is beyond 120 cm.

2nd. If the observer be within the focal distance of the mirror, although beyond the far point of the patient, the image will in this case also move against the mirror. This latter source of error can always be avoided by using a concave mirror of 22 cm. focus and keeping 120 cm. from the patient.

Therefore, if the image move with the mirror, the case is certainly one of myopia. If it move against the mirror, it is most likely one of hypermetropia; but it may be emmetropia, or a low degree of myopia.

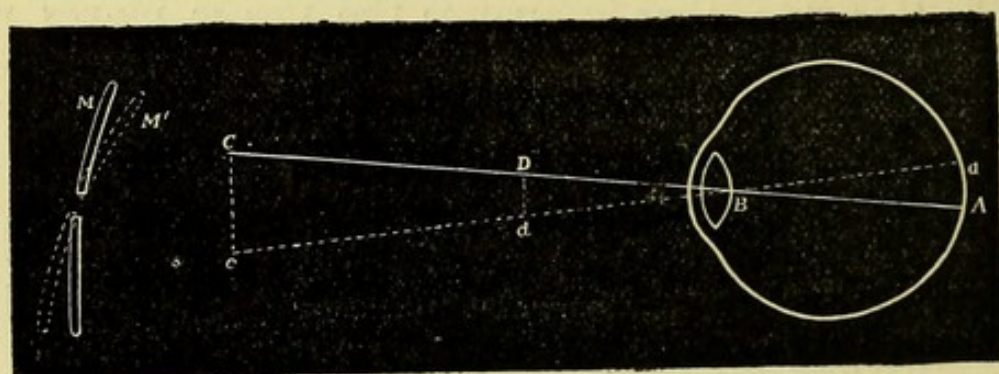
The movements tell us the form of ametropia we have to deal with. The extent of the movements on rotation of the mirror, the clearness of the image and the brightness of its edge, enable us to judge approximately the amount of ametropia to be corrected ;



some practice, however, is required before we can form an opinion with anything like accuracy.

The extent and rate of movement is always in direct proportion to the ametropia; the greater the error of refraction, the less the movement, and the slower does it take place. This may be explained in the following way :

FIG. 46.



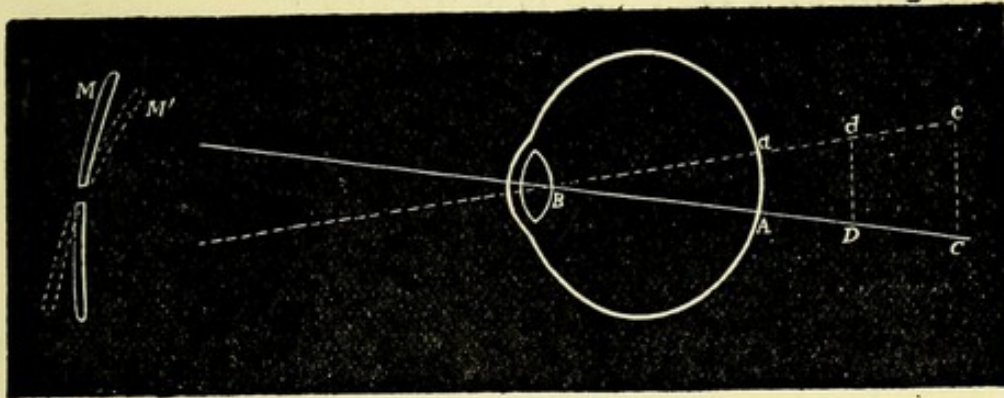
Suppose A to be the image of a luminous point formed on the retina, and that a line be drawn from A through the nodal point B to c. Now, if the case be one of myopia (Fig. 46), an inverted projected image of A is formed somewhere on this line, say at c. The higher the myopia, the nearer to the nodal point will this image be; and hence we may suppose it formed as near as D. If the mirror be now rotated so that it takes up the position of the dotted line, c will have moved to c, and D to d; whence it is clear that c has made a greater movement than D.

Had the case been one of hypermetropia (Fig. 47), the image would have been projected backwards, and, as in myopia, the higher the degree of hypermetropia, the nearer to the nodal point is the image formed.



In this case, the line from the nodal point B to A is prolonged backwards, and the image of the luminous point in a low degree of hypermetropia is formed,

FIG. 47.



say at c, and in a higher degree, say at d. On moving the mirror into the position of the dotted line, c moves to c and d to d; whence it is clear that c has made a greater movement than d.

Therefore, as the ametropia increases, the extent of the movement of the image decreases. The clearness of the image and the brightness of its edge decrease, as the ametropia increases.

As shown in Fig. 43, it was before stated that on placing before a screen a convex lens, at such a distance that converging rays from a concave mirror, having crossed and become diverging, are brought to an exact focus, there is then formed a very small, erect, well-defined image on the screen of the lamp from which the concave mirror received its rays. On moving the lens nearer to or farther from the screen, the larger becomes the area of light and the feebler



the illumination, owing to the circles of diffusion formed on the screen.

Therefore, in the case of the eye, the greater the ametropia, the larger is the circle of diffusion and the weaker the illumination, so that the image we see is less bright and its edge less distinct.

It is, therefore, in the lower degrees of ametropia that we get the brightest and best-defined shadows ; and when working out cases by retinoscopy, we may assume to be approaching the stage of correction when we thus see them.

In myopia and hypermetropia of high degrees, the shadow becomes more or less crescentic in shape, instead of linear, due to the shape of the circle of diffusion formed on the retina. Having thus answered the questions concerning the shadows which we see in retinoscopy, we are in a position to pursue further the practical working of the subject with special reference to the correction of any existing error of refraction by glasses.

The patient, then, being seated in the dark room, the pupils dilated, and the lamp over his or her head, as before described, we take up our position 120 cm. in front, with a concave mirror of 22 cm. focus (a Galezowski mirror is the one commonly used, and is found convenient). The patient is then directed to look at the centre of the mirror, so that the light from the lamp may be reflected along the visual axis. On looking through the perforation of the mirror, we get the ordinary fundus reflex, bright if the patient be emmetropic, less so the greater the ametropia.



We now rotate the mirror on its vertical axis to the right. If a vertical shadow come across the pupil from the patient's right, *i.e.* in the same direction as the movement of the mirror, or what is the same thing, if the shadow move in the same direction as the circle of light on the patient's face, the case is one of myopia. Should the edge of the image appear well defined and move quickly, in addition to a bright fundus reflex, we infer that the myopia is of low degree and proceed to correct it.

Each eye must of course be tried separately.

The patient having put on a pair of trial spectacle-frames, we place a weak concave glass, say  $-1$  D., before the eye we are about to correct. If the image still move with the mirror, we place in the frame  $-1.5$  D., then  $-2$  D., and so on, until we find the point at which no distinct shadow can be seen. Supposing this to be  $-2$  D., and that on trying  $-2.5$  D. the image move against the mirror,  $-2$  D. is assumed to be the correcting-glass. This, however, will be found not to be the full correction of the myopia, because, being situated at 120 cm. from the patient, when his far point approaches that distance, we are unable to distinguish the movements of the shadow; and when the far point of the observed, though not situated at infinity, is still at a greater distance than the observer, we get a shadow moving in the opposite direction. Hence it is customary in cases of myopia to add on  $-.5$  D. to the correcting-glass, and this would give us  $-2.5$  D. as the proper glass for our case.



In correcting myopia, I find it a convenient and reliable plan to stop at the weakest concave glass which makes the image move against the mirror, and put that down as the correcting-glass.

Had we obtained in our case a reverse shadow, we should then try convex glasses, which, if  $+0.5$  D. neutralized, we should assume the case to have been one of low myopia. Had it required  $+1$  D., then it would be one of emmetropia; above this, hypermetropia. We proceed exactly as before, putting up stronger and stronger glasses, until we are unable to make out the movements of the image. This is assumed to be the correcting-glass, and, just as in the above case the myopia was under-corrected, so in this the hypermetropia is slightly over-corrected; and hence it is usual to deduct from this glass  $+1$  D., or we may stop at the strongest convex glass with which we still get a reverse shadow.

To sum up, therefore, if the shadow move with the mirror it is a case of "myopia;" if against, it may be weak myopia if  $+0.5$  D. cause the image to move with the mirror; emmetropia if  $+1$  D. neutralized it; hypermetropia if a stronger glass is required.

The points to be observed are—(1) the direction of the movement of the image, as indicating the kind of ametropia; (2) the rate and amount of movement; (3) the brightness of the edge of the image; (4) and the amount of fundus reflex as indicating the degree.

We have taken notice only of the horizontal axis, but any other meridian will, of course, do equally well, if the case be one of hypermetropia or myopia simply.



If, however, the case be one of astigmatism, then the axes are different.

In astigmatism, the flame of the candle on the retina, instead of being, as in emmetropia, a small well-defined image, or as in myopia or hypermetropia, a circle of diffusion, is distorted so as to be more or less of an oval form, according to the position of the retina and the maximum and medium curvatures of the cornea.

In the normal eye, the focus of the vertical meridian of the cornea is slightly shorter than that of the horizontal. So long as no impairment of vision occurs, the eye is said to be normal. When, however, the acuteness of vision is diminished, then astigmatism is said to exist.

Parallel rays, passing through a convex spherical lens, disregarding some slight irregularities due to aberration, form a cone, any section of which, perpendicular to its axis, will be a circle. The size of the circle depends upon the distance of the point at which the lens is from its focus. If beyond the focus the cone be divided, as in myopia, the rays having crossed and become divergent, a circle of diffusion is formed on the retina. In hypermetropia the cone is divided before having come to a focus, and thus forms a diffusion circle. But in astigmatism the divided cone is circular only at one point, No. 4 in Figs. 61 and 62. To explain this, we place in front of the convex spherical glass a weak convex cylindrical glass, with its axis horizontal. The result of this is, that parallel rays passing through this com-



bination do not form a circular cone, because the rays which pass through the vertical meridian come to a focus before those passing through the horizontal, as shown in Fig. 61.

The rays being divided at 1, an oblate oval is formed; at 2 a horizontal straight line, the vertical rays having come to a focus; at 3, 4, 5 the vertical rays have crossed and are diverging, and the horizontal rays are approaching; at 4, a circle is formed; at 6, a vertical straight line, the horizontal rays having met and the vertical still diverging; a large prolate ellipse is formed at 7.

So that in astigmatism, the image on the retina is more or less of an oval, instead of being either a small well-defined image of the candle, or a circle of diffusion, according to whether the eye be emmetropic, myopic, or hypermetropic. This oval may have its horizontal and vertical edges, corresponding to the horizontal and vertical meridians of the cornea. Frequently, however, they have an intermediate position, which, as will be presently shown, is the cause of the oblique shadows in cases of astigmatism.

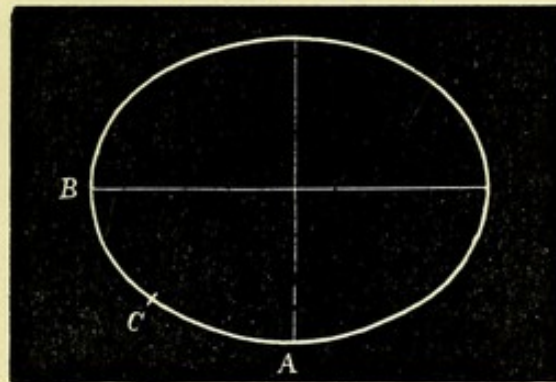
The image of this oval is formed by the dioptric apparatus of the eye in the same way as all other images are formed, as has been ably explained by my friend Mr Charnley, in a paper by him in the 'Royal London Ophthalmic Hospital Reports' for August, 1882. Thus :

" Suppose the retina of the eye to be so situated (1 in Fig. 61) that the cone of light passing through the pupil makes an oblate oval, then rays proceeding



from any point (A) on the horizontal edge, after refraction through the unequally curved meridians of the astigmatic eye, converge to, or diverge from, not a point, but two straight lines. The image of the edge will be referred to the position where the image

FIG. 48 (*Charnley*).



of adjacent points on the edge are drawn out into ovals, whose long axes are horizontal, and therefore overlap, and so cause the greatest condensation of rays. Now, this position is at the far point of the vertical meridian, where, indeed, the image of A and adjacent points are ovals, so elongated that they may be considered as horizontal straight lines.

“The position of the image of the horizontal edge of the retinal image depends, then, on the refraction of the vertical meridian of the eye, and is in front of, behind the eye, or at infinity, according as the eye is myopic, hypermetropic, or emmetropic. The horizontal edge, then, of the retinal image, and the vertical meridian of the astigmatic eye, stand then in the same relation as the whole image and any meridian in the spherical eye.



“The image of the vertical edge of the oval retinal image, depends on the refractive condition of the horizontal meridian of the eye.

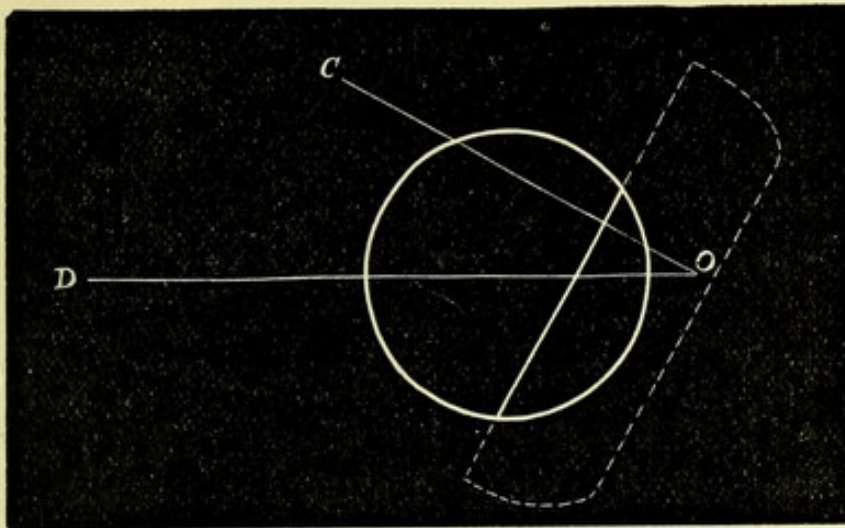
“Of the part of the edge of the oval near *c*, intermediate between *A* and *B*, we get no distinct image formed, because the images of adjacent points are ovals, whose long axes are either horizontal or vertical, whilst these adjacent points are arranged neither horizontally nor vertically with respect to one another. Hence we have only two distinct shadows, which are perpendicular to the principal meridians of refraction—that is, horizontal and vertical.”

The meridians have been assumed to be horizontal and vertical. Frequently they are so, but often they are more or less oblique, and then the shadows, being at right angles to the chief meridians, are also oblique, and so also will the movements be.

The oblique movements of the shadow are independent of the direction in which the mirror is rotated.

This obliquity is produced thus: if behind a circular opening, which is to represent the pupil, we place obliquely an oval piece of card, which is to represent the image on the retina, so that that part of its edge, which occupies with regard to the circular opening an oblique position, on moving it across in the direction *o d*, it has the appearance of moving in the direction *o c*, at right angles to the edge of the card. Hence the direction of the shadow's movement is deceiving, and its oblique edge is due to the shape of the image, and not to the direction in which the movements of the



FIG. 49 (*Charnley*).

mirror are made. Therefore the apparent movements are always at right angles to the edge of the shadow.

The same takes place in astigmatism, the two chief meridians of which are parallel and perpendicular to the shadows. In using retinoscopy, therefore, when the edge of the image is oblique, we know at once that the case is one of astigmatism. If, however, it should be horizontal or vertical, we judge, if one shadow be more distinct or quicker in its movements than the other, though we are not always able to say at once that astigmatism exists. We therefore proceeded to correct one meridian. If the shadow move against in all meridians, we first take the vertical, and put up in front of the patient, in a spectacle-frame, convex spherical glasses, until we find the strongest with which the shadow still moves against the mirror. We put this down as the correcting-glass for this meridian, and let us suppose that glass to be  $+2\text{ D.}$  We next take notice of the horizontal meridian, and if  $+2\text{ D.}$  is also the highest glass with which we still



get a reverse shadow, then of course we know the case is one of simple hypermetropia. But supposing the highest convex glass had been + 4 D., we indicate it conveniently thus :

$$-\left| \begin{array}{c} + 2 \text{ D.} \\ - + 4 \text{ D.} \end{array} \right.$$

The case is one of compound hypermetropic astigmatism, and should require for its correction + 2 D. spherical combined with + 2 D. cylinder axis vertical.

We will take another case—that in which the vertical meridian requires - 2 D. to give a reverse shadow, and the horizontal + 2 D., this being the highest glass with which we still obtain a reverse shadow. Here we have a case of mixed astigmatism which can be corrected in either of the three following ways :

1st. - 2 D. cylinder axis horizontal combined with + 2 D. cylinder axis vertical; this is a plan seldom used, and is not so easy to work with as a sphere and a cylinder.

2nd. - 2 D. spherical combined with + 4 D. cylinder axis vertical, or

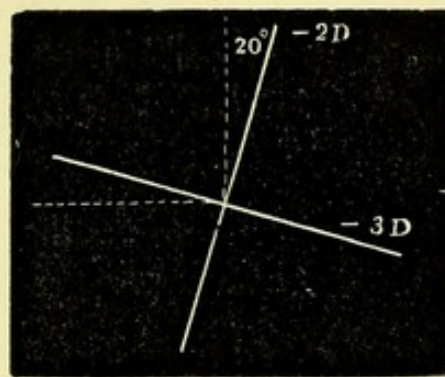
3rd. + 2 D. spherical combined with - 4 D. cylinder axis horizontal. This last is perhaps the preferable plan. Opticians like working - cylinders on to + spheres, rather than + cylinders upon - spheres.

Supposing the axis of the shadow to be oblique, we know at once that astigmatism exists, and we proceed to correct each meridian separately, moving the mirror at right angles to the edge of the shadow, not hori-



zonally and vertically. We judge of the amount of obliquity by the eye, and can frequently tell within a few degrees. If the vertical meridian be  $20^\circ$  out of the vertical, and require for its correction  $-2$  D., and the axis at right angles to this (which will be therefore at  $110^\circ$ ) require  $-3$  D. we express it thus :

FIG. 50.



and correct it with sphere  $-2$  D. combined with cylinder  $-1$  D. axis  $20^\circ$ , the case being one of compound myopic astigmatism.

Often one is able to put up the cylinder in the spectacle frame with the exact degree of obliquity.

Having found the glasses which correct the two meridians, we put up the combination in a spectacle trial frame, and if we now get only a slightly reversed shadow in every direction, the glasses are assumed to be the right ones, and we proceed to confirm it by trying the patient at the distant type, making any slight alterations that may be necessary.

I cannot too strongly recommend the use of a solution of atropine, gr. ii, to  $\mathfrak{z}$ j., frequently dropped into the eyes for three days prior to the examination, so as



thoroughly to relax the accommodation. It can be used without fear, and without a great amount of inconvenience in most young people under twenty years of age. I have worked out a great many cases of astigmatism, and feel more and more the necessity of using this drug to enable one to arrive at exact results. I might almost say that I have never seen a young person whose astigmatism has been worked out without atropine wearing the right correction; and the inconvenience entailed upon the patient for two weeks by its use is not to be compared to the trouble and asthenopia from which he or she is so liable to suffer if the glasses worn are not the proper ones.

In old persons with small pupils, in whom it is difficult to see the movements of the shadow, and in whom solutions of atropine of the ordinary strength are dangerous, on account of the occasional occurrence of that much dreaded disease 'glaucoma,' which has been clearly traceable to its use, I have often found it convenient to dilate the pupil with homatropine in solution, grs. ii, to ℥j. of water, or with an exceedingly weak solution of atropine  $\frac{1}{40}$  gr. to ℥j. of water.

A few cases from my note-book will help to make the subject clear.

CASE 1.—Boy, aged 11 years.

$$\begin{array}{l} \text{R. } \frac{6}{12} - 1 \text{ D.} = \frac{6}{8} \\ \text{L. } \frac{6}{12} - 1 \text{ D.} = \frac{6}{8} \end{array}$$

Bright fundus reflex, shadow moves with the mirror, but with  $-0.5$  D. a reverse shadow is seen. The case, therefore, looks like one of weak myopia. Ordered guttæ atropiæ grs. ii, to ℥j., three times a day; on the



third day, with retinoscopy + 1 D. still gives an opposite shadow. On trying the patient at the distant type with + 1 D. both eyes read  $\frac{6}{6}$  well. This, therefore, was a case of hypermetropia simulating weak myopia, due to ciliary spasm.

CASE 2.—Girl, aged 13, suffering from ‘tinea tarsi.’

$$\begin{array}{l} \text{R. } \frac{6}{8} + 1 \text{ D.} = \frac{6}{8} \\ \text{L. } \frac{6}{8} + 1 \text{ D.} = \frac{6}{8} \end{array}$$

Guttæ atrop., grs. ii, to 3j. Fundus reflex, moderate; a reverse shadow is seen moving somewhat slowly. On trying + 2 D. shadows become much more distinct and the movements quicker; + 4 D. is found to be the strongest glass with which we still get a reverse shadow. With + 4 D.  $\frac{6}{6}$  was read but with no stronger glass, this therefore is the measure of the patient's total hypermetropia.

CASE 3.—Young man, aged 20.

$$\begin{array}{l} \text{R. } \frac{6}{24} + 4 \text{ D.} = \frac{6}{8} \\ \text{L. } \frac{6}{24} + 4 \text{ D.} = \frac{6}{8} \end{array}$$

Under atropine; right eye at distant type sees only  $\frac{6}{60}$ . Fundus reflex very dull, movements of shadow slow and against the mirror. On putting up + 5 D. the reflex is much brighter, the edge of shadow distinct and its movements quicker. We try + 6, 7, 8, 9, and the last gives a shadow moving with the mirror. + 8 D. is the highest, which still leaves the shadow moving against. On trying the eye at distance, type  $\frac{6}{9}$  and 4 letters of  $\frac{6}{6}$  are at once read. No alteration in the glass improves sight.

Left eye. Fundus reflex, and movements as in right. We commence by trying + 8 D. which we found the







up from Cardiff about her eyes; suffers much from headache and pain in eyes, especially the right, during the evenings. Has tried many opticians to get spectacles to suit her, but has always been unable to do so. R.  $\frac{6}{36}$  slightly improved with  $-1$  D. L.  $\frac{6}{36}$  also slightly improved with  $-1$  D. On placing the patient in the dark room, retinoscopy at once shows the case to be one of mixed astigmatism, and the chief meridians horizontal and vertical; we proceed to correct each meridian, and the result is—

$$\text{R.} - \left| \begin{array}{l} -5 \text{ D.} \\ -+1 \text{ D.} \end{array} \right. \quad \text{L.} - \left| \begin{array}{l} -5 \text{ D.} \\ -+1.5 \text{ D.} \end{array} \right.$$

On trying the combination thus formed before the right eye,  $\frac{6}{12}$  is read. We express the vision of right eye thus—

$$\text{R. } \frac{6}{36} + 1 \text{ D. sp. } \ominus - 6 \text{ D. cy. axis horizontal} = \frac{6}{12}.$$

With the left eye the combination gives, with the cylinder not quite horizontal, but slightly outwards and downwards,  $\frac{6}{9}$ .

$$\text{L. } \frac{6}{36} + 1.5 \text{ D. sp. } \ominus - 6 \text{ D. cy. axis } 170^\circ = \frac{6}{9}.$$

The patient remarked that she had never seen things so clearly before. This result was very satisfactory, and was arrived at in about ten minutes, thus sparing one's self an infinite amount of time and trouble, which would have been required to work out such a case by any of the older methods. As is my usual practice in cases of astigmatism, I ordered guttæ atrop., grs. ii, to ʒj. three times a day for four days, when the result was—



$$\text{R. } \frac{6}{80} + 2 \text{ D. sp. } \ominus - 5 \text{ D. cy. axis } 175^\circ = \frac{6}{9}.$$

$$\text{L. } \frac{6}{80} + 2 \text{ D. sp. } \ominus - 5 \text{ D. cy. axis } 170^\circ = \frac{6}{9}.$$

In this case the glasses were again tried after atropine was recovered from, and the following glasses ordered, which were of course to be worn constantly :

$$\text{R. } \frac{+1 \text{ D. sp.}}{-6 \text{ D. cy. axis } 175^\circ} \qquad \text{L. } \frac{+1.5 \text{ D. sp.}}{-6 \text{ D. cy. axis } 170^\circ}.$$

In all cases before ordering spectacles, the effect of the atropine must be allowed to pass off and the result confirmed, which can usually be done in about a week or ten days; it is then frequently found that the spherical glass, in cases of hypermetropia and hypermetropic astigmatism, requires slightly diminishing, usually about 1 D., owing to the tone of the ciliary muscle. In myopia and myopic astigmatism, the spherical glass has to be slightly increased for the same reason.

Dr. Storey, of Dublin, has lately advocated the use of a plane mirror in retinoscopy ('Ophthalmic Review,' August, 1883), the observer being 4.5 metres from his patient. The advantages he claims for the plane over the concave mirror are :

1st. That the movements of the shadow are in the same direction as those of the disc and blood-vessels in the method of testing refraction, by the use of the mirror alone, viz. in the same direction as the observer or the mirror's movements in hypermetropia and in the opposite direction in myopia.

2nd. The more accurate estimate of the error of refraction, having no additions or subtractions to make



on account of the patient's far point, thus, supposing the patient to be myopic, the observer at 4.5 metres, can estimate the myopia to within .25 D.

3rd. The exercise which it compels the ophthalmic surgeon to take in walking backwards and forwards to change the trial lenses.

To some observers this last may hardly appear in the light of an advantage.

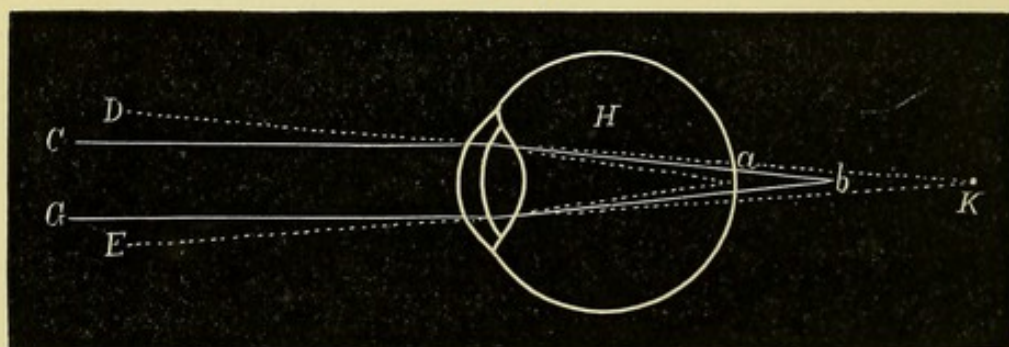


## CHAPTER V

## HYPERMETROPIA

HYPERMETROPIA (H) ('Υπέρ, in excess; μέτρον, measure; and ὤψ, the eye) may be defined as a condition in which the antero-posterior axis of the eyeball is so short, or the refracting power so low, that parallel rays are brought to a focus behind the retina (the accommodation being at rest). In other words, the focal length of the refracting media is greater than the length of the eyeball.

FIG. 51.



Parallel rays focus at *b* behind the retina; those coming from the retina emerge as diverging rays.

In the passive hypermetropic eye, therefore, parallel rays *c* and *g* come to a focus behind the retina at *b*,

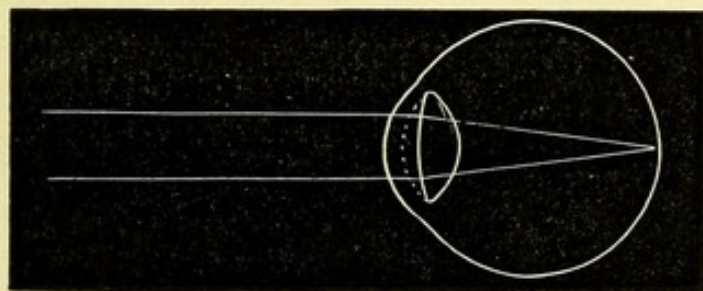


forming on it at  $a$ , a circle of diffusion instead of a point. Rays coming from the retina of such an eye emerge having a divergent direction ( $D$  and  $E$ ); these, if prolonged backwards, will meet at a point ( $K$ ) which is the punctum remotum, and being situated behind the eye it is called negative.

The distance of the punctum remotum behind the eye will equal the focus of the convex lens which corrects the hypermetropia; thus, supposing it situated 20 cm. behind the retina  $\frac{1.00}{20} = 5$ , 5 D. will be the convex glass which will render parallel rays so convergent that they will focus on the retina, or cause rays from the retina to be parallel after passing through it; allowance must be made for the distance between the cornea and the convex lens.

The hypermetropic eye at rest is only able to bring convergent rays to a focus on the retina. All rays in nature are divergent, some so slightly so that when coming from a distant object, they are assumed to be parallel. Rays can only be made convergent by means of accommodation or by a convex lens held in front of the eye.

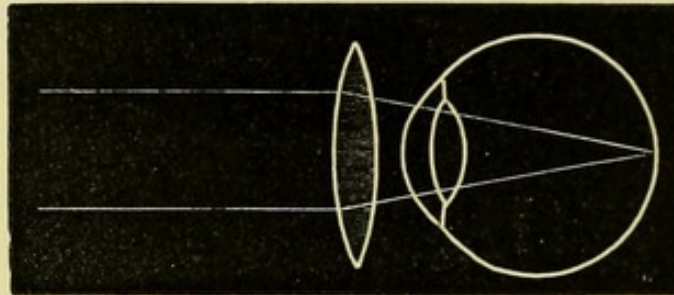
FIG. 52.



Parallel rays focussed on retina by accommodation. The dotted line shows the lens more convex as a result of the contraction of the ciliary muscle.



FIG. 53.



Parallel rays rendered so convergent by passing through a convex lens that they focus on the retina.

So that a person with hypermetropia, having to use some of his accommodation for distance, starts with a deficit for all other requirements equal to the amount of hypermetropia.

Thus, supposing an individual hypermetropic to the extent of 4 dioptries, and possessing 6 D. of accommodation, he will by the exercise of this power to the extent of 4 D., be able to bring parallel rays to a focus on the retina, leaving 2 D. of accommodation for near objects. This brings his near point to 50 cm., a distance at which he would be unable to do near work.

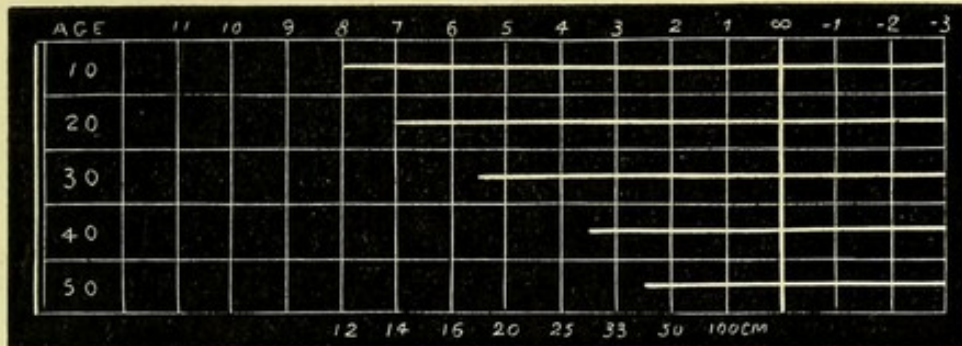
Besides, it must be remembered that only a part of the accommodation can be used for sustained vision, fatigue soon resulting when the maximum amount of accommodation is put in force.

The following diagram is intended to show by the number of spaces, each representing a diopetre, through which the thick lines are drawn, the amount of accommodation possessed by a patient who is hypermetropic to the extent of 3 D., at different ages as given on the left of the diagram. The figures above, indicate the



FIG. 54.

Diontres.



number of dioptres, and those below, the near point for each dioptre of accommodation.

The amount of hypermetropia is calculated and expressed by that convex glass which makes parallel rays so convergent that they meet on the rods and cones of the retina, the accommodation being suspended.

The commonest amount of error is about 2 D. Small degrees may require some trouble to discover, and can only possibly be found out after the eye has been atropized.

Hypermetropia is divided into *latent* and *manifest*. The manifest, Donders subdivides into absolute, relative, and facultative :

Absolute, when by the strongest convergence of the visual lines accommodation for parallel rays is not attained; this variety is seldom met with in young people.

Relative, when it is possible to accommodate for a near point by converging to a point still nearer, in fact, by squinting.



Facultative, when objects can be clearly seen with or without convex glasses.

In youth the hypermetropia may be facultative, becoming in middle age relative, and in old age absolute.

We will now consider the causes of hypermetropia and the points in which the hypermetropic eye differs from the emmetropic.

By far the most common cause of hypermetropia is imperfect development, the antero-posterior diameter of the eyeball being too short. To this variety Landolt has given the name *axial hypermetropia*. It may, however, arise from absence of the lens, from a flattened condition of the cornea produced either by disease or occurring congenitally, from detachment or protrusion of the retina owing to a tumour or exudation behind it.

The hypermetropic eye is less than the normal in all its dimensions, especially the antero-posterior. The optic nerve is smaller, and contains fewer fibres, while the expansion of the retina is also less. For these last two reasons, when the hypermetropia is high the acuteness of vision is frequently below the normal. When the development is very imperfect it constitutes the condition known as "microphthalmos."

So constant and regular is this decrease in the antero-posterior diameter of the hypermetropic eye, that from the amount of hypermetropia can be estimated the diminution in length of the axial line. The axial line in emmetropia is estimated to be 22.824 mm. in length.



For .5 D. of H. there is a diminution in the axial line of 16 mm.

1 D.	„	„	„	.31	„
1.5	„	„	„	.47	„
2.	„	„	„	.62	„
2.5	„	„	„	.77	„
3.	„	„	„	.92	„
3.5	„	„	„	1 06	„
4.	„	„	„	1.21	„
4 5	„	„	„	1.35	„
5	„	„	„	1.5	„
6.	„	„	„	1.76	„
7.	„	„	„	2.03	„
8.	„	„	„	2.28	„
9.	„	„	„	2.53	„
10.	„	„	„	2.78	„

Hypermetropia may be looked upon as a congenital defect, frequently also it is hereditary, several members of the same family suffering from it.

The ciliary muscle, upon the action of which the accommodation depends, is much larger than in emmetropia, the anterior portion, which consists chiefly of circular fibres, being especially developed, no doubt hypertrophied by the constant state of contraction in which it is kept. This contraction is called into action by the instinctive desire for clear images which all eyes possess, the accommodation having to be used for distant as well as for near objects. Another result of the constant and excessive accommodation is that the convergent power with which it is so intimately linked is kept in a state of constant tension, so that in many children convergent strabismus is gradually produced. To understand how this con-



vergent strabismus becomes developed, I must refer the reader to the chapter on that subject.

As the lens and iris are more forward, the anterior chamber is shallower, the centre of motion is relatively further back, while the angle  $a$  which is formed between the visual and optic axis is invariably greater, averaging about  $7^\circ$  (see p. 157). The result of this large angle  $a$  in hypermetropia is, that the eyes often have an appearance of divergence, so that it has been mistaken for real divergence, whereas in myopia the small angle causes the eyes to look as if they converged.

The external appearance of the hypermetropic eye is often characteristic. The sclerotic looks flat in front, and makes a strong curve backwards in the region of the equator; this can be well seen on extreme convergence; the anterior chamber is shallow, the pupil small, and there is apparent divergent strabismus.

Sometimes the face also has a characteristic appearance, being flat looking, with depressed nose, shallow orbits, and the eyes set far apart. Frequently, however, there is no distinctive physiognomy.

The hypermetropic eye is very liable to asymmetry, as will be shown when treating of astigmatism.

**Symptoms of hypermetropia.**—If the patient be young, his accommodation good, and the error of a low degree (as 2 or 3 D.), no ill effects may for some time be noticed; at length, however, a point is reached when the accommodation is not equal to reading and near work, and accommodative asthenopia is the result



(p. 174). This is especially liable to show itself after an illness, or if the patient's health has deteriorated from over work, anxiety, or other causes. He then complains that after working or reading for some time, especially during the evenings, the type becomes indistinct, and the letters run together. After resting awhile the work can be resumed, to be again shortly laid aside from a repetition of the dimness. The eyes ache, feel weak, water, &c., frequently headache supervenes. When the hypermetropia is of high degree the patient may be said by his friends to be shortsighted, because when reading he holds the book close to his eyes; by doing this he increases the size of his visual angle, and thus gets larger retinal images; this is counter-balanced by increase in the circles of diffusion, but as the pupils also contract by approaching the book to his eyes some of these are cut off; so that the advantage is in favour of holding the book close, especially as the patient is probably not accustomed to clear well-defined images. The manner in which the patient reads the distant type is often a guide to us, he takes a considerable time to make out each line, and yet if not hurried, eventually reads the whole correctly. On looking at the eyes one notices that they are red and weak, the lids look irritable, and on eversion the conjunctiva, especially of the lower lids, is hyperæmic, the papillæ frequently enlarged, and the edges of the lids sometimes affected with sycosis. All these symptoms are probably the commencement of troubles which, if allowed to go on, may develop into granular lids, derangements of the



lachrymal apparatus, &c., this much we can see ; how much more injurious must be the changes which are liable to take place in the interior of the eyeball from prolonged hyperæmia ! It cannot be too forcibly insisted on that in all ophthalmic cases, except those of an acute character, the refraction should be taken and recorded as a matter of routine, since complaints which prove very intractable are often easily and quickly cured when the proper glasses have been prescribed.

To test the hypermetropia and measure the amount we take the patient's visual acuteness, each eye separately, and having found that they are alike in their refraction, we try the two together ; stronger glasses being often borne when both eyes are used than when one is excluded from vision.

The *strongest* convex glass with which he is able to read  $\frac{6}{6}$ , or with which he gets the greatest acuteness of vision, is the measure of the *manifest* hypermetropia (Hm.). This is not, however, the total hypermetropia, for if the accommodation be paralysed, by applying a solution of Atropiæ sulp., grs. iv to ʒj, three times a day for four days (when we may feel sure that not the least vestige of accommodation remains), a much stronger glass can be tolerated, and will be required to enable the patient to read  $\frac{6}{6}$ . This strong glass represents the total hypermetropia, the additional amount to that found as Hm being called *latent* (Hl.).

The following plan, which I learnt from Mr. Tweedy, is an excellent one for measuring the mani-



fest hypermetropia. Place in spectacle-frames before the eyes such convex glasses as over correct the Hm. (+4 D. will usually do this). Then hold in front of these, weak concave glasses until we find the *weakest*, which thus held in front of +4 D. enables  $\frac{6}{6}$  to be read. The difference between the glasses is then the measure of the Hm. By this plan the ciliary muscle is encouraged to relax, and we get out a larger amount of manifest hypermetropia. Thus, supposing -2 D. the weakest glass, which held in front of the convex 4 D., enables the patient to read  $\frac{6}{6}$ , +2 D. is the measure of the Hm. (+4 D. - 2 D. = +2 D.). As age advances the accommodation diminishes, and the latent hypermetropia becomes gradually manifest. Thus, a person may have 6 D. of hypermetropia latent at 10 years of age, 3 of which may become manifest at 35, and the whole of it at about 65 or 70, when the total hypermetropia is represented by the manifest.

With the advance of age certain changes take place in the structure of the crystalline lens, by which its refraction becomes diminished; this takes place in all eyes, and at a regular rate, thus at fifty-five the refraction has diminished .25 D., at sixty-five .75 D., at sixty-eight 1 D., and at eighty as much as 2.5 D. Hypermetropia when thus occurring in eyes previously emmetropic is styled *acquired hypermetropia*, in contradistinction to the congenital form, which is called *original hypermetropia*.

Cohn and Erismann are of opinion that the normal refraction of the eye in early childhood is hypermetropic; some remain so, a greater number become



emmetropic as they get older, and a certain percentage of these pass on to myopia.

The **treatment of hypermetropia** consists obviously in prescribing such convex glasses as will give to rays passing through them an amount of convergence, so that they will meet on the retina without undue accommodation. It might be thought that having obtained the measure of the *total* hypermetropia nothing remained but to give such positive glasses as exactly neutralize the defect, and that we should then have placed the eye in the condition of an emmetropic one. Such at first was thought to be the case, though it is by no means so, because persons who have been accustomed to use their accommodation so constantly both for near and distant objects, as is the case with hypermetropes, have very large ciliary muscles which they cannot suddenly completely relax; possibly also the elasticity of the lens capsule is somewhat impaired.

In children and patients under twenty years of age it is much better to atropize them at the first, and so measure once and for all, the amount of total hypermetropia; otherwise it will frequently be found that the spectacles have to be constantly changed, the asthenopia is unrelieved, and probably the patient has to be atropized after all, or becomes dissatisfied and goes off to some one else. Another reason in favour of atropine is, that with it we cannot possibly mistake cases of spasm of the ciliary muscle in hypermetropia for myopia, which might otherwise happen, since the spasm causes the lens to become so convex that



parallel rays are even made to focus in front of the retina, thus simulating myopia.

It must always be borne in mind that it is dangerous to atropize patients above the age of thirty-five, many well-marked cases of "glaucoma" having been traced to the use of this drug; moreover, as age advances the latent hypermetropia gradually becomes manifest, so that the necessity of paralysing the accommodation becomes less.

There exists some difference of opinion among ophthalmic surgeons as to the amount of the total hypermetropia we ought to correct; some give such glasses as neutralize the manifest hypermetropia only, while others, after estimating the total, deduct perhaps 1 D. from this. It will be found that patients vary much as to the amount of correction which is most comfortable for them.

Donders has given the following practical rule, that we should prescribe such glasses as correct the manifest and one fourth of the latent hypermetropia, and this will be found to work well.

For example, a child having 6 D. of hypermetropia, of which 2 only are manifest, will require +3 D. for reading. At the age of twenty about 4 D. will have become manifest, and the patient will then want +4.5 D., at forty 5 D. will be manifest, and he may then be able to bear full correction.

Hence it will be seen that as age advances the spectacles will have occasionally to be changed for stronger ones as the latent hypermetropia gradually becomes manifest.



In some young people we may find out the total hypermetropia under atropine, and then give the full correction, deducting 1 D. for the tone of the ciliary muscle; this plan is especially useful where we are endeavouring to cure strabismus with spectacles alone. Only by experiment can we find out what amount of correction each case of hypermetropia will bear; when spectacles are to be worn constantly, our object is to give as near the total correction as is consistent with the patient's comfort. It is obvious that if a hypermetrope and an emmetrope have the same amount of accommodation, the near point of the former will be further from the eye than that of the latter, hence it follows that presbyopia will commence at an earlier age in hypermetropia than in emmetropia.

The question arises should spectacles be worn constantly or only for near work? So long as distant objects ( $\frac{6}{6}$ ) can be seen comfortably, their use is unnecessary except for reading and near work. This is usually the case in young persons where the hypermetropia does not exceed 3 D. When a convex glass improves distant vision then such can be constantly worn, somewhat stronger ones may be required for reading, &c., as is frequently necessary in old people.

The disadvantage of using spectacles constantly is that after wearing them for some time, the patient finds he is unable to see without them, which is a serious inconvenience, so that the plan is, not to give spectacles for constant use until the hypermetropia has become relative or absolute.

In the diagnosis and estimation of hypermetropia



several methods are useful. We first estimate the acuteness of vision, then proceed to retinoscopy ; with this method we get a reverse shadow, the quicker the movement and the brighter its edge, the lower is the degree of hypermetropia (see page 74).

With the ophthalmoscope by the indirect method of examination, the image of the disc is larger than in emmetropia and becomes less on withdrawing the objective from the eye (p. 50).

By the direct examination at a distance, an erect image of the disc is seen which moves in the same direction as the observer's head (page 52). On approaching the eye, the accommodation of the observer and observed being relaxed, a convex glass is necessary behind the ophthalmoscope, to enable the observer to bring the diverging rays from the observed, to a focus on his retina. The strongest convex glass with which it is possible to see the details of the fundus clearly is the measure of the total hypermetropia, Fig. 39.

Asthenopia and convergent strabismus, two of the most frequent results of hypermetropia, will be treated of in Chapters IX and X.

### APHAKIA.

APHAKIA is the name given by Donders to that condition of the eye in which the lens is absent. There are several causes, by far the most frequent being one of the various operations for cataract, extractions, needle operations, &c. Besides these, aphakia may be caused



by dislocation of the lens from injury, or may occur spontaneously, the latter being probably the cause of congenital cases where no lens can be seen.

Aphakia necessarily converts the eye into a very hypermetropic one. The length of the eyeball which would be required (the curvature of the cornea being normal) to bring parallel rays to a focus on the retina is 30 mm., whereas normally the antero-posterior diameter of the eyeball is only about 23 mm.

To test aphakia; when a bright flame is held in front of and a little to one side of a normal eye, three images of the flame are formed, one erect on the cornea, another erect on the anterior surface of the lens, and a third inverted, and formed on the posterior surface of the lens. On moving the flame up or down, the erect images move with it, and the inverted one in the opposite direction. In aphakia two of these images are absent, viz. those formed on the two surfaces of the lens.

Strong convex glasses will be required to take the place of the absent lens, the previous refraction of the eye of course influencing their strength. If hypermetropic, stronger glasses will be required; if myopic weaker.

The glass usually required by an eye previously emmetropic, to bring parallel rays to a focus on the retina, is from 10 to 13 D.

As every trace of accommodation is lost with the lens, stronger glasses will be required for reading or near work, and to find out the necessary glass for a certain distance we have only to add to the distance



glass, one whose focal length equals the distance at which we wish our patient to see. Thus if he require + 10 D. for distance, and wish to see to read at 25 cm., we add + 4 D. to his other glass and the resulting + 14 D. will bring up his vision to 25 cm.

The patient may be taught a sort of artificial accommodation by moving his spectacles along his nose, nearer or farther from the eyes, his working point being thereby moved away or brought nearer to him.

In correcting aphakia it will often be found that the vision is below the normal. Frequently also there is some amount of astigmatism, especially in cases after cataract extraction.



## CHAPTER VI

## MYOPIA

MYOPIA (M), ( $M\acute{\upsilon}\omega$ , to contract;  $\omega\psi$ , the eye) is the opposite condition to hypermetropia, to express it Donders proposed the name of "Brachymetropia," but we have been so long accustomed to the term myopia that it seems better to make no change.

It owes its name, as its derivation implies, to the habit which so many short-sighted people acquire, viz. of peering between their eyelids; by doing this they decrease the circles of diffusion and thus somewhat improve their vision.

In myopia the visual axis is too long, so that parallel rays focus in front of the retina, cross, and form circles of diffusion (Fig. 55) in place of a clear image.

Divergent rays only focus on the retina, and hence it is necessary that objects be brought so near, that rays coming from them are sufficiently divergent (Fig. 56), or they must be rendered so by passing through a concave lens (Fig. 57).

In myopia the retina is at the conjugate focus of an object, situated at a finite distance. The accommoda-



FIG. 55.

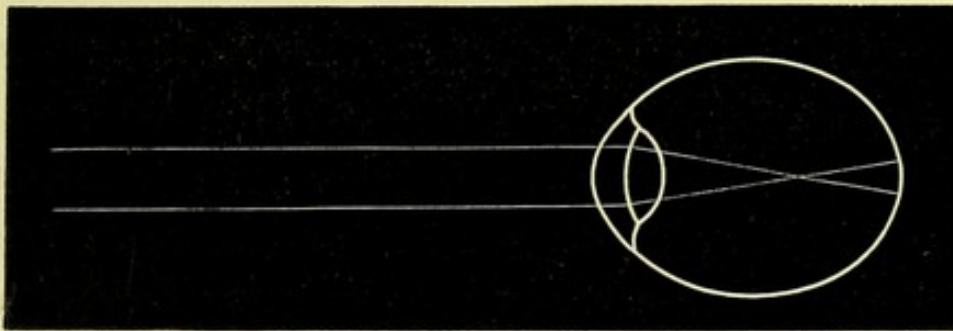


FIG. 56.

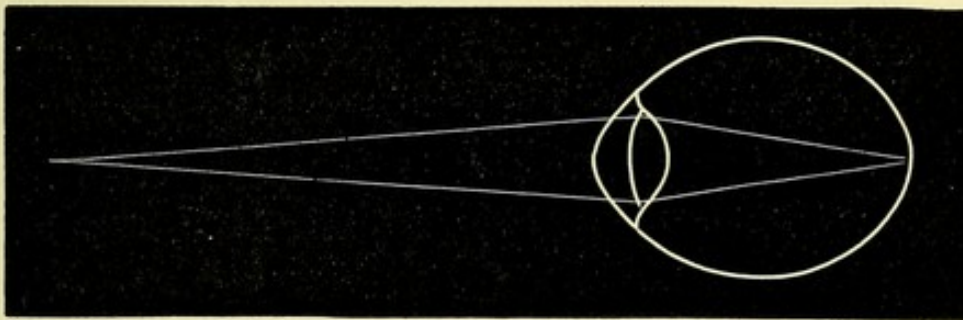
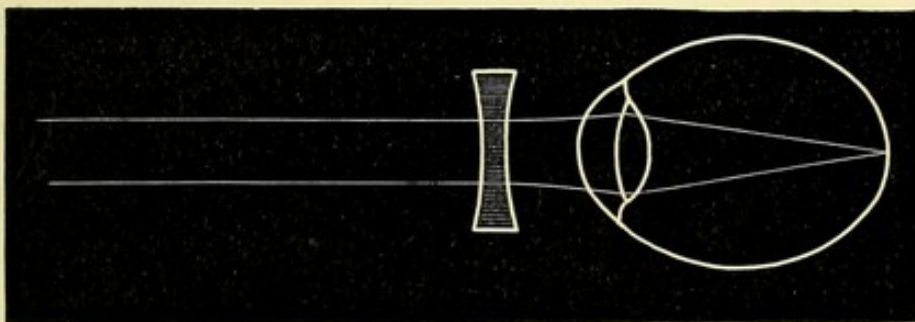


FIG. 57.



tion being at rest, an object situated at this point will be distinctly seen, further off it will be indistinct, nearer it can still be seen distinctly by putting in force the accommodation.

The distance at which objects can be seen clearly (the eye being in a state of rest) is called the far point (*punctum remotum*), and is always at a definite



distance. The higher the myopia the nearer to the eye is the punctum remotum.

This definite distance is the exact measure of the myopia; for instance, if the far point be at 1 metre, a concave glass of that strength ( $-1$  D.) would render parallel rays so divergent, as if they came from a distance of 1 metre, and with a glass of this focus the person would be able to see distant objects clearly.

Myopia was at one time thought to be due to an increase in the convexity of the cornea, but as a matter of fact, the cornea in myopes is usually less convex, and, as a rule, the greater the myopia the less the convexity.

Conical cornea at its commencement often simulates myopia.

Myopia has also been attributed to an increase of the index of refraction of the lens, and such may occasionally be the case in the development of a cataract.

It may therefore be stated that myopia almost invariably depends upon a lengthening of the visual axis, due to the formation of a *posterior staphyloma*, thereby increasing the antero-posterior diameter of the eyeball. This bulging takes place at the outer side of the optic nerve towards the macula, and consists of an extension and thinning of the sclerotic and choroid backwards with more or less atrophy of the latter. This is sometimes called axial myopia.

So constant is this lengthening of the visual axis in myopia that from the number of dioptries of myopia can be calculated the increase in the visual length.

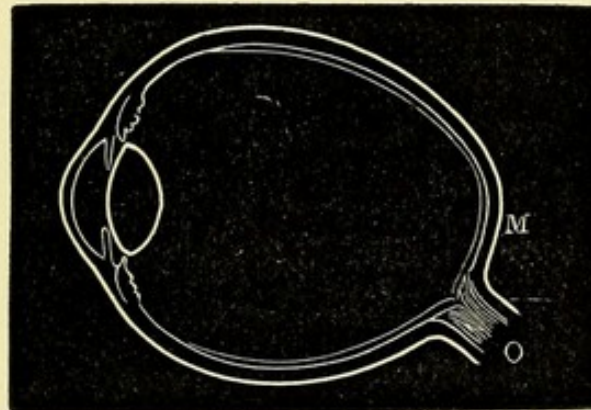


The following table from Wecker and Landolt gives the calculation up to 10 D.:

Degree of myopia.		Distance of the p. r. in millimetres.		Increase of length of the myopic eye in millimetres.
·5 D.	...	2000	...	·16
1·	...	1000	...	·32
1·5	...	666·6	...	·49
2·	...	500	...	·66
2·5	...	400	...	·83
3·	...	333·3	...	1·
3·5	...	285·7	...	1·19
4·	...	250	...	1·37
4·5	...	222·2	...	1·55
5·	...	200	...	1·74
6·	...	166·6	...	2·13
7·	...	142·8	...	2·52
8·	...	125·	...	2·93
9·	...	111·1	...	3·35
10·	...	100·	...	3·80

Fig. 58 shows a section of a myopic eye from a case at Moorfields, in which the outside measurements were:—Antero-posterior diameter  $30\frac{1}{2}$  mm.; vertical diameter 25 mm.; transverse diameter 25 mm.\*

FIG. 58.



\* For the particulars of this case I am indebted to Mr. Jennings Milles.



With the ophthalmoscope a crescentic-shaped patch of atrophy is frequently seen on the outer side of the optic disc, embracing it by its concave edge; this is called the "myopic crescent."

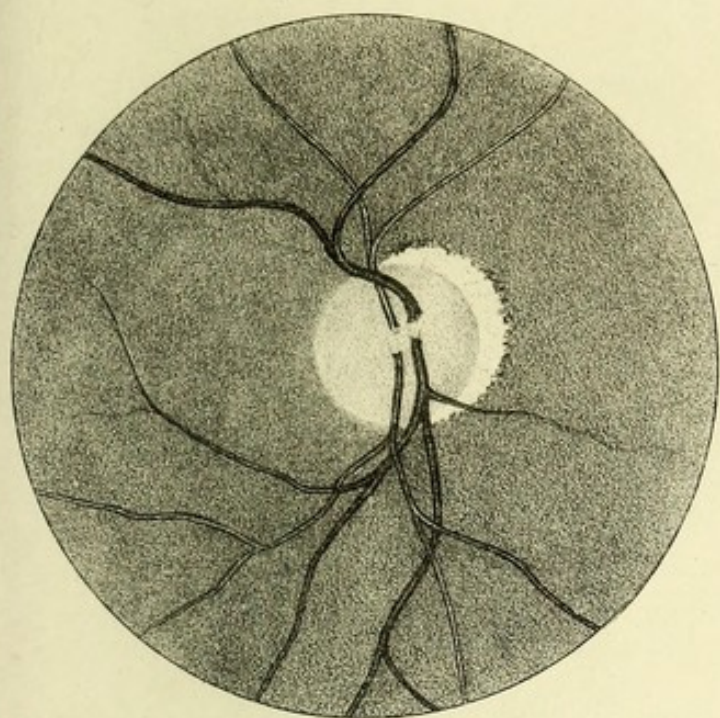
In an early stage the crescent looks somewhat white, showing the large choroidal vessels often more distinctly than on the adjoining parts, gradually the blood-vessels disappear, leaving the white sclerotic, which shows up plainly against the red of the fundus. Some remains of pigment about the convex border of the crescent are often seen, and frequently there is some thinning of the choroid beyond. The retina seems to participate in this atrophy much less than might have been expected.

Although the atrophy usually assumes the crescentic form, as shown in (I) of the plate which was drawn from the fundus of a young man, aged twenty, with a myopia of 4 D., yet it may vary much, sometimes forming a complete ring round the optic nerve (II), or it may extend outwards (III); the broadest part being usually between the disc and the macula, sometimes there is excavation of the atrophic part.

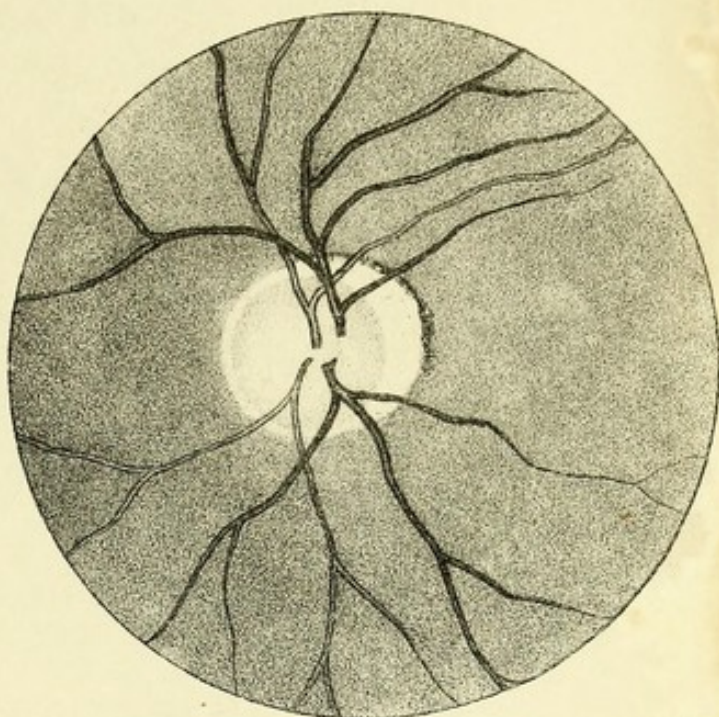
The optic nerve is occasionally displaced, somewhat inwards, and the disc, instead of being directed forwards, looks forwards and outwards, making it appear oblong in shape from its being seen obliquely (III). The retinal vessels that pass over the atrophied part are often straight in their course, and show up very clearly against the white sclerotic.

The formation of the crescent is much influenced by the amount of myopia. In slight degrees in young

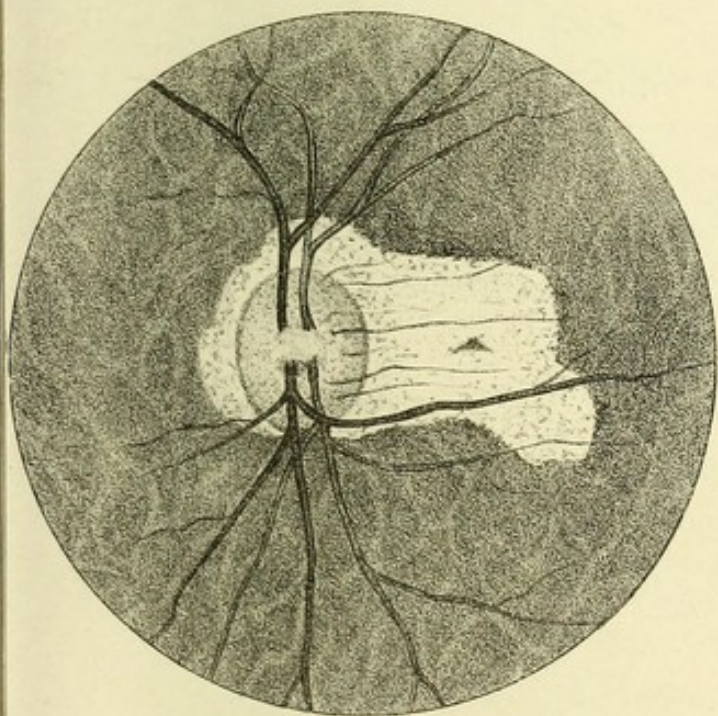




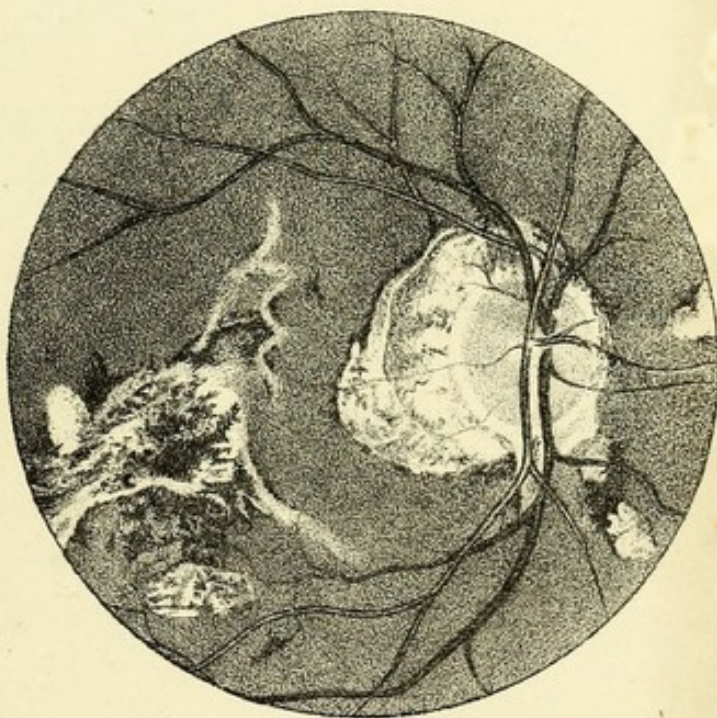
1.



2.



3.



4.







people it is often absent, but in cases of 6 D. or more, at the age of twenty we invariably find a well-marked crescent.

Secondary choroidal changes are also apt to take place in the yellow spot, as shown in (IV), which is copied from the 'Atlas' of Wecker and Jaeger; when these changes take place they cause great impairment of vision, due either to extension of the atrophy outwards, or to disease commencing there independently. If the disease be progressive the vitreous becomes disorganized, opacities forming in it; the lens may become cataractous, especially at the posterior pole, hæmorrhages may occur, and detachment of the retina sometimes takes place.

In addition to the far point, which is situated at a definite distance, there is of course also a near point,

FIG. 59.

Dioptres.

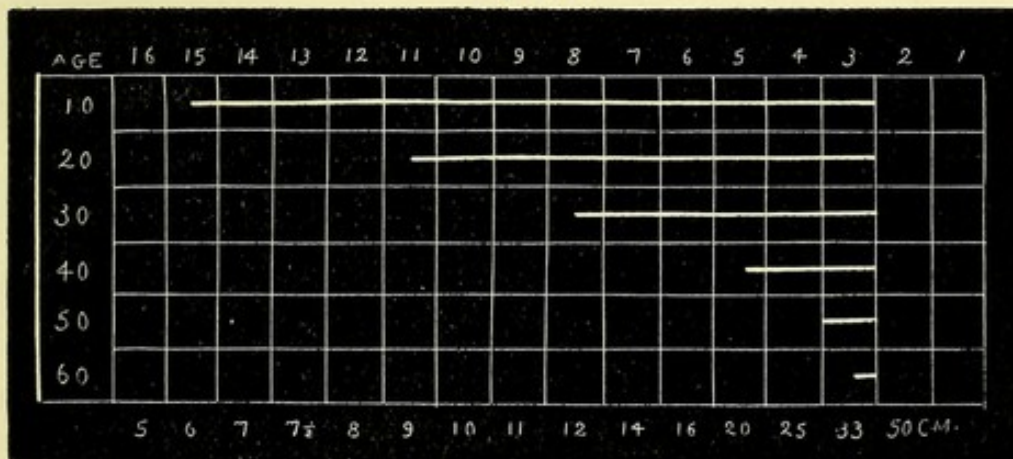


Diagram showing the amount of accommodation at different ages in a case of myopia of 2 D.

determined by the amount of accommodation. To find out the punctum proximum we place in the



patient's hand the near type and note the shortest distance, for each eye separately, at which the smallest type can be read, or we measure it by the wire optometer in the manner before described. The range of accommodation is often equal to that in emmetropia, but in the higher degrees of myopia it diminishes much.

In Fig. 59 the amount of accommodation is indicated by the number of spaces through which the thick line passes, thus at the age of 30 the accommodation is equal to 6 D. and his near point will be 12 cm. The distance of the punctum proximum is given for each dioptre at the bottom of the diagram.

As the punctum remotum in myopia is situated at a finite distance, therefore for the same amplitude of accommodation the punctum proximum is nearer the eye in myopia than in emmetropia. The near point gradually recedes with advancing age at the same rate whatever the refractive condition of the eye; it is clear, then, that the near point in myopia will be longer in reaching that point (22 cm.) at which presbyopia is arbitrarily stated to commence than in the emmetrope, so that in prescribing glasses for presbyopia the amount of myopia has to be deducted from the glass which the emmetrope would require at any given age.

If the myopia amount to 4.5 D., then the patient can never become presbyopic, because his punctum remotum is only 22 cm. away, so that he will always be able to see at that distance. Most people imagine that those who do not require glasses with advancing



age have very strong eyes; how frequently does one hear the remark, when inquiring of a patient's family history, "Oh! my father had excellent sight, he was able to read at sixty without glasses." This is proof positive that he had myopia, though probably you will be unable to convince the patient of this fact.

In hypermetropia it was shown that the power of accommodation had to be used in excess of the convergence. In myopia we have the opposite defect, the patient having to converge in excess of his accommodation; thus, if he be myopic 4 D. his far point will be at 25 cm., when looking at an object at this distance it is necessary for him to converge to this particular point, his angle of convergence being 4, while his accommodation remains passive.

Donders divides myopia into three classes:

1st. The stationary, where it does not exceed 2 D. at ten years old, nor 2.5 D. at forty.

2nd. The temporarily progressive, which may progress from 4 to 8 dioptries between the ages of ten and thirty. If the general health be good it seldom increases much after the age of twenty-six.

3rd. The progressive, which increases steadily and constantly from an early age.

**Causes.**—Myopia is one of the results of civilisation and education, and in these days of high pressure and competitive examinations it is constantly on the increase. The result of the very numerous statistics which have been collected, especially by German ophthalmologists (myopia in Germany is exceedingly common), points to the production of myopia in direct



proportion to the amount of education. The amount of myopia was found to be much greater in town than in country schools, no doubt because the general health was better amongst those living in the country. Erismann has come to the pleasant conclusion that if myopia increase in the same ratio as it has done during the last fifty years, in a few generations the whole population will have become "myopic." It behoves us therefore to endeavour by good general advice and hygiene to do all in our power to control the onward march of this disease. To those who are interested in the construction of schools where the object is to educate the young, and at the same time to reduce, as far as possible, the causes which are liable to produce or increase myopia, I would refer the reader to a lecture on this subject by my colleague, Mr. Power, in the 'Lancet' of September 22nd, 1883.

Myopia is almost unknown among the savage races.

Donders says that hypermetropia never gives way to myopia, but Cohn and Erismann are of opinion that the normal refraction of the eye in childhood is hypermetropic, that some few remain so, a great number becoming emmetropic as they get older, and that a large percentage of these pass on to myopia.

Though seldom or never congenital, it not unfrequently happens that one or other of the parents has suffered from myopia. There is little doubt that in many cases there is an hereditary tendency to it, which, transmitted through several generations, under favorable circumstances for its development, becomes very decided.



In proof of this hereditary tendency to myopia, Dr Cohn has summarised the statistics of various German writers on this subject. Thus in public schools myopia was found to exist without predisposition in 8 per cent., with predisposition in 19 per cent. In the higher schools the result was : without predisposition 17 per cent., with predisposition 26 per cent.

It may be acquired by those of studious habits, especially when these habits become developed at an early age, and by any who use their eyes much for near work.

The cause to which myopia is most frequently attributed, is the extreme convergence which is necessary to enable the patient to see at the limited distance to which he is confined, the result being that the weakest part of the globe, in fact, the part least supported, gradually bulges, forming a posterior staphyloma. In support of this method of production of myopia may be stated the well-known fact that people who use one eye only for close work, with a strong convex glass, however long their hours, such as watchmakers and jewellers, are not especially liable to myopia, proving that close work without convergence is not liable to produce it. As the eyeball becomes elongated its movements become more difficult, and the pressure produced by the muscles during prolonged convergence tends still further to increase the myopia.

The stooping position which so many myopes take up, causes an accumulation of blood in the eyeball, which tends to raise the tension as well as materially



to interfere with its nutrition. Hence results a state of congestion, softening, and extension, leading to a further increase of the myopia. The more advanced these changes, the more difficult is it for the myopia to become stationary.

In addition to these two causes, extreme convergence and the stooping position, it is possible that, as a result of the constant convergence, the optic nerves may be somewhat pulled upon, and thus further assist in producing myopia.

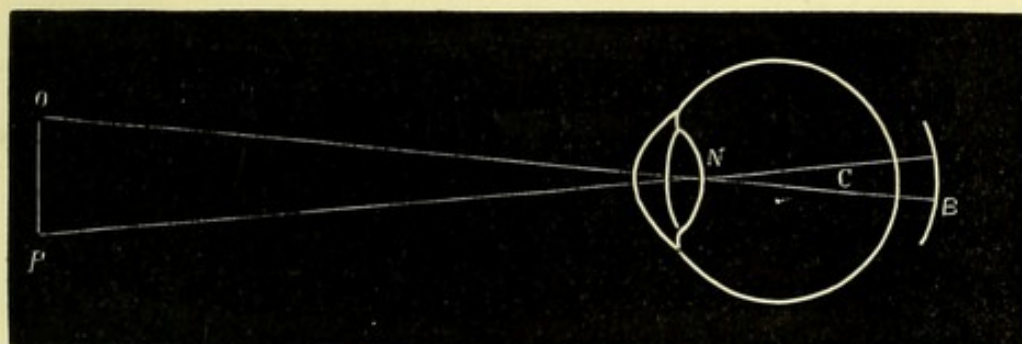
Cases of *nebulæ*, cataract, and other causes of imperfect sight in children, may give rise to myopia from constantly holding objects close to the eye.

**Symptoms.**—The patient sees distant objects badly and near objects well. The eyes look prominent; the pupils are usually large in young people, as age advances they contract, thus diminishing the circles of diffusion, and so slightly improving vision. Eserine acts in the same manner, so does the nipping together the eyelids, which is so characteristic of patients suffering from myopia. The acuteness of vision is frequently below the normal, though objects within the patient's far point appear larger than they do to the emmetrope; the distance between the nodal point and the retina being greater in myopia (Fig. 60).

Frequently limitations in the field of vision occur in the form of scotomata due to patches of retinal atrophy; in addition to seeing distant objects badly the patient complains of pain, fatigue, and intolerance of light, with a state of irritation, especially after using the eyes by artificial light. There may be



FIG. 60.



A (Accidentally omitted in figure). The retina in an emmetropic eye. B. The retina in a myopic one. C. The visual angle. N. The nodal point. The distance from NB is greater than NA, and the image of OP is greater at B than at A.

hyperæmia of the eyes and lids, spasm of the accommodation (which increases the apparent amount of myopia), pain in the eyeballs on pressure, photopsia, an appearance of convergence due to the small size of the angle  $\alpha$  (p. 159), together with “*muscæ volitantes*.” These last are often a source of great anxiety; the patient may, however, be assured that, although they cannot be removed, there is no cause for uneasiness. These *muscæ* are probably the remains of vitreous cells which, being situated a considerable distance in front of the retina throw shadows on it, and are projected outwards as much larger images than would be the case in an emmetropic eye. These appear to the patient as black spots.

The internal recti muscles often act badly, so that convergence becomes painful and difficult, often going on to strabismus divergens.

When the myopia is of high degree, the patient often uses one eye only for reading, then of course he does not require to converge.



The popular impression that myopia decreases with advancing age is incorrect; the far point can at best remain stationary, while the near point gradually recedes, and if a person of fifty reads at a further distance than he did at twenty the reason is that at the latter age he did not read at his far point. A young myope with fair accommodation may find it difficult to keep this function passive while converging to the necessary distance for reading; the pupil becomes smaller with age, thus cutting off some of the patient's circles of diffusion and enabling him to see objects somewhat more clearly. According to Donders, the refraction of the eye does somewhat diminish as age advances, in this case the myope's vision would improve (see p. 97).

The **diagnosis** of myopia is easy. At the distant type the patient requires a concave glass to enable him to read  $\frac{6}{6}$ . The *weakest* lens with which he is able to read it is the measure of his myopia; always remember the patient is apt to choose too strong a glass if left to himself. On placing the near type of Snellen in his hand he will be found to be able to read the smallest print, though at a shorter distance than that for which it is marked. The extreme distance at which he is thus able to read it is his far point, the measure of which is also a measure of his myopia. This is a most useful guide to us; for instance, he reads Sn. 1 at 25 cm. but no farther;  $\frac{1.00}{25} = 4$  D., therefore 4 D. is the measure of the myopia, and such a glass will render parallel rays so divergent that they will seem to come from 25 cm.



Had he been able to read it at 10 cm. only, then ( $\frac{100}{10} = 10$  D.) —10 D. will be the measure of the myopia.

With retinoscopy the shadows move in the same direction as the mirror so long as the observer is beyond the patient's far point (Chap. IV).

With the ophthalmoscope, by the indirect examination, the disc looks smaller than in emmetropia, and becomes larger on withdrawing the objective farther from the eye.

By the direct method of examination at a distance with the mirror alone, an inverted magnified image of the disc can be clearly seen, provided always that the observer be not nearer the aerial image than his own near point (Fig. 37). The lower the myopia the greater the image, because the longer is the distance between the image and the myopic eye. On moving the head from side to side the image will always move in the opposite direction, showing that it is an inverted one. When we bring the ophthalmoscope close to the eye the fundus cannot be clearly seen until a concave glass is placed in front of the observing eye. The *weakest* concave glass with which the details of the macula and disc can be clearly seen (the observer's eye being emmetropic and the accommodation relaxed) is a measure of the myopia (Fig. 40). This test may be relied upon for the lower but not for the higher degrees of myopia.

The chief indications for the **treatment** of myopia are :

- 1st. To prevent the increase of the myopia.
- 2nd. To enable the patient to see distant objects.



3rd. To prevent the various troubles from which myopes are so liable to suffer, as asthenopia, divergent strabismus, &c.

To carry out the first of these indications, strong convergence and the stooping position, both of which play so important a part in the production of myopia, must be avoided, the patient being directed never to read in a train or carriage where every movement requires a change in the accommodation, nor to look at near objects for too long together—the natural tendency for a myope who is excluded in great measure from seeing distant objects, is to devote himself to near ones. In reading, writing, or working he must keep 35 cm. away from the book or paper, use books printed in good, bold type, and not write too small. Do as little as possible by artificial light; when necessary it is best to use a reading lamp, so placed that it throws the light down upon the work, leaving the remainder of the room in comparative darkness, so that when the eyes become tired they may be rested by turning them from the light. The stooping position must be strictly avoided as it causes an increased flow of blood to the interior of the eyeball, producing hyperæmia with symptoms of irritation, and possibly some slight increase of tension. When reading or writing he should sit with his back to the window, so that the light may fall on his book or paper over his left shoulder, the shadow of his pen being thus thrown to the right, enabling him to see plainly the letters he is forming.

Attention must be paid to the general health, iron



internally often being especially useful, combined with regular outdoor exercise. When symptoms of irritation show themselves, with a rapid increase in the myopia, complete rest must be given to the eyes, and in no way can this be so conveniently carried out as by dropping into the eyes a solution of atropine (gr. ij to ʒj) three times a day for some two or three weeks; counter-irritation may be applied to the temples and behind the ears in the shape of small blisters, or by a solution of iodine. Sometimes where there are symptoms of congestion present, the artificial leech applied to the temple once a week for a few weeks does much good. As the irritation gradually subsides, the patient may be allowed to do a little reading daily, in a good light, the eyes all the time being kept under atropine. He may require glasses to enable him to do this. Thus, if he have myopia of 3 D. he will not require them, his far point being at 33 cm.; if he has  $-1.5$  D. he would require  $+1.5$  D. to enable him to read at about 35 cm. ( $+3$  D.  $-1.5$  D. =  $+1.5$  D.); if the myopia is 6 D. he will require  $-3$  D. to put back his far point to 35 cm. ( $+3$  D.  $-6$  D. =  $-3$  D.).

So long as the myopia is progressing it must always be a source of anxiety to us.

To enable the patient to see well both near and distant objects, we must correct the myopia. In young people with good accommodation and with a low degree of myopia, the full correction may be well borne, the patient wearing such glasses constantly. We must, however, always bear in mind that there may be some spasm of the accommodation, which



spasm would apparently increase the myopia, in which case we should be in danger of over-correcting it. To prevent this, and to enable us to make an exact record of the condition of refraction, by which we may judge if the myopia is stationary or progressive, it is much the best plan to thoroughly atropize the patient in the manner previously described. If the myopia amount to 4 or 5 D., the accommodation may be impaired and the full correction will give the best distant vision ; the patients, however, are unable with this full correction to use sufficient accommodation to bring the near point up to reading distance. To such people we must give glasses which enable them to read comfortably at 35 cm., and a second stronger pair, those with which they get the greatest acuteness of vision, for distance. Glasses may also be required for music.

One reason why we should not give the full correction in cases of high degree, for reading, &c., is because the glasses so much diminish the size of the retinal images that the individual is induced to make them larger by bringing the object closer.

To find the glass for reading we may subtract from the glass which gives the best acuteness of vision, that glass whose focus represents the distance at which the patient wishes to read or work. Thus, — 9 D. gives the best distant vision, the patient wishes for glasses with which to read at 35 cm., then — 9 D. + 3 D. = — 6 D., so — 6 D. would place our patient's far point at 35 cm., and enable him to read at that distance without using his accommodation.



It is often found that after spectacles have been worn for some time the accommodation so far improves that the full correction will be comfortable for constant use.

When muscular asthenopia is present, prisms with their bases inwards, which diminish the necessity for convergence, with or without concave glasses, are of great value.

We must remember when the myopia has been estimated under atropine to add on to the glass so found, — .5 D. for the tone of the ciliary muscle, as it will be found that the full correction under atropine is usually this much weaker than the correction found without it.

I should mention that in myopia the ciliary muscle is smaller than in emmetropia, the circular fibres (which are so hypertrophied in hypermetropia) being almost absent.



## CHAPTER VII

## ASTIGMATISM AND ANISOMETROPIA

ASTIGMATISM, 'A priv, *στιγμα* a point.

Hitherto we have seen that the cornea usually takes but little part in the defects we have been considering. It has been shown that hypermetropia is almost invariably due to the eyeball being too short, and myopia to its being too long. We now come to a defect in which the curvature of the cornea plays a very important part with or without some decrease or increase (from the emmetropic standard) in the antero-posterior diameter of the eyeball; I refer, of course, to astigmatism, which is the commonest of all the refractive errors, few cases of hypermetropia being entirely free from it, and still fewer cases of myopia. Astigmatism, then, may be defined as that state in which the refraction of the several meridians of the same eye is different; for instance, the horizontal meridian may be emmetropic, the vertical hypermetropic.

It is usually congenital, but may be acquired, and frequently there is some hereditary tendency.



Astigmatism may be divided into two chief divisions :

1. Irregular.
2. Regular.

The irregular variety, which consists in a difference of refraction in the different parts of the same meridian, may be further subdivided into normal and abnormal:—  
(a) The normal irregular astigmatism is due in great measure to irregularities in the refracting power of the different sectors of the lens; it causes a luminous point to appear stellate, as is the case when looking at a star, which is in reality round. (b) The abnormal variety may arise from the condition of the lens or of the cornea; when the lens is in fault it may be due to changes taking place in the lens itself, to partial displacement by accident, or it may be congenital. The changes in the cornea which may produce it are: conical cornea, nebulæ, and ulcers. Little can be done in the way of glasses towards correcting this form of astigmatism, though much improvement of vision sometimes occurs when stenopaic spectacles are worn, the opening being made to suit the peculiarity of each case.

We now pass on to the much more common form, which can be frequently exactly corrected by the help of plano-cylindrical lenses.

**Regular Astigmatism** is due to the curvature of the cornea being different in the two meridians, that of maximum and minimum refraction; these are called the chief meridians, and are always at right angles to each other.



In the normal eye the cornea is the segment of an ellipsoid and not of a sphere, so that there is a slight difference in the refraction of the two chief meridians, the focus of the vertical meridian being slightly shorter, than that of the horizontal.

This can easily be proved by looking at a card on which is drawn two lines crossing each other at right angles, the card is held close to the eye and gradually made to recede; both lines cannot be seen at the same time with equal clearness, the horizontal being seen clearly at a shorter distance than the vertical line. So long, however, as the acuteness of vision is not impaired it goes by the name of normal astigmatism or regular astigmatism of the normal eye.

Parallel rays passing through a convex spherical glass come to a focus at a point. If the cone of light thus formed be divided perpendicular to its axis, at any point between the lens and its focus, or beyond the focus after the rays have crossed and are diverging, a circle is formed. In astigmatism the case is different; if parallel rays pass through a convex lens which is more curved in the vertical than in the horizontal meridian, those which pass through the vertical come to a focus sooner than those which pass through the horizontal; and the resulting cone, instead of being circular, as in the previous case, will be more or less of an oval, forming a circle only at one point (4, Figs. 61 and 62). Let us now divide this cone at different points at right angles to its axis, and notice the shape of the diffusion patches thus produced.

At 1 an oblate oval is formed, at 2 a horizontal



FIG. 61.

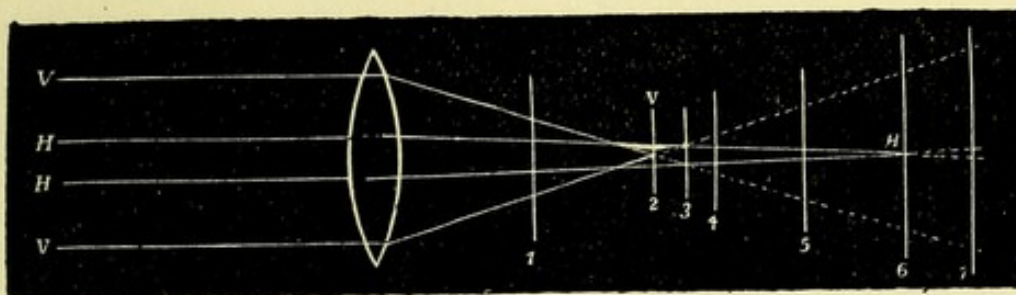
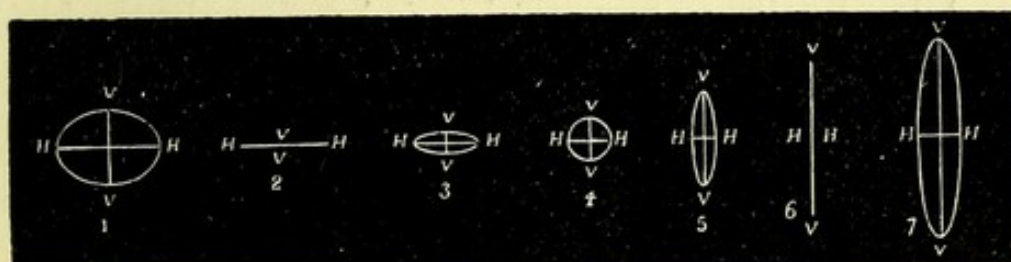


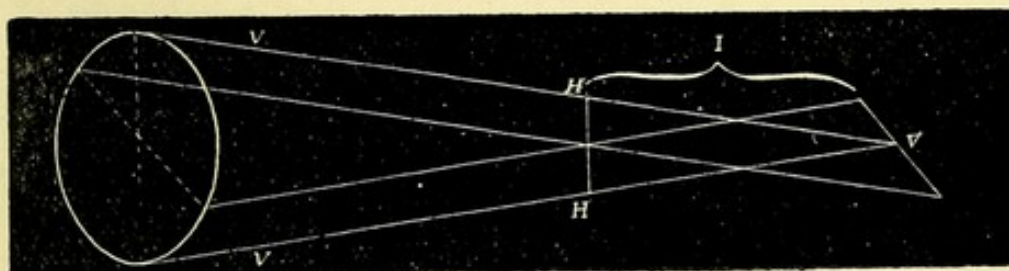
FIG. 62.



Section of cone of light at 1, 2, 3, 4, 5, 6, 7, Fig. 61.

straight line, the vertical rays having come to a focus ; at 3, 4, 5, the vertical rays have crossed and are diverging, and the horizontal rays are approaching ; at 4 a circle is formed ; at 6 a vertical straight line, the horizontal rays having met and the vertical still diverging ; a large prolate ellipse is formed at 7.

The space between the two points at which the vertical  $v v$  and the horizontal  $H H$  rays focus at  $H$  and  $v$  is called the interval of Sturm I (Fig. 63).

FIG. 63 (*Donders*).



Regular astigmatism was at one time thought to be due to defects in the curvature of the lens, but it has since been proved to depend almost entirely on asymmetry of the cornea. The lens may, however, influence it in two ways:—1st. Its two chief meridians may not correspond to those of the cornea; 2nd. Owing to the position of the eye the lens may be situated obliquely.

It has been experimentally proved that slight amounts of corneal astigmatism may be corrected or disguised by the unequal contraction of the ciliary muscle (one segment of the muscle acting while the rest of the circle remains passive); the curvature of the lens is thus increased in the direction of the ciliary contraction only.

Astigmatism was first discovered by Thomas Young in 1793, who was himself astigmatic.

In astigmatism the vertical meridian has usually the maximum, and the horizontal the minimum of curvature, corresponding to the astigmatism of the normal eye. To this, however, there are numerous exceptions. Thus, the chief meridians may occupy an intermediate position, or the vertical may occasionally have the minimum, and the horizontal the maximum of curvature. Whatever the direction of the two chief meridians, they are always at right angles to each other.

There are five varieties of regular astigmatism:

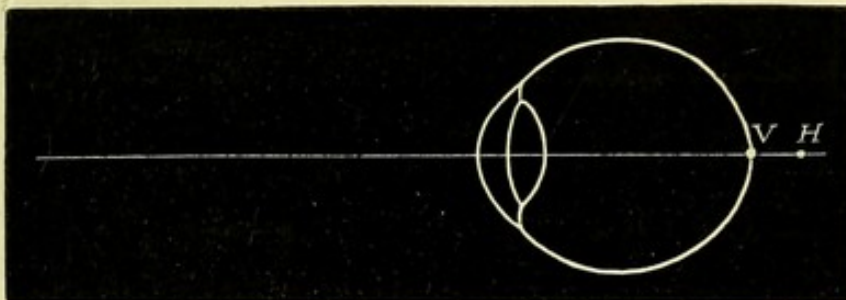
1. Simple hypermetropic astigmatism.
2. Compound hypermetropic astigmatism.
3. Simple myopic astigmatism.
4. Compound myopic astigmatism.



### 5. Mixed astigmatism.

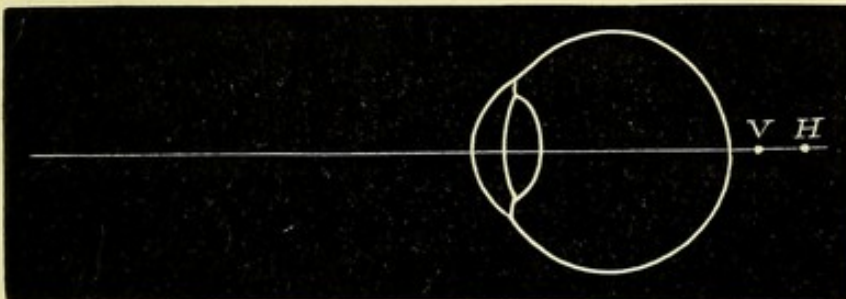
In the first variety one set of rays (we will assume the vertical,  $v$ ) have come to a focus on the retina, while those at right angles, the horizontal ( $H$ ), focus behind the eye. Thus, instead of a point, as in emmetropia, a horizontal straight line is formed on the retina (Fig. 64).

FIG. 64.



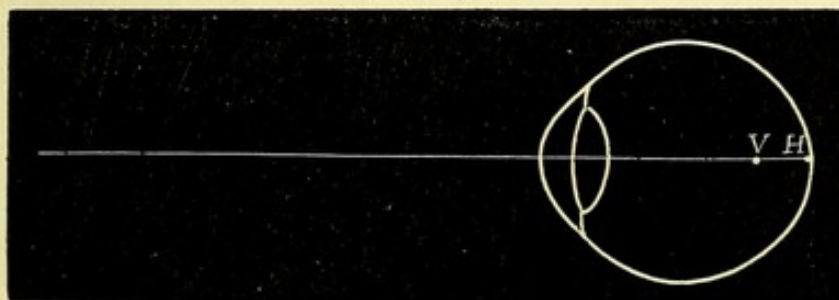
In the second variety both sets of rays focus behind the retina (Fig. 65).

FIG. 65.



In the third variety the vertical rays focus in front of the retina, the horizontal ones on the retina, thus forming a vertical straight line (Fig. 66).

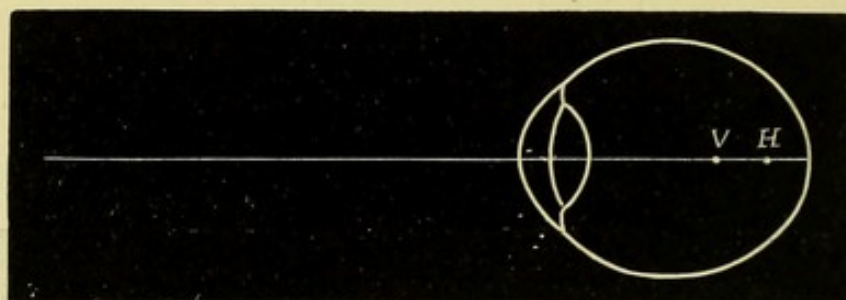
FIG. 66.





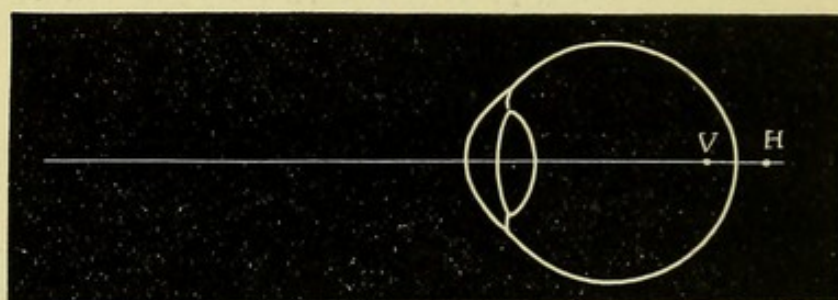
In the fourth variety both sets of rays focus in front of the retina (Fig. 67).

FIG. 67.



In the fifth variety, one set of rays has its focus in front, and the other behind, the retina (Fig. 68).

FIG. 68.



From what has been said it will easily be seen that, when an astigmatic eye looks at a spot, it sees not a spot, but a *line*, an oval or a circle, hence its name ( $\alpha$  and  $\sigma\tau\iota\gamma\mu\alpha$ ). It is necessary that it should be thoroughly understood how the image of a line is formed on the retina. The clear perception of a line depends upon the distinctness of its edge, and to gain a clear image of this line it is necessary that the rays coming from a succession of points which make up this line (they of course also emerge in every direction) should be brought to a focus on the retina,



having passed through the cornea at right angles to its axis. Should they not do so, circles of diffusion are formed, which overlap each other and so render the edges ill-defined. The rays which diverge from the line parallel with its axis overlap each other on the retinal image, increasing its distinctness, except at the extremities, where they overlap and cause some slight indistinctness. Thus, a person with simple astigmatism, myopic in the vertical and emmetropic in the horizontal, sees distinctly *vertical* lines, because the rays coming from the edges of the vertical line pass through the horizontal or emmetropic meridian, while those which come from the line parallel with its axis, pass through the myopic meridian and overlap each other without causing any indistinctness of its edges. Therefore a patient with simple astigmatism sees clearly the line which is parallel with his ametropic, and most indistinctly the line parallel with his emmetropic meridian.

**Symptoms.**—There is frequently a want of symmetry about the patient's head or face. If young, and the astigmatism hypermetropic and of low degree, few symptoms may be present; usually, however, the patient complains of defective vision with asthenopia, especially if his work be such that his accommodation is in constant use; he has probably tried all sorts of spectacles and can find none to suit him. On trying him at the distant type his acuteness of vision is always below the normal, the mixed variety of astigmatism affecting it most, and next the compound. We sometimes notice when trying the acuteness of



vision that the patient sees much better if allowed to hold his head on one side ; by doing this he places his nose somewhat in the line of vision of the eye he is using, and so cuts off some of the rays which would otherwise enter his pupil ; he thus diminishes his circles of diffusion. It is possible also that if his chief meridians are oblique, by thus tilting them he brings them to correspond with the meridians of the object looked at. Whether this explanation be the correct one, I know not, but we may generally feel pretty confident when we see the patient looking at the test type with his head on one side that astigmatism is present. One frequently hears it said that images formed on the retina in astigmatism are distorted. This, however, is not the case, as can readily be proved by making one's own eye astigmatic by placing in front of it a cylindrical glass ; a certain amount of blurring and indistinctness is produced, but no actual distortion, the distance between the cornea and retina being insufficient.

Usually both eyes are affected, sometimes quite symmetrically. Frequently, however, there is a great difference, one being almost emmetropic, the other very astigmatic.

When the chief meridians of one eye are at right angles to the chief meridians of the other, binocular may be much better than monocular vision ; we will illustrate this by a simple example. The right eye we will assume to be hypermetropic, 2 D. in the vertical meridian, emmetropic in the horizontal ; the left emmetropic in the vertical, hypermetropic in the hori-



zontal 2 D. We know that the patient, looking at the fan of radiating lines with the right eye only, will see the vertical lines distinctly, the horizontal only by accommodating; with the left eye the horizontal lines will be clearly seen, the vertical ones indistinctly; with the two eyes all the lines will appear distinct, the image in one eye overlapping that of the other. We seldom find a case in which the correction is so complete as in our example, but we meet with cases where partial correction takes place.

In my experience vision is less impaired when the chief meridians are vertical and horizontal, than when they are oblique.

As hypermetropia is more common than myopia, so also is hypermetropic astigmatism of more frequent occurrence than the myopic variety, though few myopes will be found who are quite free from astigmatism. Mixed astigmatism is the least frequently met with.

If, after trying the patient at the distant type, we are not satisfied with the result, though perhaps we have some improvement with either convex or concave glasses, we may suspect astigmatism and pass on to some of the special tests by which it may be diagnosed and estimated.

If astigmatism exist, our first object must be to find out the direction of the two principal meridians, viz. those of maximum and minimum refraction.

Most of the tests for astigmatism are based upon the facts of the perception of a line. An astigmatic eye, looking at a test object composed of lines



radiating from a centre, and numbered for convenience sake like the face of a clock, is unable to see all the lines equally clearly. The line seen most distinctly indicates the direction of one of the two chief meridians; the other chief meridian being of course at right angles to the one most clearly seen. The fan of radiating lines now very commonly used, as well as the clock face with moveable hand of Mr Brudenell Carter, are all convenient test objects. The striped letters of Dr Pray are convenient for indicating one of the chief meridians.

To test and measure the astigmatism, we place our patient at a distance of 6 metres in front of the clock, covering up one eye with a ground glass disc. Supposing he see plainly the 3 lines from 12 to 6, all the other lines being more or less indistinct, those from 3 to 9 most so, and further, if on placing before the eye a weak positive glass we find that lines from 12 to 6 are blurred, we know then that the horizontal meridian, that is, the meridian at right angles to the clearly defined line, is emmetropic, as well as being one of the principal meridians. We now direct him to look steadily at the lines from 3 to 9, *i.e.* those at right angles to the lines first seen. We try what spherical glass enables him to see these lines distinctly and clearly. This glass is the measure of the refraction of the vertical meridian, and therefore also of the astigmatism.

To obtain reliable results the eye *must* be thoroughly under the influence of atropine.

Supposing lines from 12 to 6 be clearly seen, bu



FIG. 69.

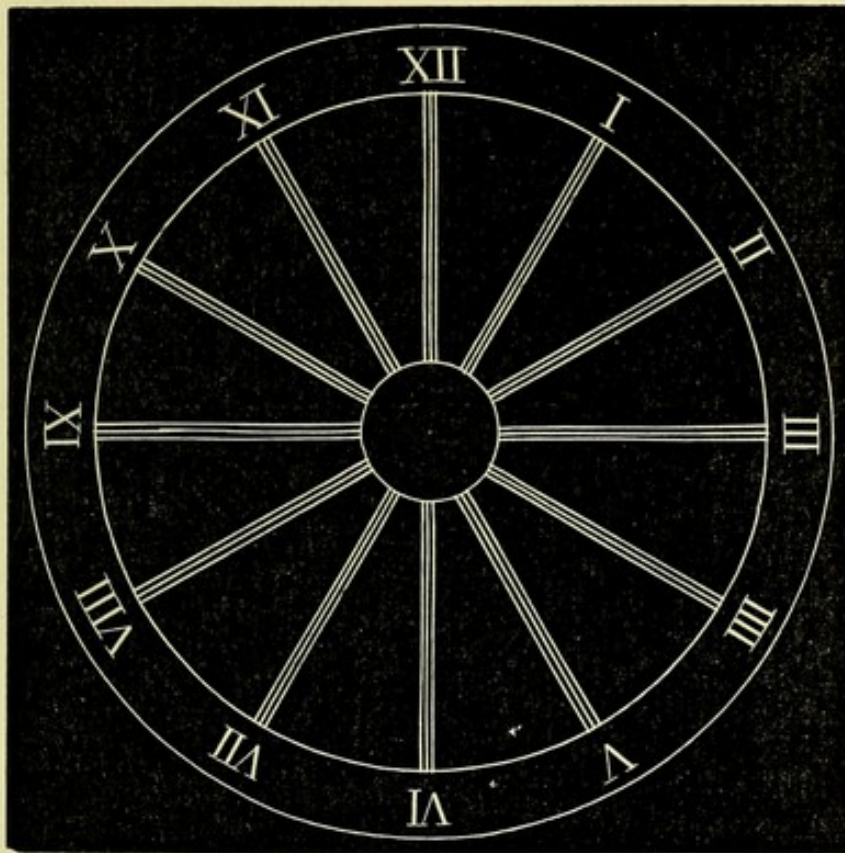


FIG. 70.

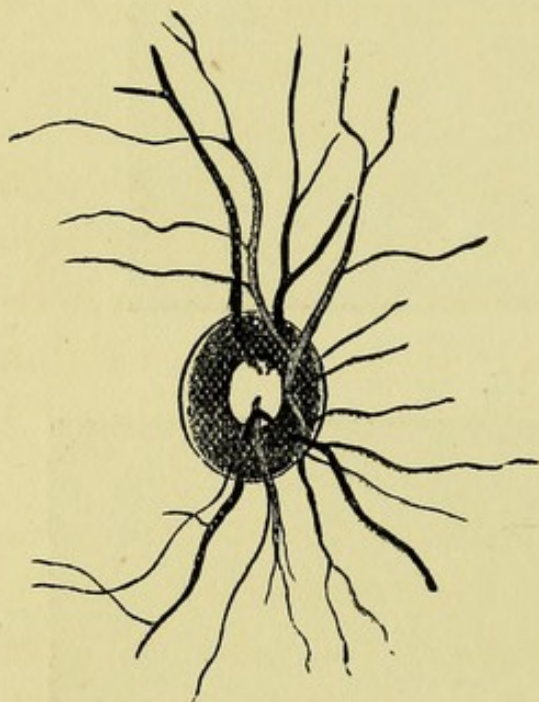


that with a weak convex glass they are blurred ; and that on looking at lines 3 to 9 no convex glass improves their clearness, while  $-1$  D renders them quite clear, the case is one of simple myopic astigmatism.



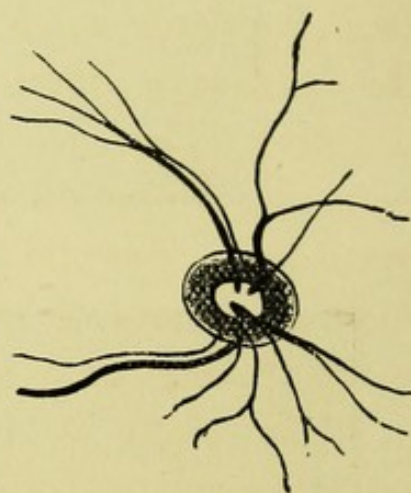
With the ophthalmoscope the astigmatism may also be recognised. Firstly, by employing the indirect method we find that the shape of the disc, instead of being circular, is more or less oval, changing its shape as the objective, which must be held exactly perpendicular, is withdrawn. Secondly, by the direct method we find that the disc appears oval, the long axis of the oval corresponding to the meridian of greatest refrac-

FIG. 71.\*



Erect image.

FIG. 72.



Indirect image of disc.

tion. Fig. 71 and 72 show the same disc as seen by the direct and indirect examination.

It is, however, the difference in degree of the clearness of the retinal vessels, that is to be taken as the

\* I have to thank Mr Nettleship for the electros of these two figures from the woodcut in his excellent work on 'Diseases of the Eye.'



guide, not only of the chief meridians, but also of the kind and amount of error. To detect this we take notice first of the lateral margins of the disc and of a vessel running in the vertical direction, and find out the *strongest* positive or the *weakest* negative glass with which these are distinctly seen, using a refracting ophthalmoscope. We then take a horizontal vessel with the upper and lower margins of the disc, and estimate their refraction in the same manner. Thus a vessel going upwards is first taken. It is seen well with a convex 1, the horizontal meridian therefore is hypermetropic 1 D. A horizontal vessel is now looked at and can be best seen with concave 1, showing that the vertical meridian is myopic to one diopetre. The case is, therefore, one of mixed astigmatism. Some observers profess to be able to estimate and order the proper correcting glasses by this method alone. I should, however, be exceedingly sorry to trust to it entirely.

Retinoscopy is, I think, without doubt the most valuable and trustworthy of all the objective methods. The patient being fully atropized, the principal axes can be seen at a glance, and the proper glasses for correcting the error easily found, by anyone who has taken the trouble to familiarise himself with this method of examination. For a full description I must refer the reader to the chapter on that subject.

Astigmatism requires for its correction a cylindrical glass, that is, one which instead of being the segment of a sphere, as is a spherical glass, is the segment of a cylinder. It may be either concave or convex, and



the result upon rays will be, that those which pass through the cylinder parallel to its axis undergo no refraction. All other rays are refracted, those most so, which pass at right angles to the cylinder. It thus possesses the power of exactly neutralising the astigmatism.

On referring back to Fig. 64, which represents a case of simple hypermetropic astigmatism, the vertical meridian being emmetropic and the horizontal meridian hypermetropic, it will be seen that a convex cylinder can be found, which with its axis vertical will increase the refraction of rays passing through the horizontal meridian, so that they meet exactly on the retina. Suppose the glass required be  $+1$  D. cylinder, this not only corrects, but is itself a measure of the astigmatism. If a patient with astigmatism of  $1$  D. be able to read  $\frac{6}{12}$  at the distant type and with the cylinder  $+1$  D., axis vertical  $\frac{6}{6}$ , it may be expressed in the following manner:  $\frac{6}{12} +1$  D. cy. axis vert.  $= \frac{6}{6}$ .

Fig. 65 represents compound hypermetropic astigmatism. We find out the refraction of each chief meridian by retinoscopy or the clock face. Assuming then the vertical meridian to be  $+1$  D., and the horizontal  $+2$  D., if we place our positive cylinder  $+1$  D. with its axis vertical, we shall have corrected the astigmatism, and the error will be reduced to one of simple hypermetropia, requiring for its correction  $+1$  D. sphere. This combination of sphere  $+1$  D. with cylinder  $+1$  D. axis vertical is made in one glass by the optician grinding upon one side the sphere  $+1$  D.,



and on the other the cylinder  $+1$  D. The lens thus formed is called a spherico-cylindrical one.

Fig. 66 represents simple myopic astigmatism, in which the vertical meridian is myopic and the horizontal emmetropic. To correct this error it is necessary to cause the rays which pass through the vertical meridian to be so refracted that they meet *at*, instead of *in front of*, the retina. Here it is obvious that a negative cylinder with its axis horizontal will accomplish this object.

Fig. 67 represents compound myopic astigmatism. Both sets of rays focus in front of the retina, one set in advance of the other. This is corrected by putting back the most anterior focus by a cylinder, and then correcting the simple myopia left by a negative sphere. This glass is called a negative spherico-cylindrical glass.

Fig. 68 represents mixed astigmatism. One set of rays focus in front of the retina, the other set behind it. The difference between these is the amount of astigmatism, and may be corrected in three different ways. Thus supposing the vertical meridian myopic 1 D., and the horizontal hypermetropic 1 D., the correction may be made by  $-1$  D. cylinder, axis horizontal, which puts back the vertical rays so as to focus on the retina, combined with a  $+1$  D. cylinder, axis vertical, which brings forward the horizontal rays to the retina. This compound lens is called a concavo-convex cylinder. There are, however, some difficulties in using this method of correction. The axes of the cylinders have to be arranged with such exact-



ness that the slightest variation may upset the whole result. Besides, it is difficult when using such a combination at the distant type to make alterations with the same facility with which one does other combinations. Moreover, during the grinding very great care is required of the optician, so that either of the following plans seems preferable. By a minus concave spherical glass of 1 D., combined with a convex cylinder of 2 D. axis vertical, or by a +1 D. sphere combined with -2 D. cylinder axis horizontal.

Having found out by one of these numerous methods, the refraction of the two chief meridians, we confirm the result by trying the patient at the distant type with the combination so found, making any slight alterations which may be necessary. The patient must be allowed a week to thoroughly recover from the atropine, and the result then finally confirmed, remembering that we shall have to reduce the convex and increase the concave glass slightly; spectacles are then ordered, which must be worn constantly.

We frequently have to be satisfied with glasses which do not raise the vision to  $\frac{6}{6}$ , and if such have been carefully chosen we often find that after they have been worn for some time the vision improves, due no doubt to the retina becoming more sensitive to well-defined images, a condition of things to which it was previously unaccustomed.

In ordering glasses for astigmatism we must be careful to give the exact axis of each cylinder; opticians supply us with convenient forms, having a



diagram of a frame marked in degrees, we indicate the axis by drawing a line through this diagram.

The **ophthalmometer of Javal and Schiötz** is an instrument for measuring the amount of corneal astigmatism. Scientifically it may be of much value, as by it we are enabled to separate astigmatism due to the cornea, from that due to the lens, but the price will prevent its coming into general use, especially as we possess so many other methods by which astigmatism may be estimated, and probably the separation of the two forms of astigmatism is a disadvantage practically, when we are seeking to correct the defect.

With the ophthalmometer two objects are reflected on to the cornea of the observed eye; these are of white enamel, one quadrilateral in shape, the other of the same size except that on one side it is cut out into five steps; these two objects slide on a semi-circular arm, which rotates round the tube through which the observer looks, one object on either side of the tube; the observer looking through this tube which contains a combination of convex glasses and a bi-refracting prism sees four magnified images in a line on the cornea under examination. First find out the meridian of least refraction, this we are able to do by finding the position of the semi-circular arm, in which the two central images (one quadrilateral, the other with steps) are furthest apart. We slide the two objects together until we see the two central images on the observed cornea just touch, the lowest step of the one with the side of the other; this



then is the meridian of least refraction, and we note it down as such, now turn the arm at right angles to this meridian, and notice the amount of overlapping of the two central images, each step in the one figure that is overlapped by the quadrilateral one, is equal to one dioptré; thus if it overlap three steps, there is a difference of 3 D. between the meridians of least and greatest refraction; we know this to be the meridian of greatest refraction, because it is at right angles to the one first found.

As there are only five steps when there is a difference of 5 D. between the two meridians the one figure will exactly overlap the other; for higher degrees we have to calculate how much the figure with the steps, projects beyond the quadrilateral figure, or we may place in the tube a stronger bi-refracting prism, then each step may be counted as two dioptrés instead of one.

Nordenson has obtained some interesting statistics with this ophthalmometer ('Ophthalmic Review' for July, 1883) in 226 school children. As a result of these statistics he is of opinion:

1st. That the correction of corneal astigmatism by means of the lens in young persons is the rule.

2nd. That corneal astigmatism amounting to one and a half dioptrés is incompatible with normal acuteness of vision.

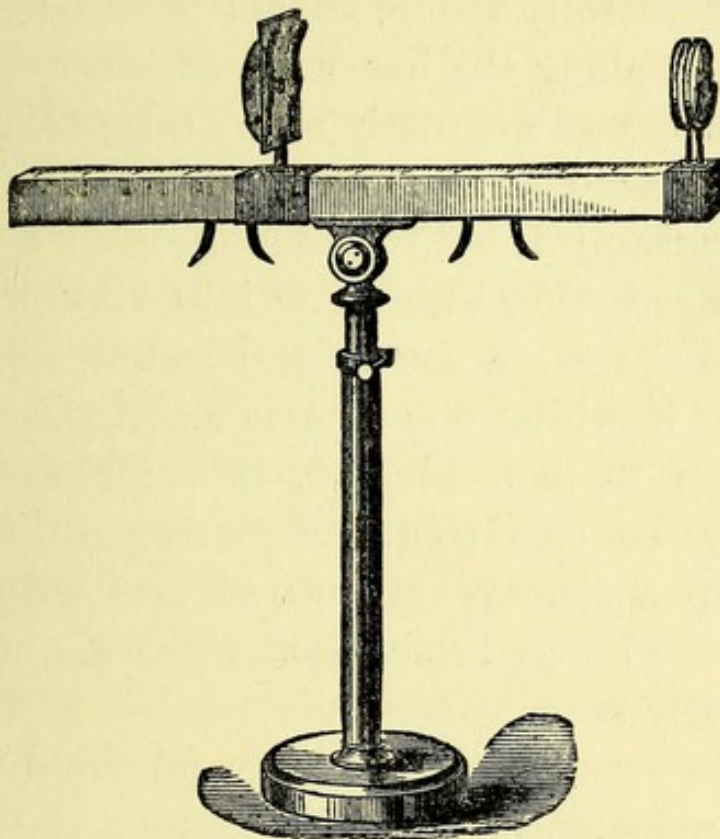
His observations add also to the opinion of Javal that astigmatism predisposes to myopia.

**Tweedy's optometer** affords an easy method of estimating the refraction in astigmatism. It consists



essentially of a plate carrying the figure of a dial marked with fine dark radiating lines at angles of  $15^{\circ}$  with each other; the plate is attached to a horizontal bar half a metre long divided into centimetres on which it may be made to slide; at the proximal end of

FIG. 73.



the bar is a semi-circular clip marked with degrees corresponding to those on the dial and intended to hold the cylindrical lens. In order to use the instrument properly the following instructions must be strictly complied with:

1st. The eye about to be examined having previously been placed completely under atropine and made artificially myopic to about 4 D. by means of a strong



convex lens placed in a spectacle frame and the opposite eye excluded by an opaque disc, the patient should sit down before the instrument, place the eye with the lens before it close to the clip and with the head erect should look straight in front at the radiating lines of the dial.

2ndly. The dial having first been removed beyond the point of distinct vision, should then be gradually approximated along the bar until at least one of the lines is clearly and distinctly seen ; after this the dial should on no account be moved, but its distance from the eye accurately noted.

If all the radiating lines come into view with equal clearness at the same time, there is but slight astigmatism, but if whilst one line is clearly seen that at right angles to it is blurred, there is astigmatism which may be corrected by placing in the semi-circular clip a concave cylindrical lens with its axis parallel to the blurred line, or at right angles to that first distinctly seen.

From the result of (2) we learn (*a*) the direction of the two principal meridians, of maximum and minimum refraction ; (*b*) the presence or absence of hypermetropia or myopia and the degree ; (*c*) the presence or absence of abnormal regular astigmatism including its direction and degree. (*a*) The meridian of greatest refraction is parallel to the line seen at the greatest distance of distinct vision, while the meridian of least refraction is always at right angles to it. (*b*) The presence or absence of ametropia is determined by the distance at which the radiating lines are clearly seen.



If there be emmetropia the lines will be seen exactly at the distance of the focal length of the lens employed to produce the artificial myopia; if there be hypermetropia the lines will be seen beyond that point, if myopia within. The degree of ametropia may be estimated by the following calculation: The greatest distance of distinct vision minus the focal length of the lens divided by multiple of these numbers equals the degree of ametropia.

(c) If, however, there be astigmatism the above calculation will give the refraction for the meridian of least refraction only; the degree of astigmatism will be represented by the focal length of the weakest concave cylinder, which, placed with its axis parallel to the blurred line, makes this line as clear and distinct as that first seen. The whole ametropia may then be corrected by combining the spherical lens required for the correction of the meridian of least refraction with the weakest cylindrical lens, which by actual experimentation has been found sufficient to correct the astigmatism. Tweedy's optometer is made by Swift, of Tottenham Court Road.

The **stenopaic slit**, which consists of a metal disc having an oblong opening in it about 2 mm. broad, is used by some for working out cases of astigmatism. The disc is placed in a trial frame in front of the eye we wish to examine; and while the patient looks steadily at the distant type the disc is slowly rotated, so that the slit is brought successively in front of each meridian, the position in which the best vision is



obtained is noted, convex and concave glasses tried in front of the slit to see if any improvement take place. The slit is now in line with one of the chief meridians; let us now turn the disc round  $90^\circ$ , so that the slit may occupy the position of the other chief meridian, and find out what glass most improves vision. Thus, supposing the slit in the vertical direction, the patient reads  $\frac{6}{6}$ , while convex glasses in front of the slit make it indistinct, the vertical meridian is emmetropic; now turn the slit so that it is horizontal, the patient reads  $\frac{6}{12}$ , but with  $+2$  D. in front  $\frac{6}{6}$ , the horizontal meridian is then hypermetropic; the case is therefore one of simple hypermetropic astigmatism, requiring for its correction  $+2$  D. cylinder, axis vertical. On looking through the slit placed between the principal meridians circles of diffusion are formed, and the object has the appearance of being drawn out in the direction of the slit.

Dr Tempest Anderson, of York, has invented an ingenious instrument by which astigmatism may be estimated in a subjective manner, an image of an illuminated radiating screen is thrown on the retina, and is visible to the oculist, the position of the screen on a graduated bar shows the refraction.

The inventor claims for his instrument the following advantages:

1. The observations and measurements are made by the observer, and are entirely independent of the patient's sensations, though these may be used as an adjunct if wished.
2. An image thrown on the retina being used as an



object, the error arising from the vessels or optic nerve being before or behind the retina is avoided.

3. The refraction and accommodation of the observer does not affect the result. It is only necessary that he should be able to see whether certain lines are sharply defined.

In addition to the methods already described for estimating astigmatism, many others are known.

### ANISOMETROPIA

is the term applied to cases which occasionally occur where the two eyes vary in their refraction. The defect is usually congenital, but it may be acquired as in aphakia or loss of accommodation in one eye. One eye may be emmetropic the other myopic or hypermetropic; or one more myopic, hypermetropic, or astigmatic than the other. When the difference is not very great (1 or 1.5 D.), and vision in both eyes is good, we may give each eye its correction; for so long as the eye whose refraction is the most defective still co-operates in binocular vision, sight is improved thereby. Especially is this full correction useful in cases of myopia with divergent strabismus, the increased stimulus to binocular vision being sometimes sufficient to prevent the squint. When one eye is emmetropic and the other myopic, no glass will probably be required, the emmetropic eye being used for distance, the myopic for reading, &c. When the difference in the refraction is greater than 1.5 D.



we may have to be satisfied with partially correcting the difference, and this result can only be arrived at by trying each case, some people tolerating a much fuller correction than others. Frequently no attempt can be made to correct the two eyes, and then we generally give glasses that suit the best eye. In cases of aphakia, &c., where one eye is entirely used, the other still possessing vision, it is an excellent plan to insist on the latter being daily exercised with a suitable glass, the good eye being at the same time covered. By this means the bad eye is prevented from becoming amblyopic, and can at any time be utilised should occasion require.



## CHAPTER VIII

PRESBYOPIA. Pr. (πρέσβυς, old; ὤψ, eye)

WITH advancing age many changes take place in the eye. The acuteness of vision becomes less, owing partly to a loss of transparency in the media, and partly also to a diminution in the perceptive and conductive powers of the retina and the optic nerve. At thirty years the acuteness of vision is almost unaltered, the bottom line of the distant type being read at a little over 6 metres. At forty it can still be read at 6 metres, but after this time it diminishes regularly, so that by the eightieth year vision has decreased to one half. In addition to these changes the accommodation gradually diminishes from a very early period, the near point slowly but steadily receding. This change in the accommodation occurs in all eyes whatever their refraction, and is due to an increased firmness of the lens, whereby its elasticity is lessened, and perhaps also in some slight degree to a loss of power of the ciliary muscle in advanced age. The lens also approaches the cornea, and becomes somewhat flatter. This failure of the accommodation begins as early as the tenth year, at an age when all the functions of the body are still developing.



FIG. 75.

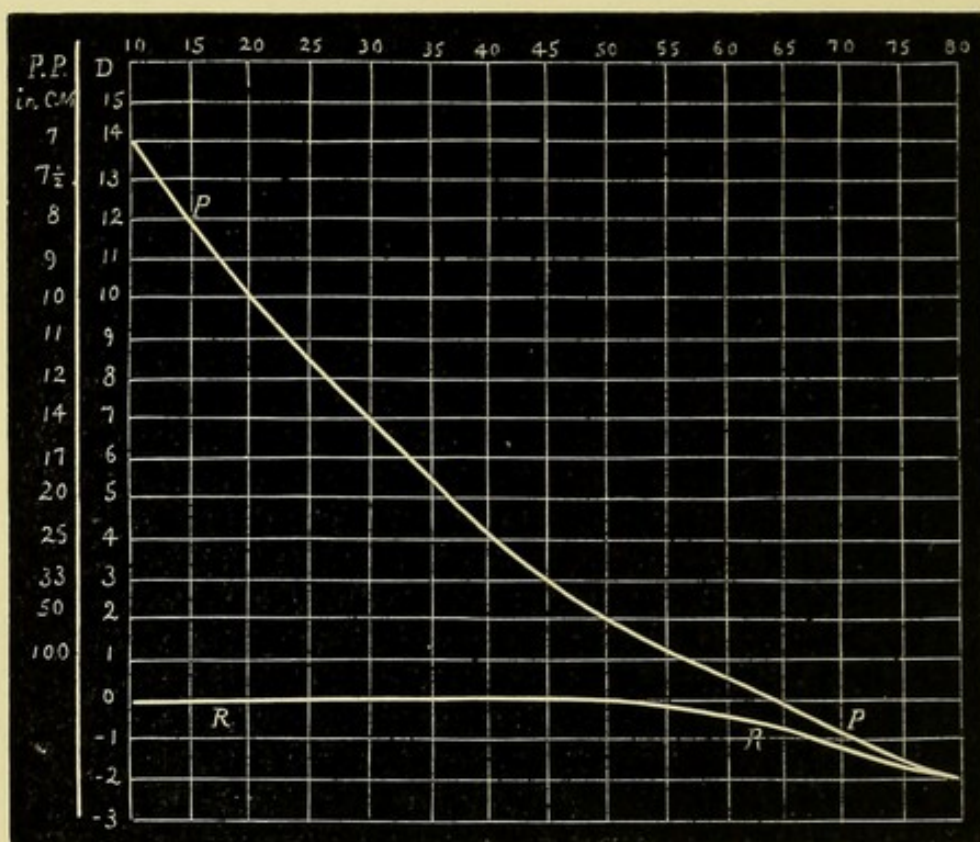


Diagram from Donders, showing the course of accommodation in an emmetropic eye. The figures at the top of the diagram indicate the age, those on the side the amount of accommodation; the oblique line represents the course of the punctum proximum, and the horizontal line that of the punctum remotum; the space between the two lines gives the amplitude of accommodation. From this diagram we can calculate the amplitude of accommodation possessed at any age.

So soon as the binocular near point has receded beyond the distance at which we are accustomed to read and write do we become restricted in our work. Donders has fixed this point at 22 cm.

Presbyopia, therefore, may be arbitrarily stated to exist when the binocular near point has receded to 22 cm., and this occurs usually in the emmetropic eye about the age of forty-five.



To find the punctum proximum of an emmetrope we have only to divide the number of dioptries of accommodation into 100 cm. Thus at twenty there are 10 D. of accommodation; this would give us 10 cm. as the near point. At forty there are 5 D., in which case the near point is 20 cm.

When the near point has receded to 22 cm., the point at which it is convenient to read is considerably further away, since for sustained vision only about half of the accommodation can be used. Thus a person with 4 D. of accommodation would have his near point at 25 cm., with the maximum contraction of his ciliary muscle, and if he can only comfortably use about half this for continuous work his reading point would be 50 cm.; this is far too great a distance. We bring back the near point by convex glasses, which is practically the same as increasing the accommodation.

Although we have said that only about one half of the accommodation can be used for sustained vision, this is not absolutely correct, the amount which must be in reserve varies much with different individuals; thus in one case with a surplus of 1 D. much work can be done, whereas perhaps in another a surplus of 3 or 4 D. is necessary.

In the emmetropic eye, then, it is usually about the forty-fifth year that inconvenience begins to arise, showing itself by a feeling of weariness in the eyes after reading, especially in the evening, small objects being less easily seen than formerly, because having to be held further from the eye they form a smaller



visual angle. The patient seeks a strong light, by which the size of his pupil is diminished, avoids small print, and holds the book or work further away. These symptoms are due to a recession of the near point, and if asthenopia occur, this may be dependent upon a disturbance of the balance between accommodation and convergence; the convergence being the same for any given point, a much greater accommodative effort is necessary than was formerly the case.

The treatment of presbyopia consists in prescribing convex spectacles for reading and near work, so as to bring back the near point to a convenient distance. In uncomplicated presbyopia distant vision is, of course, good.

The following table gives approximately the strength of glasses required by emmetropes at different ages to bring back their punctum proximum to 22 cm.:

Age.	Amount of accommodation possessed at that age.			The near point.	Glass required to bring back p.p. to 2 c.m.	
45	...	3.5 D.	...	28 c.m.	...	+ 1 D.
50	...	2.5	...	43	...	+ 2 D.
55	...	1.5	...	67	...	+ 3 D.
60	...	.5	...	200	...	+ 4 D.
70	...	0	...	infinity.	...	+ 5 D.

To find the glass required in presbyopia we subtract from the glass which represents the receded near point, the glass whose focus represents the point we wish to make the near point. Thus the near point has receded to 50 cm.; the glass representing this point is +2 D, ( $\frac{100}{50} = 2$ ). We wish to bring the



near point to 20 cm. This would be +5 D. ( $\frac{100}{20} = 5$ ). Hence +2 D. from +5 D. gives +3 D. as the glass required.

Although glasses can be frequently thus ordered by a sort of rule of thumb, it is always well to bear in mind that the definition given of presbyopia with reference to its near point is entirely an arbitrary one, and that we must take into account the distance at which the individual has been accustomed to read and work. In this there is great variety. Many small people work and read at 20 cm., whereas some very tall people may be uncomfortable unless the book they are reading is 35 or 40 cm. away. The distance for which the presbyope requires spectacles will also vary much according to the occupation for which he requires them. There exists a popular prejudice against the use of strong glasses, all sort of maladies having been attributed to their use. This prejudice is quite unfounded, the only possible harm that can arise from wearing too strong glasses is that the patient may suffer from asthenopia.

Before ordering glasses for presbyopia it is necessary to try the patient's distant vision, so that any hypermetropia or myopia may be recognised. If hypermetropia exist the amount must be added to the presbyopic glass; if myopia it must be subtracted. Thus a patient with hypermetropia requiring +2 D. for its correction, at the age of forty-five will require + 3 D. for reading (H. 2 D. + Pr. 1 D. = + 3 D.).

If with myopia 1 D. at forty-five, no glass will be



required (M. 1 D. — Pr. 1 D. = 0.). If the myopia be 4.5 D. then the patient can never require a glass for presbyopia, his far point being 22 cm. always. His near point may recede to this distance when all accommodation is lost, but he will still be able to read at that distance, though at that distance only.

Donders thinks that as age advances the refraction of the eye diminishes, in other words, the eye if emmetropic becomes hypermetropic (called acquired hypermetropia). The myopic eye becomes less myopic, so that a real improvement in vision takes place. The hypermetropic eye becomes more hypermetropic. This change takes place at a regular rate in all eyes, at fifty-five the refraction has diminished .25 D., at sixty-five .75 D., at sixty-eight 1 D., and at eighty as much as 2.5 D. Thus at eighty an emmetrope will have acquired 2.5 D. of hypermetropia, and will therefore require a convex glass of 2.5 D. for distant objects to be seen clearly. A myope of 2.5 D. would at eighty have become emmetropic, and require no glass for distance. A hypermetrope of 2.5 D. will add on to his defect 2.5 D., and will require a + 5 D. for distance. This change is due to an alteration which takes place in the structure of the crystalline lens by which its refractive power is diminished.

Some observers, while admitting that many old people who have been assumed to be emmetropic, see distant objects better with a convex glass, say that this is due to a small amount of latent hypermetropia becoming manifest, and not to any decrease in the refractive power of the eye.



Dr. Scheffler some years ago proposed the use of what he called orthoscopic lenses, that is, lenses with two elements, a sphere and a prism so proportioned, that the amount of accommodation and convergence should exactly correspond. Thus in the case of a presbyope, aged fifty, requiring +2 D. to make him read comfortably at 30 cm., it would be combined with a prism base inwards, that would bring the optic axes to exactly that point, the effect being complete repose both for the accommodation and convergence. The results, however, are not so good as might have been hoped; the glasses are too heavy, and on looking at a flat surface some distortion is produced. Nevertheless cases do occur in which, though the presbyopia is corrected, the patient after reading a short time complains of asthenopia. Such cases are frequently at once and completely relieved by combining with their spheres, prisms of  $2^{\circ}$  or  $3^{\circ}$  with their bases inwards or by having the lenses decentred, so that he looks through the outer part of them, making thereby convex prisms.

Much care should moreover be used to see that the glasses are properly centred unless they have been ordered otherwise, and that the frames are not too broad, in which case the lenses form prisms with their bases outwards, and are very apt to give rise to asthenopia by disturbing the relations between convergence and accommodation.

In cases where the convex glasses have frequently to be changed for stronger ones "glaucoma" should be carefully looked for; and if any symptoms of it



appear, no glasses must be allowed, as it is of the greatest importance to avoid all possible tension.

The commencement of cataract also appears to hasten presbyopia.

In each case of presbyopia, having tested the patient's distant vision, so as to detect any hypermetropia, myopia or astigmatism, and having found the glasses which appear to suit, make a trial with them by directing the patient to read for half an hour or so ; if found satisfactory we order spectacles of this strength.

#### PARALYSIS OF THE ACCOMMODATION

It arises from loss of power in the ciliary muscle, due to paralysis of the third nerve, or of that branch of it which supplies the muscle of accommodation and the circular fibres of the iris. Cases do occasionally occur, though very rarely, of paralysis of the ciliary muscle, not involving the constrictor papillæ. Generally both eyes are affected, frequently however only one. The cause of the paralysis may be diphtheria, fever, any complaint of a lowering character, cerebral trouble, syphilis, or some reflex irritation, *e.g.* decayed teeth, &c. ; the cause may however not be apparent. When the whole third nerve is involved, ptosis, external strabismus, &c. occur ; but in those cases where the branch supplying the ciliary muscle and the circular fibres of the iris is alone implicated, the indicating symptoms are, asthenopia, dilatation of the pupil, and loss of the power of



accommodation, whereby the patient though able to see distant objects well (if emmetropic) is unable to read or do any near work. If hypermetropic, both near and distant vision will be impaired; if myopic he is able to see only at his far point. We try the patient at the distant type, and if he is able to see  $\frac{6}{6}$  and yet is not able to read near type, the diagnosis is obvious.

Treatment consists in giving such convex glasses as enable him to read. In order to bring the emmetrope's far point from distance to 35 cm. +3 D. is required ( $\frac{100}{35} = 3$  nearly). We must bear in mind that by encouraging the action of the ciliary muscle, we hasten the patient's recovery; this we do by giving the *weakest* convex glasses with which he is able to read, changing them for weaker ones occasionally, as the ciliary muscle gains strength. Sulphate of eserine in solution grs. j to  $\frac{3}{4}$ j, causes contraction of the ciliary muscle as well as of the iris, and temporarily relieves the symptoms. I think much good sometimes results from its use once every other day for some weeks, the ciliary muscle being made to contract, relaxing again as the effect of the myositic passes off. Attention must be paid to the general health, iodide of potassium or nerve tonics being given, when indicated by the cause.

### SPASM OF THE ACCOMMODATION

It is due to excessive contraction of the ciliary muscle, and occasionally occurs in eyes whatever



their refraction, though most commonly in cases of hypermetropia and low myopia. It may occur as a result of uncorrected ametropia, or in emmetropia from overwork, especially when such work has been done in a bad light. It gives rise to symptoms of asthenopia, and sometimes to myosis, due to excessive contraction of the circular fibres of the iris. In emmetropia we may get symptoms of myopia owing to the parallel rays coming to a focus in front of the retina. In hypermetropia the symptoms may also simulate myopia, and for this we should always be on our guard. I have on several occasions seen hypermetropes going about wearing concave glasses, to correct their supposed shortsightedness. In myopia the real defect is apparently increased, and we might be in danger of ordering too strong concave glasses, &c. For these reasons the systematic use of atropine in young people (whereby one is enabled to estimate and record the exact state of the refraction) cannot be too strongly insisted upon. The treatment, where spasm of the ciliary muscle is suspected, is to drop into the eyes three times a day, a solution of atropine grs. iv to  $\text{ʒj}$  for two or three weeks, as by this means we give the eyes complete rest, to correct any ametropia that may exist, and to attend to the patient's general health, administering tonics if necessary.



## CHAPTER IX

STRABISMUS ( $\sigma\tau\rho\acute{\epsilon}\phi\omega$ , I turn aside)

INTIMATELY connected with hypermetropia and myopia is strabismus. It exists when there is a deviation in the direction of the eyes whereby the visual axes are not directed to the same object. The one eye fixes the object, the other deviates, usually inwards or outwards, and the condition is spoken of as convergent or divergent strabismus. By it the expression of the patient becomes much changed, and he gradually loses the advantage of binocular vision.

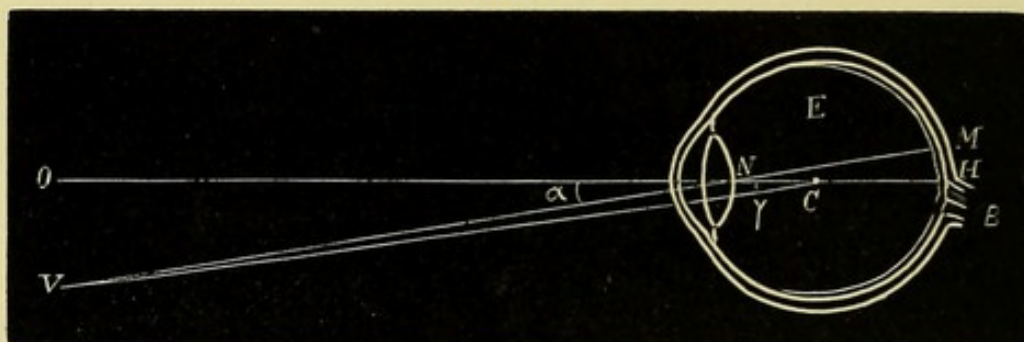
In examining a patient for strabismus it is necessary to be on our guard against mistaking the apparent for the real. This may arise from confusing the visual axis, which is the line passing from the macula through the nodal point to the object looked at, with the optic axis, which passes from the inner side of the macula, through the nodal point and the centre of the cornea, forming, with the visual axis, an angle of about  $5^{\circ}$  in emmetropia (Fig. 76). This angle is called the angle  $a$ ; and when thus formed by the crossing of the two axes it is also said to be *positive*.

In hypermetropia (Fig. 77) the angle ( $a$ ) increases with the degree of hypermetropia, and if it be high



may attain  $7^{\circ}$  or  $8^{\circ}$ , or even more; this large angle gives to the eye an appearance of divergence.

FIG. 76.



M. The macula. N. The nodal point. B. Optic nerve. V. The object. VM. The visual axis. OH. The optic axis.  $\alpha$ . The angle alpha formed between the visual and optic axes. C. The centre of rotation of the eyeball situated on the optic axis.  $\gamma$ . The angle gamma formed at the centre of rotation of the eyeball by the optic axis, and a line drawn from the centre to the object looked at.

FIG. 77.

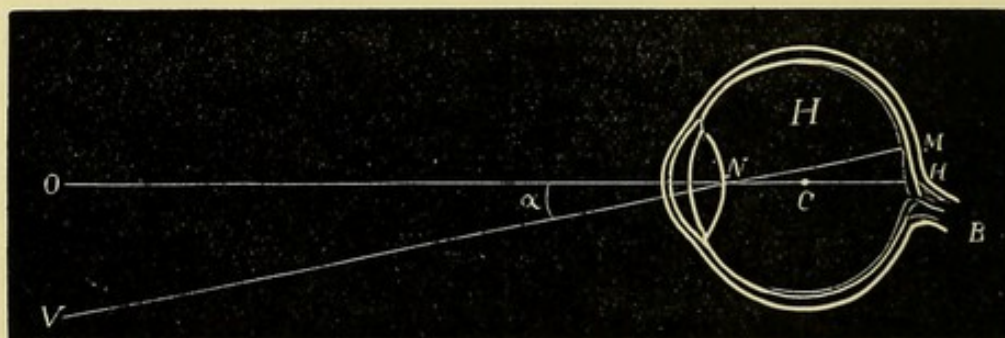
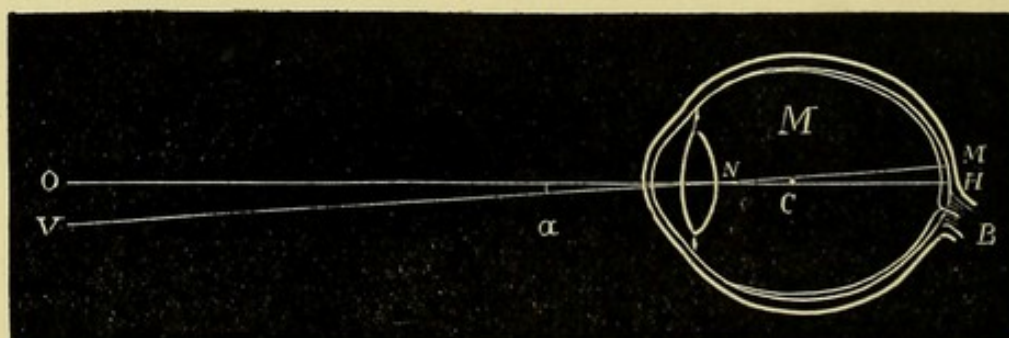


FIG. 78.





In myopia (Fig. 78) the angle ( $\alpha$ ) decreases, and in high myopia the visual axis may approach the optic axis, so that the angle ( $\alpha$ ) is very small, and it may coincide with it when no angle is formed, or even be altogether on the outer side of it, when it is said to be *negative*. This small angle ( $\alpha$ ) gives to the eye an appearance of convergence.\*

Of strabismus there are two chief varieties :

1. Convergent.

2. Divergent.

*Convergent strabismus*.—On looking at any object one eye only is directed to it; the other, as the name implies, looks inwards, so that the metrical angle is much greater in the deviating than in the fixing eye.

It is almost always due (except in cases of paralysis of the sixth nerve) to hypermetropia, probably at least 80 per cent. of the whole being due to this cause, its method of production depends upon the intimate connection that exists between accommodation and convergence.

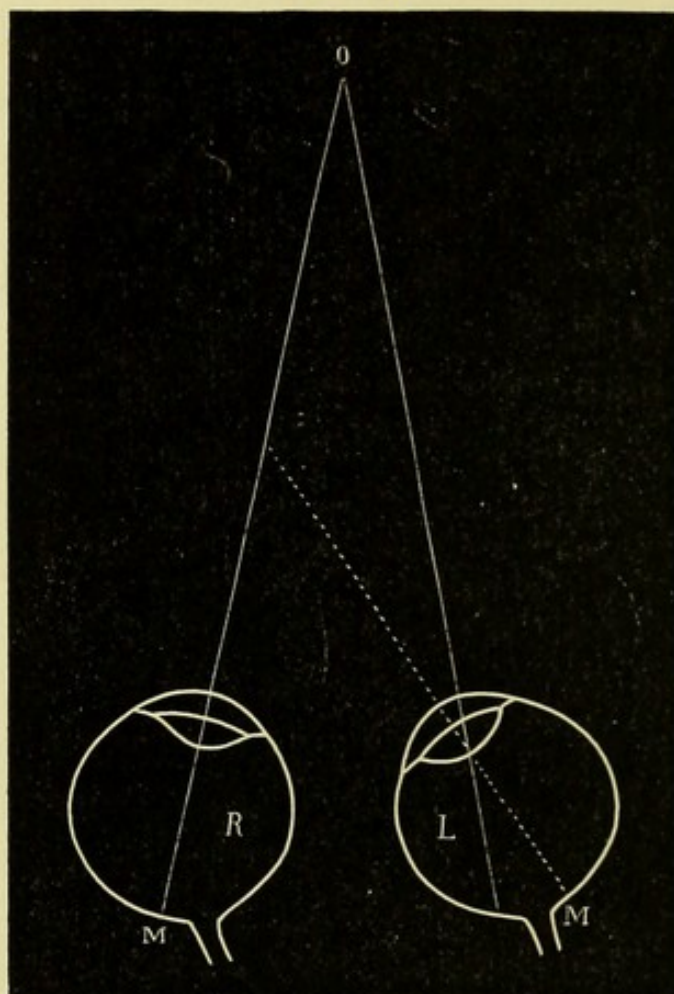
The convergence is most marked when looking at near objects; sometimes there may be no squint when distant objects are viewed.

A hypermetropic person requires to use some of his accommodation for distant objects; for near objects he must, of course, use still more, since for every increase in the accommodation there is a desire

\* Another angle sometimes mentioned is the angle  $\gamma$ , which is the angle formed at the centre of rotation of the eye by the optic axis, and a line drawn from this centre to the object looked at. Shown in Fig. 76.



FIG. 79.



R. Right eye directed to object O. L. Left eye diverging inwards. M. Macula.

for a certain increasing degree of convergence. Thus an emmetropic individual, accommodating for an object at 30 cm., would at the same time converge for that particular point. If the individual were hypermetropic to the extent of 4 D. he would probably possess the same amount of accommodation as if emmetropic, we will suppose 8 D., whilst of these, one half (4 D.) would be required to enable him to bring parallel rays to a focus on the retina. He would have the tendency at the same time to use half his convergence. Thus for distant objects he would have an



inclination to converge, his internal recti acting, and it is only by the increased tension of the external recti, called into action by the desire which all eyes possess for singleness of vision, that convergence is prevented. The more we converge the more can we accommodate; so that on looking at near objects—which means an increase of the accommodation—an increased tendency to convergence is produced. Therefore one of two things must occur; either the patient must see indistinctly by not accommodating sufficiently, or one eye must be allowed to converge. Some patients with hypermetropia prefer binocular indistinct vision, others, single clear vision with a squint.

One occasionally finds an individual who can thus choose which he will do; we are trying his acuteness of vision at the distant type perhaps, he stops at some place, we will suppose  $\frac{6}{12}$ , and says that he is unable to read the next two lines unless he squint. The accommodation necessary to read  $\frac{6}{6}$ , makes a heavier call on the convergence than can be borne. Such a case forms a good illustration of the manner in which convergent strabismus is produced in a hypermetrope.

Hence if the impulse to see distinctly is greater than the desire to retain binocular vision, one eye yields, and squint occurs; at first diplopia follows the convergence, and is always in the opposite direction to the deviation. Possibly the convergence of the deviating eye is increased by the desire that the weaker image may be made still weaker by falling on a more peripheral part of the retina. At first the



diplopia may be very annoying, but by degrees the sensorium learns to suppress the image of the weaker eye, which after a time becomes amblyopic. The earlier the age at which the squint appears the sooner does the sight in the deviating eye thus deteriorate.

In high degrees of hypermetropia, when no amount of accommodation can make vision distinct, squint is less likely to occur. It is usually, therefore, in cases of from 2 to 4 D. that convergent strabismus is most frequently met with, and it generally makes its appearance about the fifth or sixth year, so soon in fact, as the child begins to use its accommodation much for near objects. Anxious parents frequently have all sorts of excellent reasons to which they attribute the defect. They say that the child has been imitating its playmate, or that the nurse did something which caused it to squint, perhaps, by making the child look too much or too constantly in one direction.

Any cause which by rendering the image in one eye less distinct than that in the other, as *nebulæ*, ulcers of the cornea, a difference in the refraction of the two eyes, or even wearing a shade for a few days for some trivial complaint, may, where hypermetropia is present, combine to produce strabismus. The impulse for binocular vision is lessened, and the eye in which the fainter image is formed converges.

It is thus seen that convergent strabismus gradually destroys binocular vision. In cases of hypermetropia, where binocular vision does not exist owing to great



difference in the refraction of the two eyes, divergent strabismus may occur.

This intimate connection between accommodation and convergence, together with the method of the production of strabismus, will be more easily understood by carrying out some such simple experiments as the following. We will assume the observer to be emmetropic. The strongest concave glass with which he, having binocular vision and being at a distance of six metres, can still read  $\frac{6}{6}$ , is the measure of the *relative* accommodation. The *absolute accommodation* is measured by the strongest concave glass with which each eye separately can read  $\frac{6}{6}$ . In my own case, with  $-4$  D. before each eye,  $\frac{6}{6}$  can be seen singly and distinctly,  $-4.5$  D. renders it indistinct, and each increase in the glass increases the indistinctness, but produces no diplopia. Separately each eye can overcome  $-7$  D. Armed with  $-4$  D. before each eye, I am able to see  $\frac{6}{6}$  distinctly, using of course 4 D. of my accommodation. If a colored glass be placed before one eye, homonymous diplopia at once appears, proving that one eye has deviated inwards, with  $-3$  D. and the colored glass, squint was produced, but with no weaker concave glass.

On repeating the experiment in an individual with  $.5$  D. of myopic astigmatism in one eye, and emmetropia in the other,  $-2$  D. before each eye was the strongest glass with which  $\frac{6}{6}$  could be seen clearly and singly,  $-2.5$  D. did not render it indistinct, but produced diplopia. The absolute accommodation for each eye amounted to 6 D. With  $-2$  D. before each eye, the



colored glass was placed before the astigmatic one, and diplopia was produced. With  $-1$  D. and the colored glass the result was the same, except that the two images were nearer together. With  $-.5$  D. actual diplopia was not produced.

These experiments require but little explanation. In my own case, when using 4 D. of accommodation, I have the tendency also to use a corresponding amount of convergence. I am conscious of this muscular disturbance by the effort I make and by a feeling amounting almost to giddiness, produced when first looking through the  $-4$  D. The instinctive desire to see clearly and singly is so great, that the external recti contract, thereby balancing the increased contraction of the internal recti. Any increase of my accommodation above 4 D. when looking at  $\frac{6}{6}$  causes the letters to become indistinct, the desire to maintain binocular vision being greater than that for clear images. On placing the colored glass before one eye we diminish the retinal impression in that eye; the demand for binocular vision is lessened, the external recti cease to act, and as a result of the increased action of the internal recti, squint results.

In the second experiment the retinal impression in one eye, even with so slight an amount of astigmatism, is reduced, so that with 2 D. of accommodation without convergence, the desire for clear images is greater than that for binocular vision, and diplopia the symptom of squint results.

Our first object must be to ascertain to which class



the squint belongs. First, if it be real or apparent; and secondly, if it be paralytic, or due to disturbance of the muscular balance. We first direct the patient to look steadily at some object held about one metre in front of him and gradually bring it nearer so as to call into action the accommodation as the object approaches; both visual axes may continue to be directed steadily to it, it is then a case of apparent strabismus; the one eye may fix it, while the other after following it up to a certain distance suddenly deviates inwards proving it to be a concomitant squint, or it may follow the one eye to a certain point, when it stops after perhaps making a few jerking oscillating movements, then it belongs to the paralytic variety. Again, having covered one eye with a card or what is better with an opaque glass disc which, while preventing the patient seeing with that eye, yet allows us to see the movements that take place behind it; we direct him to fix with the other eye some object, as a pencil held about half a metre in front of him. If the covered eye make a movement inwards, the squint is real, and this movement is called the *primary deviation*. If now the fixing eye be covered, the squinting one uncovered and made to fix the object, the first eye, which is now excluded from vision may make a movement inwards; this movement of the sound eye is called the *secondary deviation*.

When the primary and secondary deviations are equal the squint is said to be *concomitant*.

The range of movement in concomitant squint is as great as in emmetropic eyes, it is simply displaced, in



the paralytic form, the movements of the squinting eye are usually much curtailed; this we easily detect by holding up the finger about 50 cm. in front of the patient and directing him, while keeping the head still, to follow the movements of the finger which is moved to either side and then up and down. In the concomitant form the squinting eye will almost exactly accompany the other, the visual lines being at the same angle except perhaps in the extreme periphery, whereas in the paralytic form, the movement in one eye will stop at a certain point, while the other eye continues to follow the finger.

When either eye fixes indifferently, the vision being equally good in both, it is called *alternating strabismus*. *Monolateral* or *constant* when the same eye always squints; the vision in the squinting eye being usually below that in the fixing one.

*Periodic* when it only comes on occasionally, as after looking for some time at near objects. If judiciously treated this variety can be cured without operation, if neglected it generally passes on into one of the constant forms.

In the strabismus of hypermetropia the primary and secondary deviation are equal. In the paralytic form the secondary deviation usually exceeds the primary.

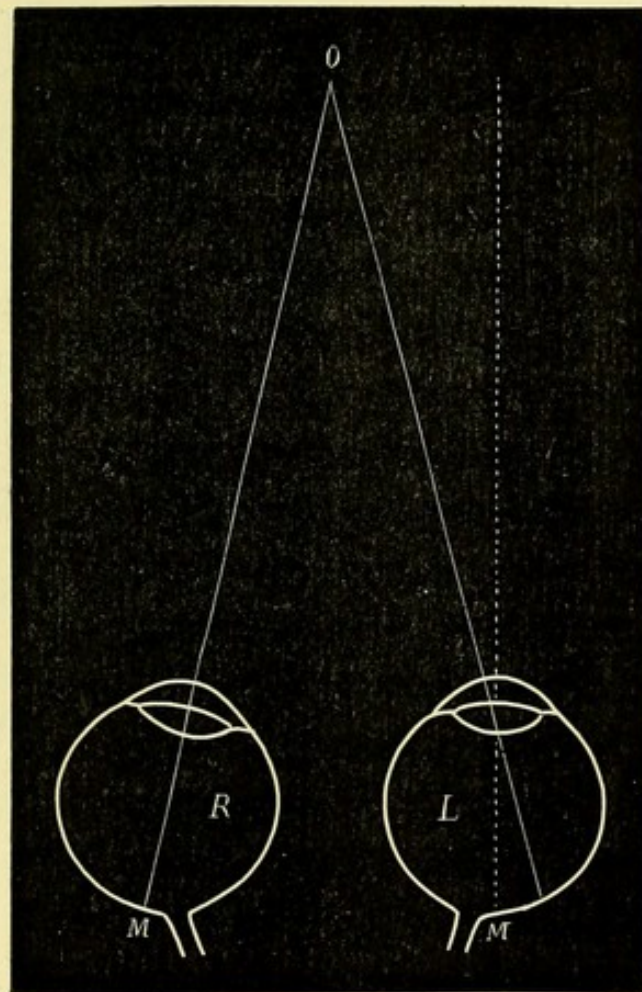
A certain number of cases of convergent strabismus get well with advancing age; the probable explanation of this is, that as the accommodation diminishes, the time at length arrives when the amount of accommodation at the patient's disposal is not sufficient to produce clear images, he therefore



relaxes his accommodation and with it extreme convergence. This spontaneous cure is most likely to take place when the sight in both eyes is good.

*Divergent strabismus* exists when one eye only fixes the object looked at, the other deviating outwards (Fig. 80). It is usually dependent on myopia, but it may

FIG. 80.



occur in any eyes in which binocular vision does not exist, as in some cases of high hypermetropia or astigmatism, or it may result from a too free division of the internal rectus muscle in attempting to cure a



case of convergent strabismus. It may also be paralytic.

The divergent is much less common than the convergent variety of strabismus.

In myopia the antero-posterior diameter of the eyeball is elongated, the range of movement is diminished, and the extreme convergence which is necessary to enable the patient to see objects within his far point, tires out the internal recti muscles, giving rise to muscular asthenopia, to relieve which one of the internal recti gives way, and the eye deviates outwards.

Sometimes the deviation only takes place after the patient has been working some time and the eyes feel fatigued; in others it is only noticed when looking at objects beyond their far point. Soon, however, the squint becomes constant, and a divergent strabismus once established usually increases.

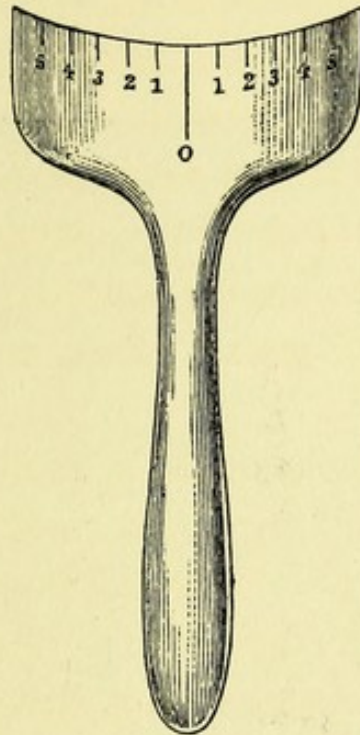
The amount of squint must be estimated and recorded. There are several ways of doing this. We may indicate it in the form of a diagram, the position of the pupil to the internal canthus when looking as far as possible to one side, will show the extreme range of the eye inwards. Then direct the patient to look in the opposite direction so that we may find the extreme range outwards, this we indicate by the position of the outer edge of the cornea with the external canthus. Our diagram must of course include both eyes, so that we may judge of their relative range of movement.

The strabismometer consists of a handle sup-



porting a small ivory plate shaped to the lower lid and having on it a scale by which we measure the

FIG. 81.



Strabismometer.

amount of deviation of the centre of the pupil. This is an easy method of measuring the strabismus, but is not to be depended upon.

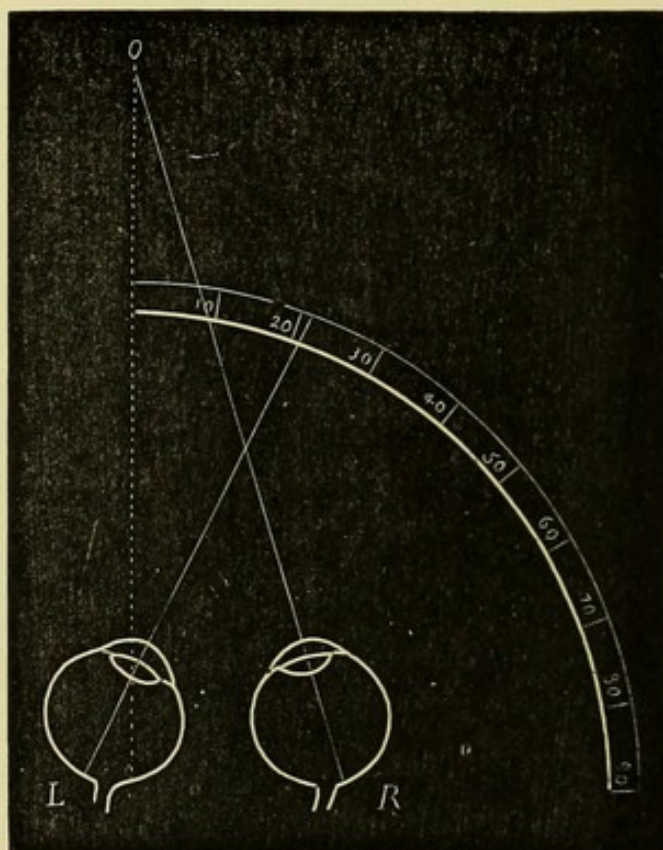
The measurement of the *angle of the strabismus* is the only reliable and exact method of recording the amount of squint. Landolt defines this angle, as that which the visual axis makes, with the direction it should have in a normal state.

For this measurement we require a perimeter. In front of which the patient is placed, with the quadrant according to the kind of squint we are about to measure; if it be a convergent or divergent one, then



the quadrant is placed horizontally. The patient being seated so that his deviating eye is in the centre of the instrument; we direct him to fix some distant object (o, Fig. 82) in a line with the centre of the perimeter,

FIG. 82.



with both eyes; a lighted candle is moved gradually along the inside of the quadrant from the centre of the instrument outwards; the observer, following the movement of the candle with his head, stops as soon as the reflection of the candle on the cornea of the squinting eye occupies the centre of its pupil, this gives us the direction of the optic axis, what we really wanted was the direction of the visual axis, but for all practical purposes the former is sufficient. The



degree is read off the quadrant at the point where the candle was stopped and this result recorded. We must next measure the angle of deviation for near vision, by requesting the patient to look at the centre of the perimeter and proceeding with the candle as before, recording the degree found.

The **treatment** of squint consists in prescribing proper glasses, and in some cases tenotomy.

In children when the squint is of small amount, and has existed only a short time as in the periodic form, the case can usually be cured by spectacles. The child is placed under atropine in the manner described when speaking of hypermetropia, and the amount of error of refraction found out by retinoscopy. If the case be convergent strabismus with hypermetropia, we order glasses that will correct  $\frac{2}{3}$  or  $\frac{3}{4}$  of the total error (sometimes even full correction will be tolerated) with directions that they be worn constantly. It also frequently assists the cure to keep the child atropized for two or three weeks, wearing the glasses at the same time. Had the case been one of the less common forms of squint, divergent with myopia, we endeavour to give the patient as nearly as possible his full correction. When the vision in the two eyes is different, that in the squinting one being more or less amblyopic, it is of service sometimes to exercise each eye separately for a certain fixed time daily.

When the squint is periodic it can always be cured by spectacles alone.

After the spectacles have been worn some time without improvement, or when the strabismus amounts



to 6 mm. or more, a tenotomy must be done. I think better results follow a limited operation on both muscles, than a free division of one.

Paralytic strabismus does not come within the province of this work.



## CHAPTER X

## ASTHENOPIA

*Asthenopia* (A priv.  $\sigma\theta\epsilon\nu\omicron\varsigma$  strength,  $\omega\psi$  the eye) is a convenient term to designate a condition of fatigue of the eyes which often accompanies hypermetropia, myopia, and astigmatism, and has been frequently referred to when speaking of these. It also occurs in a certain number of cases where no ametropia can be found. It shows itself by the inability to continue a steady and prolonged convergence, so that the patient complains that he is unable to read or write for any length of time, without the letters becoming indistinct and running together, pain over the eyes supervening. After a rest, he is able to resume his work, to be again interrupted after a shorter interval, and this is especially the case in the evening after a day's work. There is then moreover the disadvantage of an artificial light which always tends in these cases to increase the asthenopia. If the work be still persisted in, the pain around the eyes increases, there is photophobia, a sensation of dazzling and dimness, more or less conjunctival congestion, with headache which sometimes passes on to nausea and sickness,



and a generally uncomfortable feeling about the eyes themselves, which become red and irritable. In some cases the symptoms have been so severe as to lead to the diagnosis of brain disease, and there is little doubt that frequently reflex nervous disorders are caused by asthenopia.

Two forms of this complaint have usually been described, viz. that accompanying hypermetropia, which is styled *accommodative* asthenopia, and that occurring with myopia, called *muscular* asthenopia.

When Donders discovered the common occurrence of hypermetropia, he soon became aware of the intimate connection which existed between it and asthenopia; and was at first inclined to attribute every case to this cause. Where no manifest hypermetropia was present, he gave a solution of atropine to paralyse the accommodation, feeling confident that some latent hypermetropia would then display itself: such cases were usually completely cured by proper convex glasses. This accommodative asthenopia is due to the constant state of contraction in which the ciliary muscle is kept, an emmetrope looking at distant objects, does so without any accommodation, the ciliary muscle being passive; but the hypermetrope has to use his ciliary muscle even for distant objects, and so much the more for reading or near work. The ciliary muscle practically gets no rest. A young and vigorous patient whose hypermetropia is not very high, may resist asthenopia for a long time, but as he gets old, or his health suffers from any cause, if he become anæmic, or if the patient be a



woman, symptoms of this disorder are apt to appear during lactation. In some cases where convex glasses do not produce the desired relief, prisms of  $2^{\circ}$  bases inwards combined with the spherical correction are often of great use, or what comes to the same thing, we place the convex glasses somewhat near together so that the patient looks through the outer part of the glass (Fig. 84). This plan is also frequently very useful in presbyopia. Here the asthenopia is in part due to a disturbance of the balance between the two functions, accommodation and convergence, and perhaps also in part to the difficulty of maintaining an exact state of equilibrium between the internal and external recti muscles. An individual with hypermetropia has to use his accommodation in excess of his convergence. When we correct his refraction with glasses, he will have to use these two functions in an equal degree, or at least in different proportions to that to which he has been accustomed. Many people are able at once to accommodate themselves to this new state of affairs; but there are others in whom the force of habit is so strong that they cannot at once throw off the acquired habit of using the accommodation in excess of the convergence. You must not, therefore, be discouraged, if occasionally your patient is not at once and completely relieved of his asthenopia, as soon as you have given him convex spectacles. A fortnight's trial should be made before we can decide that such spectacles will not relieve the patient of his asthenopia.

Asthenopia depends much upon the nervous system



of the individual; one hypermetrope will have no uncomfortable feelings, while another whose condition seems exactly similar will suffer much.

Hypermetropes who squint are not usually troubled with asthenopia.

A very slight amount of astigmatism will in some people produce accommodative asthenopia.

Muscular asthenopia is almost invariably due to myopia. In this form of ametropia the eyeball is elongated, impeding somewhat its free movements. Von Graefe declared the cause of the symptoms in these cases to be the strain thrown upon the internal recti in maintaining a prolonged convergence, and described it as due to "insufficiency of the internal recti." Since then this cause has been universally accepted, and for the relief of this insufficiency, division of one or both external recti has been practised, with the object of weakening them. Von Graefe proposed two tests by which we might find out this weak condition of the internal recti.

The patient is to look steadily at the point of the finger, about 30 cm. away. One eye is then covered with a card, so as to conceal the object from it, but so as not to prevent the observer from seeing the movements of the eye behind the card. If the eye which is thus excluded from vision retain its direction unchanged, the interni are normal, but if it deviate the interni are insufficient.

The other and more accurate test, is to place a prism of about  $15^{\circ}$ , with its base downwards, in a spectacle frame before one eye; by this means we



cause a displacement of the eye upwards, and of course also vertical diplopia, thus doing away with the possibility of fusion. The patient is now directed to look steadily at a card on which is drawn a line with a dot in its centre, placed at the patient's ordinary reading distance (Fig. 83). Naturally he will see two dots. If he see one line only with two dots on it, his muscles are assumed to be of the normal strength; if, however, two lines are seen with a dot on each, then insufficiency is supposed to exist; and the strength of the prism which is necessary with its base inwards to produce fusion, is the measure of the insufficiency.

FIG. 83.



This theory of Von Graefe was implicitly followed by ophthalmologists until a few years ago, when Mr Brudenell Carter, Dr Theobald, and others paid some attention to this subject, with the effect I think of upsetting the theory itself and the value of the tests, which they say merely show that there is a diminution of the nerve stimulus by which convergence is produced. Many emmetropes and even hypermetropes tested in this way could be thus proved to have insufficiency of the internal recti, if these tests were reliable. Many myopic eyes, which answer well to this test of the two lines and two dots, and in which one was accustomed to say that insufficiency existed, have nevertheless good powers of convergence of each eye, and a range of movement equal to normal eyes.



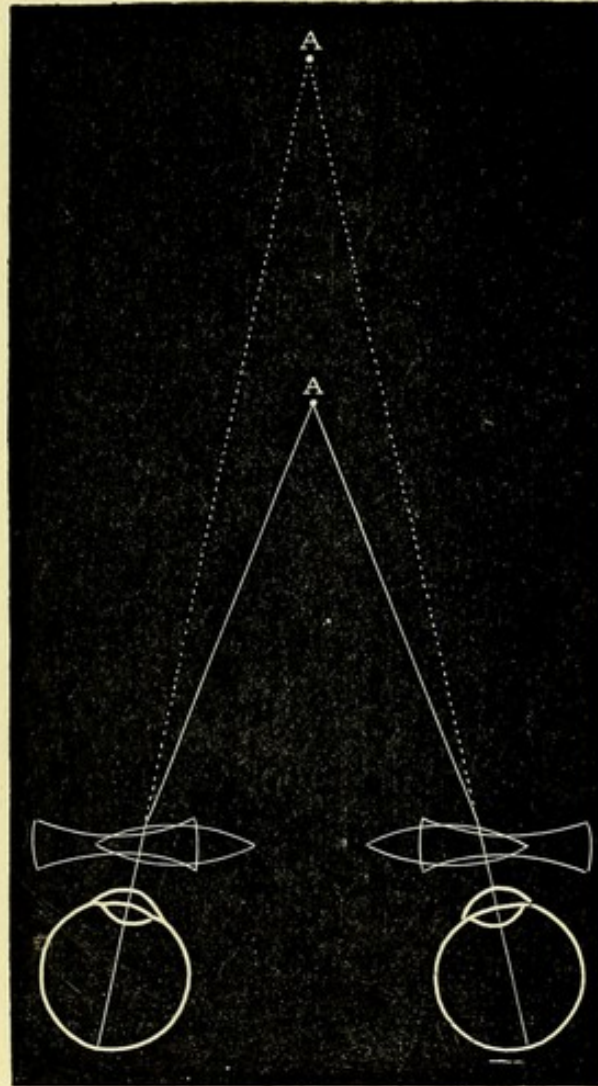
It seems probable that muscular asthenopia is due to a cause somewhat similar, but of an opposite character, to that producing the accommodative form. In hypermetropia the patient has to use his accommodation in excess of his convergence; but in myopia the convergence has to be used in excess of the accommodation. Thus a patient with 4 D. of myopia has his punctum remotum at 25 cm. To see at that distance he must converge to that point, maintaining a passive condition of his accommodation. Such cases are at once relieved by weak prisms with their bases inwards, which diminish the amount of convergence necessary. It is sometimes useful to combine prisms with concave glasses, or by separating the glasses somewhat widely, we produce the same result. Fig. 84 shows concave spectacles acting also as prisms by being somewhat separated, and convex ones having the same effect when placed so close together that the patient looks through the outer part of the lenses.

In addition to these cases of asthenopia occurring with hypermetropia, myopia, and astigmatism, which should be relieved by the glasses which are necessary to correct these errors and restore the balance of their extra and intraocular muscular systems, everyone will occasionally meet with cases in which no ametropia exists, as proved by placing the patient under atropine and then testing his refraction. *Reflex asthenopia* has been the name given to these cases, they are often exceedingly troublesome, and occur most frequently in young unmarried girls of an



hysterical or nervous temperament. If it occur in men, such are usually feeble, hypochondriacal, and nervous. Frequently the only symptom present in addition to the patient's feelings of pain, tension,

FIG. 84 (*Landolt*).



heat, &c., is a certain amount of conjunctival trouble and increased secretion, with a feeling of itching and pricking. Sometimes with the ophthalmoscope, the retinal veins seem rather full, with or without a slight amount of haziness about the edges of the disc. This



form of the disorder may be attributed to long hours of working, reading, or writing. I have met with several cases amongst those making gold lace, and no doubt the bright materials here worked with had something to do with the production of the asthenopia. Complete abstinence from work does not always bring relief. It seems generally accepted by all authorities on this subject, that in such cases the nervous system is exceedingly sensitive and unstable. Frequently there is disturbance of the uterine organs, when leucorrhœa exists in young unmarried women with troublesome asthenopia, masturbation may be suspected. Irritation of the fifth nerve from carious teeth may also be a cause. The treatment of this reflex form of asthenopia is to endeavour to find out the cause and remove it, with rest for the eyes during certain fixed portions of the day.

Some hypermetropic ladies refuse to wear glasses because they think them unsightly, preferring to suffer from asthenopia.



## CHAPTER XI

## SPECTACLES

As I have already treated the subject of spectacles somewhat fully when considering the correction of different forms of ametropia, it will only be necessary here to make a few general remarks concerning their use.

Glasses may be made of rock crystal or crown glass. There is an impression abroad that those made of the former material (which are called pebbles) are the best, because they are harder and therefore less liable to be scratched. In reality, however, those made of crown glass are superior, because they refract more regularly, besides being much cheaper.

The frames may be made of gold or steel. They should fit the face well. The bridge must suit the nose and be of such a height, that each eye looks exactly through the centre of its glass. When worn for myopia or hypermetropia they should not be further from the eye than 13 mm. For presbyopia the person may be allowed to suit his own convenience and comfort,  $2\frac{1}{2}$  cm. being an ordinary distance.

Single glasses may occasionally be allowed in low degrees of myopia for looking at distant objects.



They have this disadvantage, however, viz. that sometimes one eye is used so entirely, that the sight in the other may deteriorate from want of sufficient use. Folders (pince-nez), may be used in similar cases to the above, and also to read or work with in presbyopia. Spectacles are as a rule to be preferred, since they are more accurately centred and fit better. For distant vision the glasses should be parallel; for near vision they should slightly converge, so as to be exactly at right angles to the visual axes. In addition to concave, convex, and cylindrical glasses, others are sometimes used.

*Stenopaic spectacles* consist of an oval plate with a small central aperture which may be of any shape according to the case, so that all the peripheral rays are cut off; only such as are in the optic axis being allowed to pass through. They can be combined with convex or concave glasses, and are often exceedingly useful in cases of leucoma, nebulæ, irregular astigmatism, myopia, &c., where the vision is much disturbed.

*Prismatic spectacles* may consist of prisms alone, or in combination with concave or convex lenses. Their use is called for in certain cases of paralysis of muscles, to prevent diplopia; also in some cases of hypermetropia, when they are combined with convex glasses of the strength of  $2^{\circ}$  or  $3^{\circ}$ . With their help the patient is able to converge more, and therefore accommodate more, for a given point. Some myopes, who can read well without glasses, suffer from asthenopia, which can be relieved by prisms, bases inwards;



because without them, they have to use their convergent power, their accommodation being at the same time passive.

*Pantoscopic glasses*, the upper half of these glasses have one focus, the lower half another. Thus a presbyopic person may also be myopic. The upper half of the glass would then be concave for distance, the lower half convex for near work. Painters sometimes find such glasses very useful.

*Tinted glasses* are sometimes required for diminishing too much light, in cases of irritation or inflammation of the retina, or of photophobia from various causes, as myopia, &c. In these cases light blue, which cut off the orange rays are the best, but smoke colored are preferred by some surgeons. Tinted glasses are always somewhat heating to the eyes, in proportion to the amount of rays they absorb. We sometimes combine them with convex or concave glasses.

There are also various forms of *protectors*; those hollowed out like a watch glass so as to fit closely are to be preferred to those with wire sides called goggles, or those with sides of glass, which last have the disadvantage of being too heavy. Workmen wear different sorts of protectors to keep off dust, fragments of stone, &c. which may be made of glass, talc, or other materials.

It is sometimes necessary to find out and record the strength of glasses that are being worn; this is easily done. If convex, we take a concave glass out of the trial box, hold it against the glass we are trying and look through them at a line, *e.g.* the bar of a



window or any similar object, we move the glasses to and fro in front of the eye, if the line remain immovable the neutralization is complete, if it move in the same direction the concave glass is too strong; if in the opposite direction it is not strong enough.

### CASES

Commence the examination in a systematic manner:

First, notice the general appearance of the patient, then the shape of the head and face. Next the eyes, as to whether they are large and prominent, or small and sunken-looking. Listen patiently to the sufferer's complaints, and having submitted to this ordeal, test the acuteness of vision of each eye separately, writing down the result, remembering always to commence with convex glasses. Then place the near type in the patient's hand, noting the punctum proximum and the punctum remotum. Next pass on to the ophthalmoscope, first applying the "retinoscopic test," then the "indirect examination," and finally the "direct method," first at a distance, and then close to the eye. If any ametropia exist, the advisability of paralysing the accommodation with atropine must be considered.

In order to illustrate this method of examination I will give a few cases:

CASE 1.—E. M—, a young woman, a bookbinder, æt. 17, suffering from tinea tarsi, complains that her eyes get very tired at night, so much so, in fact,



that she is unable to read for any length of time. Her general appearance is healthy, and nothing special is noticed about her face, except that the eyes are small. The acuteness of vision for both eyes is normal. We try weak convex glasses 1 D. and she says that she sees somewhat clearer with them. We next try +2 D., then +3 D., and find that with these last the patient is unable to read  $\frac{6}{6}$ . +2 D. for each eye, is the strongest convex glass with which  $\frac{6}{6}$  can be read, and is therefore the measure of her Hm.

We next place the patient in the dark room, directing her to look at some distant object or at a black wall, so as to relax as much as possible her accommodation, and apply the retinoscopic test. The shadow we perceive moves slowly against the mirror, we put +2 D. in a spectacle frame, in front of the eye. The shadow is more distinct, and moves more quickly. We try stronger glasses and then find that +3.5 D. is the highest with which we still get a reverse shadow. Both eyes are alike.

Next examine with the ophthalmoscope. By the indirect method the disc becomes smaller on withdrawing the objective from the eye. With the mirror alone at a distance, we see an image of the disc which moves with the observer's head, showing it therefore to be an erect image. On approaching the eye the disc is not seen well, unless we put in force our own accommodation; with our accommodation suspended if we turn the wheel of the ophthalmoscope so as to bring forward convex glasses, the clearness of the fundus will be improved. +3 D. is the strongest



convex glass with which the details can be distinctly and clearly seen by myself.

We might be satisfied with this result, assuming 3.5 D. to be the amount of total hypermetropia; but in young people it is much more satisfactory to be able to record once and for all the total hypermetropia beyond doubt. I therefore order the patient *Guttæ Atrop.*, grs. iv to  $\text{ʒj}$ , two or three drops to be placed in both eyes three times a day for four days, warning her that she will be unable to see so well and that the pupils will be dilated during their use. We also recommend a shade to be worn to protect the eyes from the light.

On her return she reads only  $\frac{6}{60}$  with each eye, and she now requires +5 D. to enable her to read  $\frac{6}{6}$ . We also find with retinoscopy that +5 D. is the strongest glass with which we get an opposite shadow.

Our patient, therefore, has a total hypermetropia of 5 D., two of which were manifest and three latent. For work and reading we order her spectacles +3 D. At present she will not require them for distance. About thirty she will probably require her glasses increased to +4 D., and may then begin to wear them constantly; about forty she may be able to bear her full correction.

We must remember that when atropine has been used it is necessary to take off 1 D. from the measurements thus found, for the tone of the ciliary muscle.

CASE 2.—A young man, æt. 20, next presents himself. He has a long intellectual face with prominent nose. The palpebral apertures are wide; on directing



him to look inwards as much as possible the eyeballs seem elongated in an antero-posterior diameter.

His eyes, he says, are excellent, but he is unable to recognise people as well as formerly. We test the acuteness of vision, and find that he reads  $\frac{6}{36}$  with each eye. Convex glasses make even that line indistinct. Our patient is probably myopic. We place in his hand the near type, and he reads Sn. 1, at once and easily. The farthest point at which he can read it, is 25 cm. ( $\frac{100}{25} = 4$  D.)  $-4$  D. should be the measure of his myopia. We try  $-4$  D. directing him again to look at the distant type. He reads with each eye  $\frac{6}{6}$ ; we reduce the glass to find the *weakest* with which he reads the same, and with  $-3.5$  D. he reads it, though hardly so well; with  $-3$  D. he reads only  $\frac{6}{9}$ ,  $-3.5$  D. is therefore the measure of his myopia. If we employ retinoscopy  $-3.5$  D. is the weakest concave glass with which a reverse shadow is produced.

We next examine the eye with the indirect ophthalmoscopic examination. The disc becomes larger on placing the objective near the eye and gradually withdrawing it, and in addition we see also a slight myopic crescent on the apparent inner side of the disc. From this case disc I was drawn (Page 108).

With the direct ophthalmoscopic examination at a distance from the eye, the disc cannot be well seen, because in our case the aerial image would be formed 25 cm. in front of the eye. To enable us to see this aerial image it is necessary we should be some 30 cm. away; so that we should require to be  $25 + 30 = 55$  cm.



from the observed eye, and at that distance the illumination will be very weak. With the mirror close to the patient's eye, the details appear blurred until we put on a concave glass, by turning the wheel of our refracting ophthalmoscope. The weakest concave glass with which we are able to see the details of the fundus clearly is the measure of the myopia. Thus we have four distinct plans of measuring our case of myopia :

1st. The farthest distance at which the near type is read 25 cm. ( $\frac{100}{25} = 4$  D.).

2nd. The *weakest* concave glass which gives the greatest acuteness of vision.

3rd. The *weakest* concave glass with which we get a retinoscopic shadow moving in the opposite direction to the movement of the mirror.

4th. The *weakest* concave glass with which the details of the fundus can be distinctly seen by the direct ophthalmoscopic examination *close to* the eye.

Should any of these results vary much we should suspect that the myopia is increased by spasm of the accommodation, and we atropize the patient in the manner before described, and at the end of four days go over the ground again, remembering that when atropine has been used, it is necessary to add on about  $-.5$  D. to the glass found, because the ciliary muscle is probably never so completely relaxed as when it is under the influence of atropine. Therefore we add  $-.5$  D. for what is called the tone of the ciliary muscle.

Having found then that our patient's myopia



amounts to  $-3.5$  D. we give folders of that focus for distance. He will also require a weaker pair of spectacles for reading or music  $-1.5$  D. will answer this purpose well. These glasses would remove his far point to 50 cm. ( $3.5 - 1.5 = 2$  D.  $100 \div 2$  D. = 50 cm). Probably, after a time, if the myopia is not progressive, the patient may be allowed his full correction to be worn constantly. In addition to ordering spectacles we give him also some very important general directions; he must always hold his book or work 35 cm. away, bring the work to his eyes, and not his eyes to the work, his writing should be done at a sloping desk, he should sit with his back to the window so that the light comes over his left shoulder on to his work, and do as little near work as possible by artificial light.

CASE 3.—A gentleman, æt. 60, comes with the complaint that he cannot see to read as comfortably as formerly, though he sees distant objects well. We try his acuteness of vision, and find that he reads  $\frac{6}{9}$  badly. With  $+1$  D. he sees much better, reading some of the letters of  $\frac{6}{8}$ . We then try  $1.5$  D. and these he rejects. Hence we conclude that he has Hm. 1 D. We know from his age that he will also be presbyopic 3 D., and we add on to this  $+1$  D. for hypermetropia, directing him to read the newspaper with  $+4$  D. for half an hour. He thinks these rather strong for him, as they make his eyes ache. With  $+3.5$  D. he feels quite comfortable, and we therefore give him  $+3.5$  D., telling him that he will require them changed for slightly stronger ones in about five years.



Case 4 is that of a young girl, æt. 12, who has been very ill from diphtheria, but is now much better. She complains that she is unable to read or work, though able to see distant objects well. The pupils are very large and act badly to light. Hence we suspect paralysis of the accommodation. We test her acuteness of vision, and she sees  $\frac{6}{6}$  with each eye. We try convex glasses .5 D., and she still reads  $\frac{6}{6}$ , but 1 D. she rejects. Our diagnosis is therefore confirmed. We next find the weakest glass with which she is able to read, *weakest* because we are anxious to encourage the ciliary muscle to act, since by replacing it entirely we should prolong the patient's recovery.

The glasses must be changed for weaker ones as the ciliary muscle recovers tone.

We saw that she had a slight amount of hypermetropia and also saw that there was some accommodation left, enough at least to correct this, otherwise she could not have read  $\frac{6}{6}$  without +.5. She was given a tonic containing iron and strychnine.

CASE 5.—A young woman, æt. 20, has never seen well, has tried spectacles of all sorts, but never been able to find any that suited her. The eyes look somewhat irritable, but there is nothing conspicuous about their size or shape. There is some want of symmetry about the face, the nose being deviated from the median line slightly to the left.

We first try the acuteness of vision of the right eye. She reads  $\frac{6}{12}$  and with +1 D. vision is somewhat improved; with +1.5 D. it is made worse. Still armed with +1 D. we direct the patient to look at the



fan of radiating lines (Fig. 70). She sees plainly the horizontal lines, whilst all the others are more or less indistinct, the vertical line most so; still looking at the horizontal line, we alternately hold in front of +1 D., +.25 D. which makes it worse, then -.25 D. which she says at once makes it perfectly clear and distinct. We, therefore, put down +.75 as the correction for the vertical meridian, and pass on to the horizontal. Our patient is directed to look steadily at the vertical line. We try +1 D., then +2 D.; and it becomes clearer with +3 D.; a stronger glass than this renders it slightly indistinct. It is evident, therefore, that her horizontal meridian is hypermetropic +3 D. We put up the correction found, +.75 D. sp., +2.25 D. cylinder axis vertical, and direct her again to look at the distant type.  $\frac{6}{8}$  is read though with some difficulty. This result is not, however, reliable, and we proceed to confirm it by retinoscopy, obtaining +3 D. for the vertical, and +5 D. for the horizontal meridians. On trying this correction, however, the vision is not so good. We now test the acuteness of vision in the left eye. She sees  $\frac{6}{36}$ , and neither convex nor concave glasses improve it. On looking at the fan of radiating lines all seems indistinct, and having thus far no data to go upon, we, instead of wasting time, at once pass on to retinoscopy. We get oblique shadows, the horizontal moving with the mirror and the vertical against it; here then is a case of mixed astigmatism. We find out that -2 D. is the weakest concave glass, with which we get a reversed shadow horizontally, and



+3 D. the strongest convex with which an opposite shadow is still obtained in the vertical meridian, the degree of obliquity being about  $25^\circ$ . This result we note down as—

$$\text{L. } \begin{array}{c} \text{---} \\ \text{---} \end{array} \begin{array}{c} 25^\circ \\ \dots \end{array} \begin{array}{c} +3 \text{ D.} \\ -2 \text{ D.} \end{array}$$

We, therefore, place in a spectacle frame +3 D. spherical combined with -5 D. cylinder, axis deviating outwards from the vertical  $25^\circ$ . With this correction the patient at once reads  $\frac{6}{12}$ . We are not to be satisfied with this result, but give the patient a solution of atropine grs. 4 to  $\overline{3j}$  with directions to come again in four days. At the end of the time she returns, and we find with retinoscopy—

$$\text{R. } \begin{array}{c} +2.5. \\ \text{---} +4.5 \text{ D.} \end{array} \qquad \text{L. } \begin{array}{c} \text{---} \\ \text{---} \end{array} \begin{array}{c} +3.5 \text{ D.} \\ -2 \text{ D.} \end{array}$$

The right eye with this correction reads  $\frac{6}{6}$  and the left also  $\frac{6}{6}$ . This result is very satisfactory. We now allow the patient to recover from atropine, and at the end of a week confirm the result before ordering spectacles. Then we found for the right eye the best vision with +1.5 sp.  $\ominus$  +2 D. cy. axis vertical  $\frac{6}{6}$ ; the left +3 D. spherical  $\ominus$  -5 D. cylin. axis  $20^\circ$  from the vertical gave  $\frac{6}{9}$ . These spectacles were therefore ordered and the patient directed to wear them constantly.

CASE 6. Jane W—, æt. 30, presents herself com-



plaining that the sight in her left eye has been gradually dim for some months. She is a small, healthy-looking woman, with nothing characteristic in her appearance. We test the acuteness of vision—

Right  $\frac{6}{6}$  Hm. 1 D. =  $\frac{6}{6}$ .

Left  $\frac{6}{18}$ , not improved with spherical glasses.

We try retinoscopy, but the pupils are so small that the result is not very satisfactory. We are, however, able to make out in the left eye a reverse shadow in the horizontal meridian, which +2 D. overcorrects, +1.5 D. being the highest glass with which we get an opposite shadow. The vertical meridian appears emmetropic. There is, therefore, no doubt that the defective vision in this eye is due to astigmatism. The patient complained that the examination had made her eyes ache, so we do not proceed further, but order a solution of hydrobromate of homatropine (2 gr. to the ℥j) to be used every two hours, and direct her to come again on the following day. Then the result with retinoscopy is—

R. +1.5 D.

L. —  $\left| \begin{array}{l} +.5 \text{ D.} \\ - +2 \text{ D.} \end{array} \right.$

We try this at the test type.

R.  $\frac{6}{24} + 1.5 \text{ D.} = \frac{6}{6}$ .

L.  $\frac{6}{36} + \frac{.5 \text{ D. sp.}}{1.5 \text{ D. cy. axis. vert.}} = \frac{6}{6}$ .

The effect of the homatropine soon passes off on discontinuing its use, and in a couple of days we confirm the result.



Finally we then find—

$$R. \frac{6}{8} + 1 D. = \frac{6}{8}.$$

$$L. \frac{6}{24} + 1.5 \text{ cy. axis. vert.} = \frac{6}{8}.$$

These spectacles are to be worn constantly. Other cases are given at the conclusion of the chapter on retinoscopy.

---

## APPENDIX

IN the metrical system the unit of length is a metre, equal to 100 centimetres, 1000 millimetres or 40 English inches, so that 1 inch is equal to  $2\frac{1}{2}$  centimetres, a lens of 1-metre focus is called a diopetre, a lens of 2 metres is 2 D., 10 metres 10 D., &c.

In the old system the lenses were numbered according to their focal length in inches, a lens of 1-inch focus being the unit; a lens of 2-inch focus was expressed by the fraction  $\frac{1}{2}$ , one of 10-inch focus  $\frac{1}{10}$ , and so on. If we wish to find the number of a given glass in dioptries, its corresponding number according to the old system of inches, we have only to remember that the unit 1 metre = 40 English inches, so that a glass of 1 D. =  $\frac{1}{40}$  in the old system, 2 D. =  $\frac{2}{40} = \frac{1}{20}$ , 5 D. =  $\frac{5}{40} = \frac{1}{8}$ , and so on.

The table on the next page gives approximately the equivalent of each diopetre or part of a diopetre in English and French inches and in centimetres.



Dioptries.	English inches.	French inches.	Centimetres.
.25	160	146	400
.50	80	73	200
.75	52	50	130
1.	40	36	100
1.25	31	29	77
1.50	26	24	65
1.75	22	21	55
2.	20	18	50
2.25	17	16	43
2.50	16	15	40
2.75	14	13	35
3.	13	12	33
3.50	11	10	27
4.	10	9	25
4.50	9	8	22
5.	8	7	20
5.50	7	6½	17
6.	6½	6	16
7.	6	5	15
8.	5	4½	12½
9.	4½	4	11
10.	4	3½	10
11.	3½	3¼	9
12.	3¼	3	8
13.	3	2¾	7½
14.	2¾	2½	7
15.	2½	2¼	6½
16.	2¼	2⅛	6
18.	2⅛	2	5½
20.	2	1¾	5



Authors to whom the writer is indebted :

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MACNAMARA. Manual of Diseases of the Eye.

MORTON. Refraction of the Eye.

CHARNLEY. On Keratoscopy (The Royal London Ophthalmic Hospital Reports for August, 1882).



## TEST TYPES (AFTER JAEGER)

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### No. 1.—*Brilliant.*

For the three ensuing days I was in a state of anxiety to know what reception my letter might meet with; but in the meantime was frequently solicited by my wife to submit to any conditions rather than remain here, and every hour received repeated accounts of the decline of my daughter's health. The third day and the fourth arrived, but I received no answer to my letter: the complaints of a stranger against a favourite nephew were no way likely to succeed; so that these hopes soon vanished like all my former. My mind, however, still supported

0·5

### No. 2.—*Pearl.*

to comfort, to strengthen her, to receive her last wishes, and teach her soul the way to heaven. Another account came—she was expiring, and yet I was debarred the small comfort of weeping by her. My fellow-prisoner, some time after, came with the last account. He bade me be patient—she was dead! The next morning he returned and found me with my two little ones, now my only companions, who were using all their innocent

0·6

### No. 4.—*Minion.*

efforts to comfort me. They intreated to read to me, and bade me not to cry, for I was now too old to weep. "And is not my sister an angel now, papa?" cried the eldest; "and why then are you sorry for her? I wish I were an angel, out of this frightful place, if my papa were with me." "Yes," added my youngest darling, "heaven, where my sister

### No. 6.—*Bourgeois.*

is, is a finer place than this, and there are none but good people there, and the people here are very bad." Mr Jenkinson interrupted their harmless prattle by observing that, now my daughter was no more, I should seriously think of the rest of my family, and attempt to save my own life, which was every

### No. 8.—*Small Pica.*

day declining for want of necessaries and wholesome air. He added that it was now incumbent on me to sacrifice any pride or resentment of my own to the welfare of those who depended on me for support; and that I was now, both by reason and justice, obliged to try to reconcile my



*No. 10.—Pica.*

landlord. “Heaven be praised!” replied I, “there is no pride left me now. I should detest my own heart if I saw either pride or resentment lurking there. On the contrary, as my oppressor has been once my parishioner,

*No. 12.—English.*

I hope one day to present him up an unpoluted soul at the eternal tribunal. No, sir, I have no resentment now; and though he has taken from me what I held dearer than all my treasures, though he has wrung my

*No. 14.—Great Primer.*

heart—for I am sick almost to fainting, very sick, my fellow-prisoner—yet that shall never inspire me with vengeance. I am

*No. 16.—2-line Great Primer.*

**the white light  
from the paper**



*No. 18.—Canon.*

will see the  
paper of that

*No. 19.—4-line condensed.*

arises all  
from the

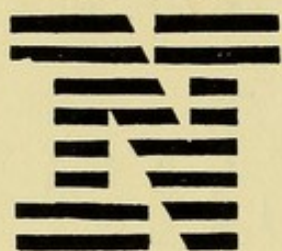
*No. 20.—8-line Roman.*

sails



PRAY'S TEST TYPES FOR ASTIGMATISM.

Horizontal.



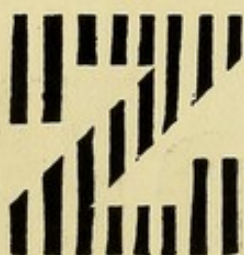
15°.



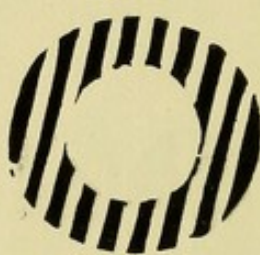
30°.



90°.



105°.



120°.



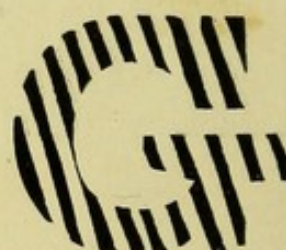
45°.



60°.



75°.



135°.



150°.



165°.





**T**

D. = 36.

**N E**

D. = 24.

**D E N**

D. = 18.

**V E N E**

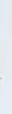
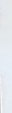
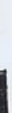

D. = 12.

**L N E Z B**

D. = 9.



$$\frac{8}{11} \div \frac{1}{10}$$

0.15

PHNH

९  
॥  
८

VENETIAN

6  
11  
D

# NEOVENE

5

# L A O N D F Z L V



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