ERRORS OF REFRACTION

CHARLES BLAIR, M.D., F.R.C.S.

SECOND EDITION

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ERRORS OF REFRACTION
AND
THEIR TREATMENT

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THEIR TREATMENT:

A CLINICAL POCKET-BOOK
FOR PRACTITIONERS AND STUDENTS

BY

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PREFACE

THE object of this little book is to endeavour to supply in a condensed form the more practical and clinical points in connection with Errors of Refraction, in the hope that it may be of use to some who are not able to give much time to this relatively uninteresting subject; a subject which is unfortunately too apt to be crowded out of general medical work.

C. B.

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ERRORS OF REFRACTION.

I.—INTRODUCTION.

THE conditions which are necessary for distinct vision are :—

1. That the media,—namely the cornea,—aqueous, lens, and vitreous—through which luminous rays have to pass, shall be transparent.

2. That the refractive apparatus shall be such that rays coming from an object looked at shall be focussed correctly upon the rods and cones of the retina, and so form a clear and distinct retinal image.

3. That there shall be a normally sensitive retina that can receive these luminous vibrations, and can transform them into nervous stimuli, and as such pass them on to the nerve fibres.

4. That these fibres shall be capable of transmitting the nervous stimuli throughout their course along the optic nerves, chiasma and optic tracts, to the external geniculate bodies and other ganglia, and to the nerve cells of the cortical centres about the cuneate lobule and calcarine fissure on the median surface of the occipital lobe.

5. That this optical area of the cortex of the brain shall be able to transform these nervous stimuli into a conscious perception of the object.

It is with the second of these conditions that we have to do, namely, that it is necessary, in order to obtain distinct vision, that **the object be clearly refracted upon the retina.**

The refractive apparatus of the eye may be compared with the mechanism of a camera obscura. This is an instrument composed of a dark chamber into which light is admitted from one side through a convex lens, which so refracts the rays passing through it that an object situated in front of the camera is reproduced on a screen at the back of the chamber as an inverted image. By means of a certain adjustment, any object, whether near or distant, may be thrown as a defined but inverted picture on the screen.

Instead of using this optical adjustment, the same end may be obtained by placing convex or concave lenses of different power in front of the camera lens, and so adding to or taking from the refractive power of that lens, when the rays may in like manner be brought to a focus on the screen.

As with the camera, so with the living eye. There is a dark chamber into which luminous rays are admitted through the pupil; these rays, passing through certain refracting media, particularly the lens, are thrown as an inverted image on the retina. In place of the adjusting screw of the camera there is the **accommodation**, by means of which the eye is adjusted to focus on the retina objects situated at various distances.

This accommodation is able under ordinary circumstances to so regulate the refractive power of the eye as to produce a correctly focussed retinal image of all external objects within a certain range of distance.

When, however, this accommodation is insufficient, owing to certain errors of refraction, lenses of different power are placed before the eye, which so modify the refraction and assist accommodation, that the necessary clear image is obtained.

It is the study of this Refractive apparatus or Dioptric system of the eye, and its imperfections, which is comprised in the term "Refraction," and is becoming more and more an important branch of Ophthalmology, the more the human race develops its higher mental functions, involving a greater demand upon the visual organs, and the more the eyes are used as the chief portal of knowledge in the education of children. It is the object of this study to consider the means by which the difficulties arising from errors of the refraction may be overcome.

Before determining what these errors of refraction consist in, it is necessary to know what a normal eye is. An eye to be normal as a visual organ must come up to a recognized standard of perfection. This is not the highest degree of perfection that it is possible for a human eye to reach, but one which it may be reasonably expected to reach under ordinary circumstances. Also, an eye may be perfectly healthy, have excellent vision, good powers of accommodation and convergence, etc., and yet, on account of perhaps a little hypermetropia, not be normal according to this recognized standard.

For the sake of convenience, an empirical standard of perfection has been determined, viz., **an eye whose visual acuity is normal, and whose refraction is emmetropic.**

The first thing to do therefore, is, to define (1) Normal visual acuity ; and (2) Emmetropia.

II.—VISUAL ACUITY.

The **Visual Acuity** of an eye is the amount of vision which the eye possesses for form sense (as distinct from colour or light sense), indicated by the smallest retinal image recognizable, any error of refraction being corrected.

This acuity of vision is not the same all over the retina, but is most acute at the yellow spot or Macula. In fixing or looking at an object, therefore, the visual axis is directed in such a way that the macula receives the image of the particular object looked at, and the rest of the retina receives the remainder of the picture.

Thus there is central vision and peripheral vision ; the former to give a distinct impression of the object looked at, and the latter to give a less definite, but still important vision of surrounding objects. The extent of peripheral vision is estimated by means of the Perimeter.

The smallest retinal image which can as a rule be perceived is found to be one which subtends an angle of about 50″ at the nodal point* of the eye, the actual size of the image

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* The nodal point is the central point of the refractive apparatus of the eye, and the rays which pass through this point are not refracted, but continue their course in a straight line. It is situated in the lens, close to its posterior pole, and about 7 mm. behind the cornea. (Correctly speaking there are two nodal points very close together.)

on the retina being about ·004 mm. and covering approximately two retinal cones.

A somewhat lower standard than this has however been chosen, and all who are able to reach it are considered to have normal visual acuity. This standard is the recognition of an object which subtends an angle of 1′ at the nodal point of the eye. Such an object is illustrated by the D=6 line of Snellen's distance types, seen at six metres distance, with an illumination about equal to ordinary daylight. Each letter as a whole subtends an angle of 5′, but the different parts or strokes of the letter subtend an angle of 1′.

A person, therefore, who can read D=6 line at 6 metres distance (i.e., $V=\frac{6}{6}$) with any error of refraction corrected, is considered to have normal visual acuity.

The degree of visual acuity depends not only upon the condition of the nervous and vascular apparatus of the eye, viz., the optic nerves, the retina, and the choroid ; but also on the degree of transparency of the refractive media, viz., the cornea, aqueous, lens, and vitreous, and the evenness of their refractive surfaces ; any opacity or unevenness interfering with the transmission of rays, and the consequent distinctness of the retinal image.

III.—EMMETROPIA.

The normal refraction of the human eye is one in which rays emanating from a distant object (or parallel rays), are, on passing through the dioptric system, so refracted that they come to a focus on the retina while the accommodation is at rest. This condition is called **Emmetropia.** In emmetropia, therefore, the position of the retina corresponds to the principal focus* of the refractive apparatus.

In emmetropia the farthest point of distinct vision, the *punctum remotum*† is at infinity; which is to say, that an object situated at infinity, or at any distance from the eye beyond 20 feet, comes to a focus on the retina, and is therefore distinctly seen, without using the accommodation.

An emmetrope, with normal visual acuity, can therefore see distant objects distinctly without using his accommodation; and by using his accommodation is able to focus all near objects, so long as they are not nearer to him than his *punctum proximum*† or nearest

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*The principal focus of a lens or of the refractive apparatus is the point at which parallel rays passing through it are brought to a focus; and the principal focal distance of a lens is the distance between this point and the nodal point of the lens.

† *Vide* page 11.

point of distinct vision ; and the whole of his accommodation is available for near vision. An emmetrope, therefore, has the most advantageous and useful sight, and has the longest range of clear vision ; while he only has to use his accommodation for near objects.

Emmetropia, though taken as the normal state of refraction, is not the most frequent condition. It is more common to find a small degree of hypermetropia than exact emmetropia. Most eyes at birth are hypermetropic, and though their tendency is to lengthen as the body grows, still they generally remain slightly hypermetropic rather than pass on to emmetropia or myopia.

IV.—ACCOMMODATION.

The refraction of the human eye, with its accommodation at rest (i.e., its static refraction) is equal to that of a convex lens of about 48 dioptres, and the retina is normally situated at such a distance behind this refractive apparatus, that parallel rays are brought to a focus on its rods and cones.

By the term parallel rays is meant, ophthalmologically, all rays which enter the eye from objects at or beyond a distance of 20 feet. These are considered to be parallel, though strictly they are only approximately so.

If the refraction of a normal human eye remained always the same, no rays but those which are parallel could ever be focussed on the retina, and the eye would therefore be more or less useless for anything but distant vision.

This refracting power is capable, however, of being altered at will by what is called the **accommodation**, so that near objects as well as distant ones can be clearly seen, and a range of clear vision obtained, the extent and position of which depends on the age of the patient and on the condition of the static refraction of the eyes.

When the accommodation is at rest, the refractive apparatus is adjusted for the farthest point of distinct vision, or *punctum remotum*, and its refractive power is at its lowest. On the other hand, when the accommodation is exerted to its utmost, the eye is adjusted for its nearest point of distinct vision, or *punctum proximum,* and its refractive power is at its highest.

In **emmetropia** the farthest point of distinct vision is at infinity, because the emmetropic eye, at rest, is adapted for parallel rays, and the more distant an object is, the more truly are the rays coming from it parallel. Therefore, in emmetropia the *punctum remotum* is said to be at infinity.

In **myopia** the *punctum remotum* is somewhere nearer than 20 feet, because the myopic eye is adapted for focussing only divergent rays, and these must come from some near object.

In **hypermetropia** vision is indistinct at all distances when the accommodation is at rest, because a hypermetropic eye, at rest, is adapted for focussing convergent rays only, and the rays coming from any object are always parallel or divergent, never convergent. It is only by bringing the accommodation into use that the hypermetropic eye can be made to focus parallel and divergent rays on the retina, or be able to see any object clearly.

Therefore, without accommodation an emmetrope can only see objects clearly which are situated at or beyond 20 feet ; a myope can only see objects clearly which are situated nearer than 20 feet; and a hypermetrope can see no object distinctly, whatever its distance.

By using the accommodation, however, the eye is enabled to focus objects which are nearer to it than its *punctum remotum*, a range of vision being obtained which extends from the *punctum remotum* to the *punctum proximum*.

The position of the *punctum proximum* depends upon the age of the patient and his state of refraction. The younger the patient, the nearer is the *punctum proximum*; and at a given age the *punctum proximum* is nearer to the eye in myopia than in emmetropia, and farthest away in hypermetropia.

The range of distinct vision is called the **range or amplitude of accommodation**, and is expressed by the number of dioptres through which the accommodation can act. This is represented by the convex lens which would enable the eye to see clearly at its *punctum proximum*, while its accommodation was completely paralysed.

If a represent the range of accommodation, p the refraction of the eye when accommodated for its *punctum proximum*, and r the refractive power when adjusted for its *punctum remotum*, then $a = p - r$.

The range of the accommodation, like the *punctum proximum* varies, with the age of the patient. For instance, in an emmetropic child of ten, the *punctum proximum* is 7 cm. from the eye; that is to say, his accommodation is strong enough to enable him to focus on his retina any visible object from an infinite distance up to 7 cm., or $2\frac{3}{4}$ inches, from his eye. If his accommodation were paralysed or rendered inactive by atropine, it would require a supplementary lens of 14 D to enable him to see clearly at this near point. The measure of his accommodation is therefore expressed by this lens, and the range of the accommodation of an emmetropic child of ten years is said to be 14 D.

But the *range* of accommodation is the same at a given age whatever the state of *refraction*, and a child of ten has an amplitude of accomodation equal to about 14 D, whether he be an emmetrope, a myope, or a hypermetrope.

The *region* of accommodation, however, varies in different conditions of the refraction ; being nearest the eye in myopia, farther away in emmetropia, and still farther in hypermetropia. As shown above, a child of ten has usually a range of accommodation equal to 14 D ; but its region of activity extends in emmetropia from infinity to 7 cm., while in myopia of say 4 D, it extends from 25 cm. to 5·5 cm., it needing the same power of accommodation for the emmetropic child to look from a distant object to one 7 cm. away, as it does for the child with 4 D of myopia to look from an object 25 cm. to one 5·5 cm. ; that is, respectively, from the *punctum remotum* to the *punctum proximum*.

The manner in which accommodation changes the refractive power of the eye, is chiefly by altering the shape of the crystalline lens. If the lens of a child's eye be removed from its attachments, it quickly assumes a spherical shape, showing that its natural tendency is to become more spherical, a tendency which is restrained by the tension of its capsule, which is pulled upon all round by the fibres of the suspensory ligament, or zonula of Zinn ; which, in its turn, is kept tense by the natural disposition of the globe to maintain a spherical shape owing to intra-ocular pressure. Any relaxation, therefore, of this suspensory ligament will, by slackening the capsule of the lens, allow the latter to assume a more spherical form, which will result in an increase in its refractive power. This relaxation is produced by the contraction of the ciliary muscle, *i.e.*, by an effort of accommodation. This intra-ocular muscle consists of two portions, one composed of radiating fibres, which are contained in the ciliary processes, and arise by a tendinous origin near the sclero-corneal junction, and are inserted behind into the suspensory ligament of the lens and into the choroid ; the other portion is composed of annular fibres, which run in a circular direction round the free inner border of the ciliary body, analogous to the circular fibres of the iris. The action of the radiating portion is to draw forward the choroid, and slacken the fibres of the suspensory ligament, allowing the lens, by its natural elasticity, to become more spherical. This action is supplemented by the annular portion, the contraction of which lessens the size of the ciliary ring, and thus further relaxes the suspensory ligament.

The effect of this ciliary contraction, or effort of accommodation, is therefore to make the lens more spherical, or possibly more paraboloid, thus increasing its refractive power and rendering the eye capable of focussing objects which are nearer than its punctum remotum. Thus, when the ciliary muscle is contracted to its utmost, and the suspensory ligament slackened, the lens assumes its maximum of convexity and therefore of its refractivity; the function of accommodation is used to its utmost extent, and the eye is adjusted for its nearest point of clear vision, its punctum proximum. When, on the other hand, the ciliary muscle is completely relaxed, the suspensory ligament becomes taut and pulls on the capsule of the lens all round, the latter becomes compressed, assumes its minimum of convexity, and therefore its minimum of refractivity; the function of accommodation is then at rest, and the eye is adjusted for its farthest point of clear vision, its punctum remotum.

The punctum proximum is therefore the nearest point of distinct vision when the accommodation is acting to its fullest extent.

The whole of this power of accommodation is not, however, available for *continued* use; and an emmetropic child of ten is not able to keep on reading for any length of time at a distance of three inches, or an emmetrope of forty at nine inches. On the contrary, only about two-thirds of the full range of accommodation can be comfortably so used. One can only see distinctly at one's punctum proximum by a maximum effort of accommodation, and then only for a very short time.

Though the range of accommodation is pretty much the same at a given age, whatever the state of refraction, it does vary to a certain extent. It is relatively higher in hypermetropia, and lower in myopia, owing chiefly to the annular fibres of the ciliary muscle being well developed in the former condition, and ill developed or sometimes practically absent in the latter. This difference in the development of the muscle is an acquired one, and is the result of excessive use in hypermetropia and comparative inaction in myopia.

During accommodation, when the lens becomes more spherical, its posterior surface does not alter its position much, but the anterior surface bulges forward towards the cornea, pushing the pupillary portion of the iris with it and lessening the depth of the anterior chamber. The antero-posterior diameter of the lens increases from 3·6 mm. to 4 mm. When the ciliary muscle contracts, the circular fibres of the iris also contract, the two being closely associated together; also there is a tendency for the visual axes of the two eyes to converge. The muscles of convergence, the ciliary muscle, and the circular muscular fibres of the iris, are all supplied by nerve fibres which have a closely-associated origin on the floor of the fourth ventricle, and all pass through the third cranial nerve.

The power of accommodation, as shown by the table on page 18, steadily diminishes from childhood up to old age. The principal reason for this is that the lens becomes firmer and less elastic, not that the ciliary muscle becomes less active; the latter may still be increasing in size and development, in common with other muscles, while the power of accommodation is gradually diminishing. Not only, however, does the lens become harder and less elastic, and therefore less readily altered in shape by the variations in the tension of the suspensory ligament, but other tissues of the eye participate in this change, more especially the outer coat of the globe; and in consequence the annular fibres of the ciliary muscle have more difficulty in contracting up the ciliary ring and in relaxing the suspensory ligament.

Besides the gradual diminution of accommodation as age advances, a change takes place in the static refraction of the eye after the age of fifty. A person who up to fifty has been emmetropic, slowly becomes hypermetropic, till at 80 he has over 2 D of hypermetropia.

Likewise a hypermetrope increases his hypermetropia 2 D, and a myope lessens his myopia to the same extent.

This should not be confused with the opposite effect produced by an **incipient cataract,** when the change is in the reverse direction—a hypermetrope becoming less hypermetropic, and a myope more myopic.

Under ordinary circumstances the exercise of the function of accommodation does not entail much effort or fatigue. But that some effort is experienced is easily shown by closing one eye and holding some print, or a pencil, as close to the other eye as one can focus it, and alternately look at a distant object and the near one ; one is conscious of a considerable effort, which, if continued, causes fatigue and pain.

As has been said, the " near point " gradually recedes from the eye from childhood to old age. A time therefore arrives when it becomes difficult to read and do fine work at the ordinary distance. This happens in emmetropia soon after the fortieth year, when the punctum proximum is at about nine inches, which means that continued work is difficult within a distance of thirteen or fourteen inches. It is then that **presbyopia** is said to begin, and that lenses soon become necessary for near work.

Accommodation **cannot be completely relaxed at will.** A certain amount of muscular tone or tonic contraction remains, which can only be overcome by using a mydriatic. Occasionally, however, this involuntary contraction of the ciliary muscle is unusually great, and constitutes what is called "spasm of accommodation." When this is present there is generally an error of refraction, especially with astigmatism ; but it may be produced by some inflammatory affection of the eye, or by some central nervous irritation.

Age.	Range of Accommodation.	Punctum Proximum.	Nearest comfortable reading point.
10 years	14 D	7 cm.	11 cm.
15 ,,	12 D	8·5 ,,	12½ ,,
20 ,,	10 D	10 ,,	14 ,,
25 ,,	8·5 D	12 ,,	16½ ,,
30 ,,	7·0 D	14 ,,	20 ,,
35 ,,	5·5 D	18 ,,	27 ,,
40 ,,	4·5 D	22 ,,	33 ,,
45 ,,	3·5 D	29 ,,	43 ,,
50 ,,	2·5 D	40 ,,	60 ,,
55 ,,	1·5 D	67 ,,	
60 ,,	1·0 D	100 ,,	
65 ,,	0·5 D	200 ,,	
70 ,,	0·25 D	400 ,,	
80 ,,	0·00		

V.—CONVERGENCE.

Two other functions are closely associated with accommodation, viz., contraction of the pupil and convergence. The former promotes distinct vision by cutting off the rays which would pass through the peripheral parts of the lens, and allowing only the central ones to be transmitted. This is especially necessary when the accommodation is acting. The other function in close association with accommodation is convergence. In looking from a distant to a near object, one has not only to accommodate in order to obtain a clear retinal image, but to converge the *visual axes* of the two eyes, so that the image may in each eye be received on to the yellow spot, and thus binocular single vision be obtained.

The visual axes are imaginary lines drawn from the yellow spot, though the nodal point of the eye, to the object looked at. If this object be 20 feet or more away, the visual axes of the two eyes are practically parallel; whereas if the object be near, these visual lines must converge so as to meet at the object. And the nearer the object is, the more have the eyes to converge.

The **angle of convergence** is that angle which is subtended by the visual axis when parallel to that of the other eye, and the visual

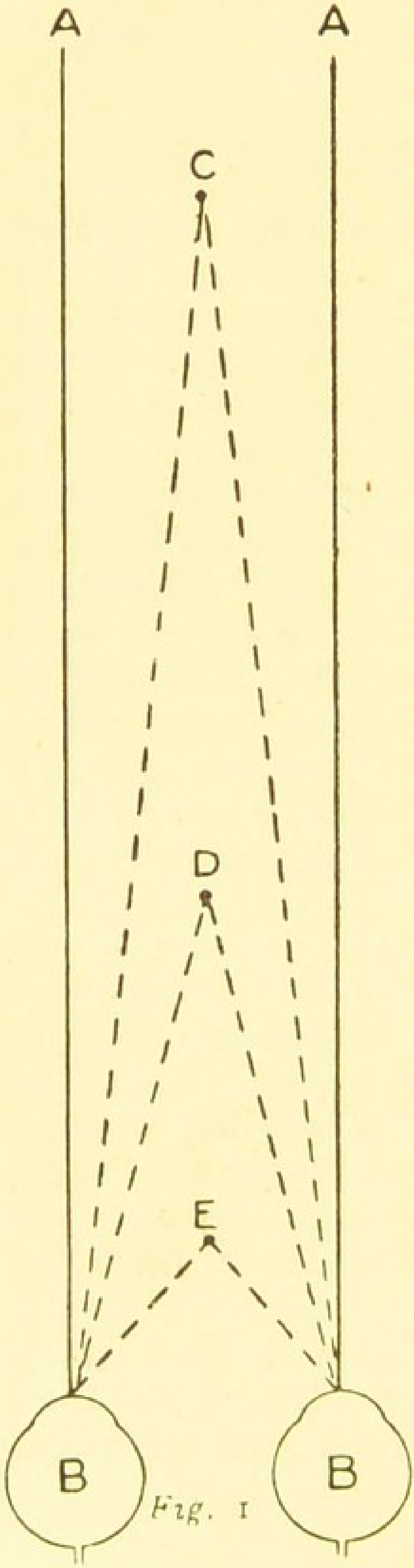

Fig. 1

axis when converging towards a near object, i.e., the angle A B C, A B D, or A B E in *Fig.* 1, C, D, and E being objects situated at different distances from the eyes B. The nearer the object the greater is this angle; the angle of convergence being in inverse proportion to the distance of the object looked at. (Just as the power of accommodation is in inverse proportion to the distance of the object.)

To facilitate the estimation of this angle of convergence, a standard unit angle has been determined upon, and this unit is the angle of convergence required to "fix" an object one metre distant. This is called a **metre-angle** (about 1°45′). The angle of convergence for an object half a metre away would therefore be two metre-angles; and the angle of convergence for an object one-third of a metre away (13 inches) would be three metre-angles; and again the angle of convergence for an object one-ninth of a metre away (4 inches) would be nine metre-angles.

As ordinary reading is done at a distance of about one-third of a metre, or 12 inches, the degree of convergence brought into use is about three metre-angles; but in order to keep this up comfortably one must possess a maximum power of convergence of at least nine metre-angles, and be able for a short time to "fix" an object one-ninth of a metre away. Practically therefore about two-thirds of one's converging power has to be kept in reserve, and only about one-third brought into general use; otherwise fatigue and muscular asthenopia will result. The maximum power of convergence can only be brought into use for a short time, and then only with an effort.

Though an amplitude of convergence of nine metre-angles will suffice for ordinary near work, a much higher degree is commonly found, even up to fifteen, or more.

For reading, therefore, at 12 inches distance, three metre-angles of convergence are actually brought into use; though it is necessary to possess nine metre-angles, and to be able with an effort to converge to a point 4 inches from the eyes. If a patient possess this degree of convergence, it may be concluded that he has no insufficiency of his internal recti, and if symptoms of asthenopia are present, some other cause must be found ; for instance, some error of refraction, or want of harmony between the associated acts of accommodation and convergence.

If, however, he has less than nine metre-angles of convergence, and therefore has an insufficiency of his internal recti, any asthenopic symptoms present may be due to this defect, and should straightway be remedied. This may be done either by having recourse to *prisms*, or by doing a *tenotomy* of an external rectus, or an *advancement* of an internal rectus.

The effect of placing prisms before the eyes, is to alter the direction of rays coming from an object, in such a way that they are deflected towards the bases of the prisms. In *Fig.* 2 the rays of the object O passing through the prisms P do not go straight on to *x*, but are deflected in the direction of the bases of the prisms to the point *y*. Thus in looking at the object O through the prisms P, the visual axes will be directed as P *y* not as P *x* ; and the degree of convergence of these axes will therefore be lessened in proportion to the strength of the prisms.

Prisms are numbered according to their angle of refraction, which is about double of the angle of deflection or deviation. In the figure, *r* is the angle of refraction, and *d* the angle of deviation.

Now, if worked out, it is found that a prism

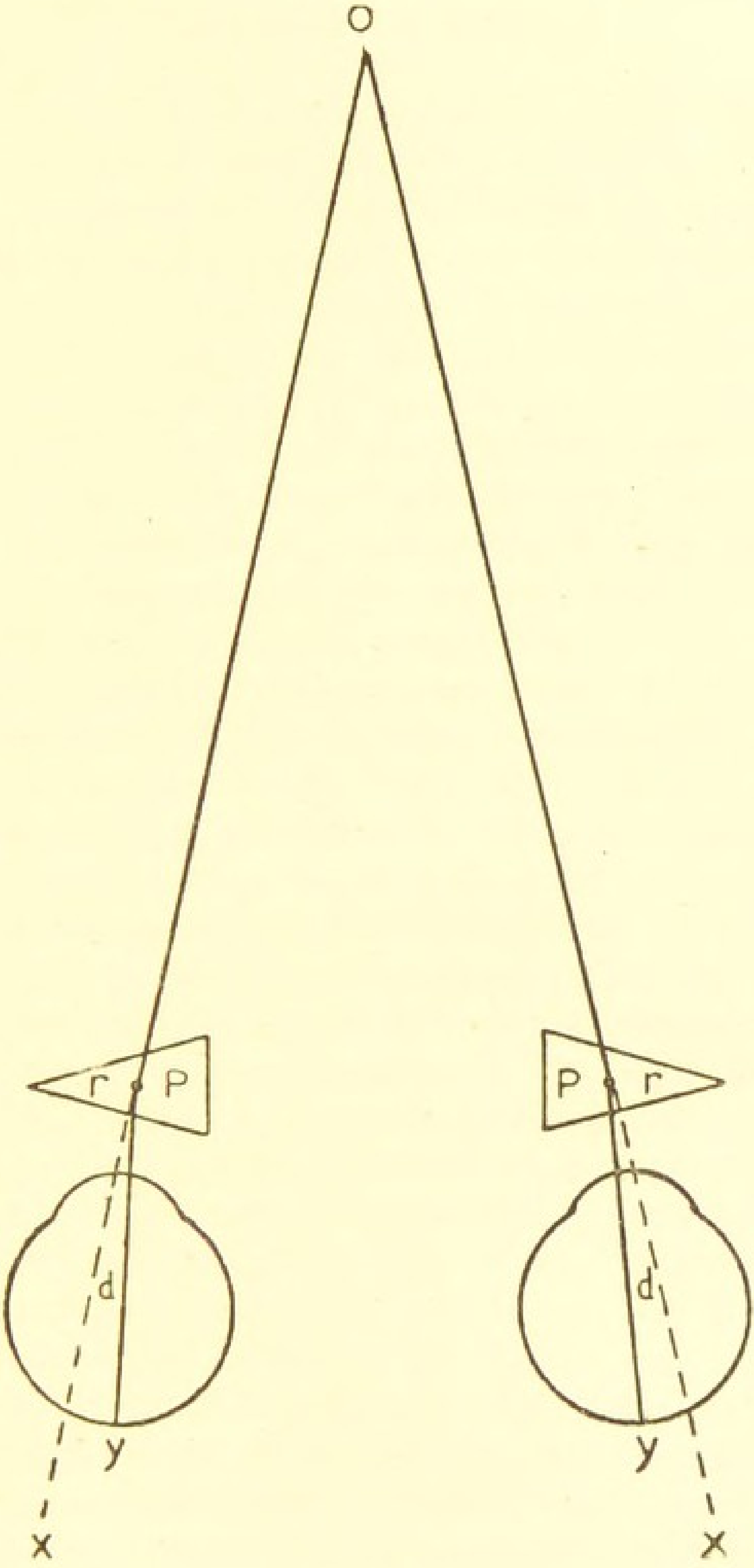

Fig. 2.

whose angle of refraction is 3·5°, if placed before each eye (or, which is the same thing, one of 7° before one eye) lessens the convergence of each eye one metre-angle. Thus in a patient whose power of convergence is in each eye only 8 metre-angles instead of 9, and who suffers from muscular asthenopia, the wearing of prisms of the strength of 3·5°, bases in, will be likely to relieve his symptoms, and enable him to read and do near work more comfortably.

The use of prisms is very limited, however, and can only be employed satisfactorily to the extent mentioned above. Stronger prisms than these would not generally be tolerated; they are heavy, cause chromatic aberration, i.e., dispersion of light into its spectral colours, and also interfere too much with the judgment of distance and size, which are estimated greatly by the effort of convergence brought into use.

If a patient's maximum power of convergence is less than 8 metre-angles, it is better to perform a *tenotomy* of an external rectus or an *advancement* of an internal rectus, than attempt to relieve the difficulty by the use of prisms; though the effect of the operation may be assisted afterwards by their use.

A myope whose far point of distinct vision is within 12 inches, has to use more than three metre-angles of convergence in reading and near work, and thus is liable to suffer from muscular asthenopia. This is usually at once relieved by ordering him *concave lenses* to put back his reading distance to 12 inches, and directing him not to bring his work nearer than that. If his power of convergence is weak, as often is the case in myopia, the addition to his concave lenses of a weak prism, base in, will further help him ; or a tenotomy of the external rectus may be advisable.

Between the functions of **accommodation** and **convergence** there is a *close relationship* both anatomically and functionally. The nerves to the muscles of accommodation, and those to the muscles of convergence, arise close to one another on the floor of the fourth ventricle, the nuclei being associated, although able to be separately stimulated. They also pass through the same nerve trunk, the third cranial nerve.

Physiologically the association is also close. They both come into use in near vision. When the eyes are accommodated for a near object, they converge towards that object. In normal eyes, so much accommodation goes with a corresponding amount of convergence. When an object one metre distant is looked at, 1 D of accommodation is used, and 1 metre-angle of convergence. If the object is one-third of a metre away, as in ordinary reading, 3 D of accommodation are required, and 3 metre-angles of convergence. When accommodation is at rest, as in distant vision, there is also an absence of convergence. Thus normally the two functions always act in harmony. This relationship, however, is not absolute. Though it is natural for them to act in harmony, it is not necessary for them to do so entirely. To quite a considerable extent one may act independently of the other, or in excess of the other.

In errors of refraction the association of these two functions is interfered with. For example, in hypermetropia accommodation is always in excess of convergence, and in myopia convergence is in excess of accommodation.

For instance, looking at an object one metre distant, an emmetrope has to use one dioptre of accommodation ; while a hypermetrope of say 2 D has to use three dioptres of accommodation (two dioptres to overcome his hypermetropia, and one in consequence of the object being one metre distant). Both of them have, however, to converge to the same degree, namely, 1 metre-angle. Thus the hypermetrope has to accommodate three dioptres while he converges only one metre-angle. There is thus a relationship between the two functions which is unnatural, and often produces symptoms of asthenopia.

Whether there is a common centre of innervation, or whether the functions are really distinct, and the desire for clear vision and the fusion of the images supplies the impulse to accommodate and to converge together, it is certain that troublesome symptoms often arise when these functions are dissociated, and are relieved when the proper relationship between them is restored.

VI.—ASTHENOPIA.

By the term **asthenopia** is meant a certain state of discomfort and pain in the head and eyes, which is associated with muscular and nervous fatigue, in certain abnormal conditions of the visual organs, or in their over-use.

This **headache** is generally frontal, but may be temporal or occipital, or may be referred to the vertex. It is either temporary, persistent, or recurring, and may be of a dull aching or of a sharp neuralgic character. The headache comes on usually in the evening, or after prolonged reading or close work, or any occupation or amusement in which the eyes are especially brought into use. Gazing at the stage of a theatre, at pictures in a picture gallery, or at any rapidly-moving objects, as in travelling, may occasion it. Sometimes the headache will begin in the early morning, after prolonged use of the eyes the day before. Associated with this pain there is frequently much lacrymation, conjunctival and palpebral congestion and irritation, and vertigo.

Asthenopia is somewhat artificially divided into three classes: accommodative, muscular, and retinal.

The first is caused by an overstraining of the muscles of accommodation in certain errors of refraction; or by an unequal contraction of these muscles when the refraction of the two eyes differ; or by these muscles of accommodation being in an atonic and weak condition in consequence of some illness or disease. The second is caused by the muscular effort to maintain the excessive degree of convergence necessary for binocular vision in myopia, owing to the closeness with which objects have to be held to the eyes; or by the effort to keep up an ordinary amount of convergence in cases of insufficiency or weakness of the internal recti muscles. And the third is caused by an over-sensitiveness or hyperæsthesia of the retina, in consequence of which the ordinary stimulation of its nerve elements by luminous rays produces not only visual sensations, but discomfort and pain.

Accommodative asthenopia is found generally in hypermetropic conditions, in which the accommodation is never at rest, as it has to be used for distant as well as for near vision. The ciliary muscle is therefore in a state of constant contraction, which is increased to an excessive degree when near objects are looked at. This continual strain naturally produces a sensation of fatigue, and pain in the eyes and a reflected pain in the head, and other symptoms of asthenopia. The degree of asthenopia present is in no way commensurate with the amount of error of refraction. On the contrary, it is more frequent for asthenopia to be present with a small than with a large amount of error, especially if it is accompanied by astigmatism. The reason for this is that an attempt is only made by the ciliary muscle to overcome the error if it is of a low degree.

If there is some **anisometropia** present, that is to say, a *difference* between the refraction of the two eyes, and therefore a difference in the amount of accommodation required in each, the patient is particularly liable to suffer from asthenopia.

Some people suffer from accommodative asthenopia who have no hypermetropia or other refractive error, owing to their ciliary muscles being deficient in tone and vigour, in consequence of a debilitated condition or general ill-nutrition of the body, or of some exhausting illness or disease. In these conditions excessive use of the eyes in near work may bring on accommodative asthenopia even with a normal refraction.

The second form of asthenopia is called **muscular asthenopia,** and is the common cause of headaches in myopia. It is due to fatigue of the muscles of *convergence,* viz., the internal recti ; this fatigue being caused either by the excessive action or insufficient power of these muscles.

Any one who has normal converging power can continue to work or read for a reasonable time at a distance of about 12 inches, without suffering from muscular asthenopia.

In *myopia* of more than 3 D it is necessary to hold objects nearer to the eyes than 12 inches to see them distinctly, and this requires more than the ordinary amount of convergence. One of two things will now happen: Either the patient will by an effort maintain this excessive degree of convergence, and suffer in consequence; or he will unconsciously give up binocular vision, look at the object with one eye only, allowing the other to wander where it will, and so be saved the painful effects of excessive convergence. What generally happens is that, if he has a moderate amount only of myopia, and has not therefore to bring his work so very close to his eyes, he will struggle to maintain binocular vision; whereas, if he has a high degree of myopia, his work will have to be held so very close to the eyes that it will be too great a strain to maintain the necessary convergence, and the attempt to do so will unconsciously be given up. Thus, a myope of a moderate degree may suffer from muscular asthenopia, while a high myope will probably escape.

Sometimes the cause of muscular asthenopia is not an excessive convergence of the visual axes, but a deficient power in the muscles of convergence. Such patients are not able to maintain even the ordinary degree of convergence required for reading and working at 12 inches, and the effort to do so produces symptoms of asthenopia.

The third variety is **retinal** or **nervous**

asthenopia, in which there is hyperæsthesia, or over-sensitiveness of the nervous elements of the retina, and in which luminous rays striking upon it not only produce visual sensations, but give rise to a feeling of discomfort, photophobia, fatigue, and pain. This may be connected with either of the other forms of asthenopia, or be present alone. It is closely associated with a want of tone in the general nervous system, a general neurasthenia, in which slight causes are sufficient to determine various neuroses. This hyperæsthesia of the retina may be brought on by exhausting illness, mental strain, physical shock, the depressing effect of a sedentary life, or by menstrual disorders, anæmia, etc.

In the **treatment of asthenopia,** the first thing to be done is to carefully estimate the condition of the refraction. And this should be done, as a rule, with the help of a mydriatic.

If *hypermetropia,* with or without astigmatism, is found, the whole of the error should be corrected, and the glasses used constantly. If these can be tolerated, the headaches will probably soon disappear. Frequently, however, if the patient has never hitherto worn glasses, it will be difficult for him to at once accustom himself to the sudden change of wearing full correction. It is therefore often necessary, and especially when the refraction of the two eyes differs, to modify the lenses to such a degree as to overcome this difficulty, and postpone the wearing of the full correction till later. If the patient is presbyopic, other glasses allowing for the presbyopia will also have to be ordered and used for near work, either in separate frames, or combined with the distance lenses as bi-focal glasses.

When *myopia* is the cause of the asthenopia, the one thing which is generally necessary is to order such glasses as will put back the reading distance to 12 inches, and so avoid excessive convergence.

If the patient be young, glasses which fully correct or almost fully correct his myopia, together with any existing astigmatism, may be given for constant use, and the ciliary muscle be thus educated up to a normal standard of efficiency. In an older patient this will not always be possible, and the strength of the glasses ordered will depend upon whether the patient has, or has not, worn glasses hitherto. If he has not had his myopia corrected at all, he will not be able to stand anything like full correction for near work, as his muscles of accommodation will be undeveloped. But if he has had his myopia even imperfectly corrected, he will have become accustomed to use his ciliary muscles and to accommodate more freely, and may be able, if under forty, to wear full or nearly full correction for constant use.

When patients are over forty, however, reading becomes difficult with their myopia fully corrected, and weaker glasses will have to be used for near work.

Whenever *astigmatism* is present, whether hypermetropic, myopic, or mixed, it should be as completely and exactly corrected as possible, and glasses constantly worn.

If the asthenopia is not relieved by correcting the refractive error, it may be found that the power of *convergence* is defective; that is, that even the natural amount of convergence in reading at 12 inches cannot be maintained without undue strain. The addition then of a weak prism, base in, to the reading glasses will lessen the amount of convergence and help to relieve the symptoms. Or, if this is not enough, then the power of convergence may be increased and the headache relieved by a tenotomy of an external rectus. This little operation, by weakening the action of this muscle, enables the internal rectus to contract more freely, and the function of convergence to be performed with less effort. A similar effect may be obtained by an advancement of the corresponding internal rectus, so as to make it more efficient as a converging muscle.

There are cases of retinal or nervous asthenopia which resist all such treatment, or in which there is no error of refraction or weakness of convergence. As the cause here is constitutional, the treatment must be given accordingly. This consists in such measures as will improve the general tone of the nervous system, as an open-air life, healthy surroundings, regular hours, a sufficient amount of sleep; drugs, such as strychnine, vegetable tonics, and iron, with more or less rest to the eyes. Sometimes the instillation of a weak solution of eserine will brace up the ciliary muscle and enable it to act without fatigue; while a good dose of antipyrine, aspirin, bromide of potassium, or a combination of the latter with salicylate of soda, will temporarily remove the headache.

VII.—AMETROPIA.

All conditions of the refractive apparatus of the eye which do not come under the definition of emmetropia, are included in the broad term **ametropia.**

In ametropia, therefore, parallel rays, coming from a distant object, do not come to a focus, or do not all come to a focus, on the rods and cones of the retina when the accommodation is at rest. The principal focus of the eye is not situated on the retina, but is either behind it, the eye being too short, as in **hypermetropia**; or in front of it, the eye being too long, as in **myopia**; or the rays do not all meet at the same plane, as in different forms of **astigmatism**; some may come to a focus on the retina, while the rest do not, as in **hypermetropic astigmatism** and **myopic astigmatism**; or all the rays may come to a focus behind the retina, but at different planes, as in **compound hypermetropic astigmatism**; or all may come to a focus in front of the retina, but at different planes, as in **compound myopic astigmatism**; or, lastly, some rays may meet in front of the retina and the rest meet behind it, as in **mixed astigmatism.**

Thus there are several conditions comprised in the term ametropia. And these vary very much in degree of severity; some being so insignificant as to escape detection unless looked for; others, though definite, are yet not serious; while others again may be so severe as to be a constant source of serious infirmity, leading perhaps to absolute blindness.

These different forms of ametropia may be clinically divided into three groups:—

1. In the first may be included those cases of simple hypermetropia and myopia which do not exceed, say, 2 dioptres, and which, in the absence of any marked astigmatism, insufficiency of convergence, or other complications, may be considered as healthy eyes. In this class it is not necessary in young subjects to insist upon the wearing of glasses, if there is no discomfort, asthenopia, squint, deficiency of convergence, or other symptoms, and, in the case of myopia, no tendency towards its increase. Of course there is some disturbance of harmony between the associated acts of accommodation and convergence, and the wearing of correcting lenses would restore this harmony. Yet this dissociation is not so great but that the effect of it may be overcome by the natural power the eyes have (to a limited extent) of adapting themselves to such irregular conditions.

2. In the next class may be included different forms of ametropia, varying in degree from 2 D to 6 D, with or without astigmatism or other complications. Here also there may be an absence of any actual pathological changes,

and therefore of defective visual acuity ; but the wearing of glasses is more necessary, both in order to make the eyes efficient for distant and near vision, and to restore the equilibrium between the two functions of accommodation and convergence, and avoid symptoms of asthenopia.

3. The last group comprises cases of high degrees of errors of refraction, which are generally accompanied by pathological changes or developmental defects. The visual acuity is nearly always below normal, and frequently very considerably so, and the action of the ocular muscles commonly defective. There is frequently an absence of binocular vision, and the harmony between the accommodation and convergence is much disturbed. Here it is essential to do all in our power by lenses and other means to counteract the defect and add to the patient's comfort.

Included in the general term ametropia are the following errors of refraction : Hypermetropia ; myopia ; simple and compound hypermetropic astigmatism ; simple and compound myopic astigmatism ; and mixed astigmatism.

In treating these different forms of ametropia, the natural course to adopt would be to estimate the exact error, and order the glass which fully corrects it. Unfortunately this would prove in many cases unsatisfactory. Having found the exact error, the surgeon often has to bring all his experience and skill to bear on the question of the appropriate lenses to give, his decision depending on many conditions, such as the age, sex, temperament, and occupation of his patient, as well as whether glasses have previously been used, and if so what glasses. Nothing but experience will enable the surgeon to come to a right decision on these points and to give his patients that comfort for which they seek his advice.

VIII.—HYPERMETROPIA.

Hypermetropia is the condition in which parallel rays, entering the eye, come to a focus behind the retina. Either the eyeball is too short, or the refractive power of the media is too low ; generally the former.

The human eye *at birth is generally hypermetropic,* more than two-thirds of the children born in this country being so ; while the remainder are mostly emmetropic, only a few being myopic.

A moderate degree of simple hypermetropia (say, under 2 dioptres) in a child is, as a rule, little felt. He is able by using his accommodation to see both distant and near objects clearly, and no difficulty is complained of so long as the eyes are not used much for near vision. If, however, the child is kept too closely to school-work, fatigue, headache, and other symptoms which result from excessive use of the accommodation will generally come on. As the patient grows up the difficulty increases, until a time arrives when he is unable to see near objects, and, later, distant objects, clearly, without the aid of appropriate lenses.

If the hypermetropia is of a higher degree, the accommodation may be insufficient to compensate for the error even in childhood ;

and the patient may experience difficulty in near or even in distant vision, and may suffer from symptoms of asthenopia.

In hypermetropia the eyes are generally deep-set, small, and near together; the pupils contracted and very active; the anterior chambers shallow, and the movements of the globes particularly free. By direct ophthalmoscopic examination the fundus is seen with or without a convex lens, and the disc looks small. If the shadow test (*retinoscopy*) be applied, and a concave mirror used, the shadow is seen to travel in the opposite direction to that in which the mirror is tilted.

If the patient be placed 20 feet in front of Snellen's types, he may be able to see the $\frac{6}{6}$ line with the naked eye, but will also see it as well or better with the addition of a convex lens. The strongest convex lens which still gives the maximum vision, is the measure of his manifest hypermetropia, i.e., the amount of the hypermetropia which can be made evident without paralysing the muscle of accommodation with atropine, or some other cycloplegic.

When atropine is used, a further amount of hypermetropia is found to be present, which under ordinary conditions is rendered latent by a certain involuntary contraction or spasm of the ciliary muscle, which always exists to a greater or less extent, but specially is present in hypermetropic conditions.

Thus hypermetropia is divided into a portion called **manifest hypermetropia** (H *m*) and a portion called **latent hypermetropia** (H *l*), the two making up the **total hypermetropia** (H *t*).

The relative amounts of manifest and latent hypermetropia depend chiefly on the age of the patient; the older the patient is, the greater portion of the hypermetropia is manifest, and the less of it is latent, until a time arrives when the whole of it is manifest, or H *m*=H *t*.

A hypermetrope has to use his accommodation in order to focus even distant objects, or parallel rays, on to the retina; much more has he to do so when he looks at near objects, from which the rays are divergent and require a correspondingly greater amount of refracting before they are made to converge to a point on the retina. Thus a hypermetrope's first complaint is that he has difficulty in reading and near work. He finds that the print becomes indistinct, and that he experiences a certain effort in maintaining clear vision, which, if persisted in, leads to a feeling of fatigue or pain in the eyes and head. Especially does this happen in the evening, or when he is in less vigorous health than usual.

The *complications* commonly met with in hypermetropia are **blepharitis, styes, meibomian cysts, hyperæmia** of the margins of the lids and conjunctivæ, **accommodative asthenopia,** convergent **strabismus, spasm of** accommodation, defective visual acuity of one or both eyes, and sometimes a predisposition to glaucoma. Accommodative asthenopia is the most frequent and often most troublesome of these complications, and for which the patient most commonly seeks advice. Children at school, students, clerks, type-writers, tailors, dressmakers, compositors, engravers, and others are alike liable to suffer from it.

A hypermetropic eye, even of high degree, is not necessarily a diseased organ. The prognosis is therefore better than it is in high myopia, where actual pathological conditions are generally present. The eye may be deficient as regards visual acuity; there may be defects in the development of its different structures; but these will remain stationary and not be progressive, and will not have the same danger of serious complications as in high myopia. On the contrary, if proper treatment is commenced early and persevered in, the visual acuity may improve, a convergent strabismus may be cured, and asthenopic symptoms removed.

The treatment of hypermetropia depends on its degree, upon the age of the patient, and upon the presence of complications and symptoms. The management of the case may be allowed to be influenced to a certain extent by the urgency of the symptoms. A healthy school-child with, say, 2 dioptres of hypermetropia, may have normal visual acuity, may experience no trouble whatever, no fatigue or headache, no difficulty in doing his school-work, and be able to read the smallest print without its becoming indistinct, because he possesses a vigorous ciliary muscle which wholly compensates for the error. Here no harm is being done, and there is no need to insist on the child wearing glasses for distant vision, though it is wiser, and would prevent the onset of symptoms, for glasses to be used for school-work.

If, however, the child complains of difficulty at school, of fatigue or headache, or other symptoms of asthenopia, it is necessary, after careful examination under a mydriatic, to prescribe glasses that will correct the error, however small, and generally to insist on their constant use.

In a case of simple hypermetropia, without asthenopia or strabismus, or other complications, when vision can be brought up to the normal standard without difficulty, no mydriatic need be used. But whenever symptoms of asthenopia or any complications are present, or a good result cannot be obtained, it is generally advisable in an adult, and always better in a child, to instil homatropin or atropin, or some other mydriatic, and then carefully estimate the refraction, first objectively by means of retinoscopy, then subjectively before Snellen's types, any astigmatism being specially searched for and corrected. Whenever a mydriatic is used great care must be taken to ascertain that there is no plus tension, or any symptom suggestive of glaucoma.

Having found the exact error of refraction, lenses should be prescribed which correct it, $\frac{1}{2}$ to 1 dioptre being deducted if a mydriatic has been used. If the patient has any presbyopia, the above lenses would be given for distant vision, and others, allowing for his presbyopia, given for reading and near work.

There is no constant rule in hypermetropia with regard to the presence or absence of asthenopia. In some cases very little error is accompanied by severe symptoms, especially when the patient is weakly, neurasthenic, or overworked, or has any accompanying astigmatism; whereas in other cases a decided error, with considerable astigmatism, is unattended by any asthenopia, and perhaps in spite of continued close work or feeble health.

In the treatment of higher degrees of hypermetropia, as indeed in any form of error, it is especially important that the lenses should be very correctly centred and the frames carefully adapted by the optician, as the *prismatic effect* of badly-centred strong lenses, whether convex or concave, is very great, and the result, after the most careful testing, may thus be frustrated by defective fitting.

IX.—MYOPIA.

Myopia is that condition of refraction in which parallel rays come to a focus in front of, instead of on, the retina. As a rule this is in consequence of the antero-posterior diameter of the eye being too long, though occasionally it is owing to the refractive power of the lens and other refracting media being too high.

The normal antero-posterior diameter of a fully-developed human eye is about 23 mm.; but it may vary in abnormal conditions of refraction from 17 mm. in hypermetropia to 32 mm. in high myopia.

Though myopia is rarely congenital, the tendency to become myopic frequently is so. It generally commences early in childhood, and increases during school life, and is essentially *a result of civilization and education.* If it is of a moderate degree, say below 3 dioptres, and is not progressive, nor accompanied by complications, it is more of an inconvenience than a serious defect; the loss of distinct distant vision being more or less compensated for by the advantage of being able to read and do close work without an effort of accommodation, or without the help of lenses, and from the fact that in near vision a myope gets a larger retinal image, and can therefore see minute objects more clearly than an emmetrope or hypermetrope can.

High myopia is, on the contrary, a serious and often a dangerous condition. Not only is the patient unable to see any object clearly which is further than a few inches from his face, but he is always liable to serious complications or total loss of vision from choroidal changes, vitreous opacities, posterior staphyloma, hæmorrhage into the macula, or detachment of the retina, etc. Myopia is nearly always acquired, and comes on generally as a result of using the eyes too much for near vision during the period of active growth, with other unfavourable conditions during school life, such as long school hours, a badly-lighted schoolroom, unhealthy surroundings, general malnutrition, etc., and the habit of holding the book too near. The latter causes excessive convergence, with resulting compression of the globe by the recti and oblique muscles, and a bulging in the direction of least resistance, that is, backwards. This bulging is increased by the traction of the optic nerve, which is then put on the stretch.

Myopia may be *progressive* or *stationary*. The earlier myopia begins, the worse is the prognosis, and the more likelihood is there for it to advance to extreme limits, with such complications as are mentioned above. It is generally stationary after adult life is reached.

In myopia the eyes are usually prominent and often wide apart ; the pupils more dilated and less active than in other states of refraction ; the anterior chambers deep, and the movements of the eye-ball limited. In examining the eye ophthalmoscopically by the direct method, it is necessary to use a *concave* lens in order to see the fundus distinctly ; and if the myopia be high, it is difficult to get a clear view of it. The disc appears large, and there is generally a **white crescent** (*myopic crescent*) along its outer side, which may be prolonged round the disc to form a **myopic ring**, or may even extend outwards towards the macula as a white bulging area, a **posterior staphyloma.** There may be atrophic and pigmentary changes at the macula itself, interfering materially with central vision, Besides these abnormal conditions of the fundus, the *vitreous* may be degenerated and too liquid, containing floating opacities, and the *lens* may be cataractous, especially at its posterior pole.

If the indirect method of examination be used, the fundus is easily seen, however high the myopia, though the disc and vessels look very small. If the test called retinoscopy be applied, and a concave mirror used, the shadow is found to travel in the *same* direction that the mirror is tilted.

If the patient be placed 20 feet (i.e., 6 metres) in front of Snellen's types, it will be found that he is unable to read the $\frac{6}{6}$ line without the help of a concave lens. He will generally, however, be able to read the smallest print (Jaeger 1) if held near enough to his eyes.

The lowest concave lens which gives the maximum distant vision is the *measure* of the myopia; and the focal length of this lens will be equal to the maximum distance from his eyes at which he can read small print (that is, his *punctum remotum*).

As soon as a tendency to myopia is detected in a child, he should be *carefully watched*, and any *excessive school-work or reading stopped*, and measures taken to prevent undue convergence. Lenses should be ordered and constantly used which correct the myopia, together with any accompanying astigmatism, and the child be prevented from holding his book nearer than 12 inches from his eyes. The lighting of the schoolroom should be efficient and rightly placed, and stooping at work prevented by means of slanting desks. The general health should be especially attended to, and plenty of outdoor recreation should be allowed, as also sufficient rest and sleep, frequent holidays, appropriate food, and early hours.

In an older patient, lenses should be used for reading and near work which keep the reading distance at least 12 inches away; and an occupation should be chosen which does not entail close and prolonged eye-work, or close confinement indoors.

In all cases it is important not to over-correct the myopia. There is a great danger of this if subjective testing is alone depended on. It is often necessary to temporarily paralyse the accommodation by means of a mydriatic, before completing the examination.

The amount of correction ordered in each case depends on the age of the patient, the degree of myopia, and as to whether lenses have been hitherto used or not. In children and young people with a moderate degree of myopia, the *full* correction under atropine should be ordered for constant use. But in high degrees it is generally necessary at first to *under-correct* the error, the strength of the glasses depending upon the condition of the muscles of accommodation. It is then generally satisfactory to give for constant use the highest concave lenses with which the patient can read small print. The wearing of lenses in myopia tends to strengthen the ciliary muscles by bringing the accommodation more into use, and prevents excessive convergence by removing the reading distance farther from the eyes. In severe cases of progressive myopia in children, it is sometimes necessary to postpone for a while the wearing of lenses, to put a stop to all reading and near work, restrain all accommodation by the continued use of atropine, and order dark glasses, tonics, generous food, and an open-air life.

In older patients it is generally necessary to order *two pairs* of glasses—one for distant vision, and the other for reading and near work. In low degrees of myopia the patient will often read more comfortably without any lenses at all. If he has always worn glasses and has an active accommodation, he will prefer, and ought to use, lenses for near work as well as for distance. The distance lenses should correct the whole or nearly the whole of his myopia, and the others be strong enough to keep his reading point at the required distance of 12 inches.

Myopes frequently suffer from muscular asthenopia in consequence of the fatigue produced by excessive *convergence* in reading. When the internal recti are so weak that convergence, even to the usual reading distance of 12 inches, is difficult to maintain, the addition to each concave lens of a *weak prism* of 2° or 3° (base in) may relieve his asthenopia by diminishing the convergence; or the same result may be obtained by *decentering* outwards the concave lenses in their frames.

When an external squint is present, this may be remedied and the power of convergence improved by dividing the external rectus or advancing the internal.

A high myopia may be treated by the **removal of the crystalline lens.** This is generally done by a discission or needling. In children this is generally all that is necessary, the lens slowly becoming absorbed without further operative interference, beyond, perhaps, a second or a third needling. In an adult, however, and sometimes in children, the lens matter must be let out through a linear incision within a day or two of the needling, as the lens swells and is liable to produce + tension. This treatment should only be adopted when there is more than 12 dioptres of myopia, and when there is an absence of serious pathological changes: as gross choroidal disease, tendency to retinal hæmorrhage, extensive posterior staphyloma, or vitreous opacities.

In many cases it is convenient to operate on *one eye* only, and leave the other alone; then the patient uses the aphakic eye for distance, and keeps the other with its accommodation intact for near vision.

X.—ASTIGMATISM.

Rays of light emanating from a point (beyond its principal focus) on one side of an ordinary convex spherical lens, are so refracted on passing through the lens that they come to a focus or meet again in a point. Likewise, in the human eye, when there is an absence of astigmatism, rays coming from a point in front of the eye meet behind the refractive apparatus in a point.

When, however, there is **astigmatism** present, such rays, instead of meeting in a point, come to a focus at different distances according to the meridian of the refractive apparatus through which they pass. Thus, the rays passing through one, say the vertical meridian, will come to a focus in front of or behind those passing through the other, or horizontal, meridian.

Astigmatism is divided into **regular** and **irregular astigmatism.** The latter is nearly always caused by irregularity in the form and surface of the cornea, generally the result of ulcers and other inflammatory conditions, which leave behind them facets and nebulæ, or a general unevenness of the corneal surface. There is no regularity or method in this form of astigmatism, and the condition cannot be satisfactorily corrected

Regular astigmatism is, on the other hand, correctible, and is generally caused by the cornea being more curved in one direction than in the other, somewhat similar to the bowl of a spoon, the meridians of the maximum and minimum curvature being always at right angles to one another; that is, one may be perpendicular while the other is horizontal, or both may be oblique but at right angles to one another. Sometimes this abnormal condition of curvature is situated in the lens, instead of, or in addition to, the cornea.

There are several different forms of regular astigmatism :—

1. Simple myopic astigmatism, in which the eye is emmetropic in one meridian and myopic in the other; that is to say, parallel rays passing through one meridian, say the horizontal one, come to a focus on the retina, while those passing through the opposite meridian are focussed in front of the retina. This would be corrected by a concave cylindrical lens, with the axis of the cylinder horizontal, so as to affect only the vertical rays.

2. Compound myopic astigmatism, in which the eye is myopic in both meridians, but more so in one than the other. The rays passing through both meridians are brought to a focus in front of the retina, but at different levels, or distances from the retina. This would be corrected by a combination of a *concave spherical* lens with a *concave cylindrical* one.

3. **Simple hypermetropic astigmatism,** in which the refractive apparatus of the eye is emmetropic in one meridian, but hypermetropic in the other. Thus, parallel rays passing through the one meridian come to a focus on the retina, while those passing through the other meridian come to a focus behind the retina. This is correctible by a *convex cylindrical* lens, so placed as to affect the hypermetropic meridian alone.

4. **Compound hypermetropic astigmatism,** in which the eye is hypermetropic in both meridians, but more so in one than the other; the rays passing through both meridians coming to a focus behind the retina, but at different levels. This would be corrected by a combination of a *convex spherical* and a *convex cylindrical* lens.

5. **Mixed astigmatism,** in which the eye is myopic in one meridian and hypermetropic in the other. That is, parallel rays entering the eye through one meridian, are brought to a focus in front of the retina; and those entering through the other meridian come to a focus behind the retina. This would be corrected by a combination of a *convex spherical* with a *concave cylindrical* lens, or vice versa.

It is a general rule in astigmatism, to which, however, there are many exceptions, for the rays which pass through the *vertical* meridian to come to a focus in front of those which pass through the horizontal meridian.

All forms of *regular* astigmatism agree in one respect—they all require for their correction the use of a *cylindrical* lens, either alone or in combination with a spherical one.

Astigmatism is generally a congenital condition; but it may be acquired, for instance in progressive errors of refraction, in certain affections of the cornea, in which it becomes softened and bulges, after accidental wounds of the cornea, or certain operations involving an incision of the cornea, and after the division of an external muscle.

As there is *manifest* and *latent* hypermetropia, so may astigmatism be rendered more or less *latent* by a compensating uneven contraction of the ciliary muscle. The effort made by the muscle of accommodation to compensate for any existing astigmatism causes considerable fatigue, and is a fruitful source of asthenopia.

When, in the examination of a patient, the vision cannot be brought up to the normal standard by means of spherical lenses, and no cause is found for this in the media or fundus by ophthalmoscopic examination, it is probable that some *astigmatism* is present, and the next step is to carefully ascertain whether this be so or not. To the spherical lens which so far gives the best result a − ·5 D *cylinder* should be added, with its axis* horizontal. If vision

* The *axis* of a cylindrical lens is the direction in which a straight-edge will lie flat, or in continuous contact with its curved surface.

is not improved by this, the direction of the axis should be changed by revolving the lens. If the vision cannot be improved, but remains the same in whatever direction the axis is placed, and other cylinders also fail to improve the vision, it is *probable* that there is no astigmatism. If, however, it is found that the vision differs according to the direction of the axis of the cylindrical lens (for instance, that with the axis horizontal vision is distinctly better than when it is vertical), it is evident that astigmatism is present, and steps should be taken to estimate its degree with the help of retinoscopy, with or without a mydriatic. One would in a young patient order atropine (grs. ij ad ℥j) three times a day for three days; or, in one older, would drop homatropin (grs. iv ad ℥j), or a combination of this with cocaine, into the eyes three or four times at intervals of five minutes, and continue the examination after the lapse of about one hour. The patient would then be taken into a dark room and examined by means of retinoscopy (*see* p. 80). The result would then be confirmed subjectively before Snellen's types.

It is found that an adult who has never had his astigmatism corrected cannot as a rule bear the full correction at once, as it often causes giddiness and other uncomfortable symptoms. It is often necessary, therefore, to *under-correct* at first, and postpone the full correction till later. In a young patient, however, the whole of the astigmatism should from the first be corrected. It is always important when there is any astigmatism for glasses to be worn *constantly*, otherwise the patient may never get accustomed to them, or derive full benefit from their use.

It is often impossible to get a true estimate of astigmatism without a mydriatic. Both the degree of astigmatism, and the direction of its axis, can be concealed or modified by an unequal contraction of the ciliary muscle, so that varying results are obtained at different examinations.

The nearest approach to accuracy without using a mydriatic, as far as corneal astigmatism is concerned, is obtained by means of an ophthalmometer or keratometer. With it the amount of corneal astigmatism is estimated by observing the relation to one another of images reflected by the instrument upon the surface of the cornea. These instruments show accurately and quickly the amount of corneal astigmatism, but not that produced by the lens.

XI.—PRESBYOPIA.

From childhood onwards the range of accommodation is gradually diminishing, and the *punctum proximum,* or nearest point of distinct vision, is steadily receding, until a time comes when reading and other near work become difficult without the aid of convex lenses. It is then that **presbyopia** is said to commence.

Presbyopia is the result of certain changes in the textures of the eye, principally consisting in a progressive hardening of the crystalline lens, and a resulting diminution of its elasticity. In consequence the lens becomes year by year less capable of altering its shape and increasing its refractive power when its suspensory ligament is relaxed in accommodation. Eventually (generally at about the age of eighty) it ceases to have any elasticity, and then all power of accommodation ceases.

Not only the lens, but the coats of the globe become progressively harder and more resistant, and as years advance the ciliary muscles become less active. The result of all these changes is that the near point of clear vision gradually recedes from the eye, until reading and other near work are no longer possible without the aid of lenses.

Presbyopia is said to begin when the near point of distinct vision recedes beyond 22 cm.;

that is to say, when small print can no longer be seen at that distance even for a short time, and near vision cannot be maintained for a length of time at 33 cm., or the usual reading distance.

The period of life at which presbyopia begins varies with the state of the refraction. In *emmetropia* difficulty is generally first felt soon after the age of forty, whereas in *hypermetropia* it comes on earlier than forty, and in *myopia* it is correspondingly delayed.

An emmetrope must always possess at least 4·5 dioptres of accommodation in order to read and do near work comfortably. At ten years of age he has 14 dioptres, but this diminishes year by year until at forty he generally has just about 4·5 dioptres. Up to this age, therefore, he has no presbyopia. At forty-five his power of accommodation has usually sunk to 3·5 dioptres, so that he has now 1 dioptre of presbyopia, and needs a + 1 D Sph. (spherical) lens to enable him to read comfortably. At fifty he only has 2·5 dioptres of accommodation, so that he needs a + 2 D Sph. to read with. At fifty-five his accommodation has sunk to 1·5 dioptres, so that he now needs a + 3 D Sph. lens to make up the necessary 4·5 dioptres, and so on. The rule is that between the ages of forty and sixty the power of accommodation diminishes on an average 1 dioptre for every five years.

In ordering lenses for presbyopia the distant vision has to be first carefully taken, and the lenses which correct any error of refraction must be combined with that lens which would be required by an emmetrope to correct his presbyopia. For instance, if a patient of fifty has 1 dioptre of hypermetropia, he will probably need a + 3 D Sph. lens to read with (that is, + 2 D Sph. to correct his presbyopia, together with + 1 D Sph. for his hypermetropia). Again, if a patient of fifty has 1 dioptre of myopia, he will probably read best with + 1 D Sph. (that is, + 2 D Sph. for presbyopia, together with – 1 D Sph. for his myopia).

This average rule is not absolute, however, because the decline of accommodation is not constant, but varies somewhat according to the constitution and vigour of the patient. The rule should *guide*, but not *determine*, the treatment of each case.

After the age of fifty the refractive power of the crystalline lens diminishes, so that a hypermetrope becomes more hypermetropic, and a myope less myopic. A person who is emmetropic up to fifty has about $\frac{1}{2}$ a dioptre of hypermetropia at sixty, about 1 dioptre at seventy, and about 2 at eighty.

Again, in *incipient cataract* the opposite change may take place; the refractive power of the lens then often increases, so that an emmetrope becomes slightly myopic, a myope more myopic, and a hypermetrope less hypermetropic.

These facts should be kept in mind in the treatment of presbyopia.

XII.—STRABISMUS.

Normally, an object looked at is focussed by the two eyes in such a way that the retinal image in each eye is thrown on to the macula, and the visual axes are directed towards the object, and if produced would meet at that object. The maculæ are corresponding points of the two retinæ, and although each receives a separate image of the object looked at, only one object is seen by the individual. This is because the same cortical cells receive the impressions from the two maculæ. In the same way other symmetrical points of the two retinæ are associated together in such a manner that if there is no squint (that is, if the visual axes of the two eyes are accurately directed towards the object), each point in the visual field is thrown on to corresponding points of the two retinæ, and one united impression of the whole view is perceived.

This is called **binocular single vision,** or **binocular fixation,** and is thus dependent on the fusion of the two retinal images into one mental impression. It is a most important function, being useful not only in producing general acuteness of vision, but in estimating distances, and the relative position of different objects. It is governed by a special cerebral centre, the stimulus being the natural desire to fuse the two retinal images into one visual impression.

In strabismus this function of binocular single vision is interfered with, because of the faulty direction of the visual axes. The visual axis of one eye is directed towards the object looked at, while that of the squinting eye deviates from it. In *convergent* or *internal* strabismus it deviates inwards, and in *divergent* or *external* strabismus it turns outwards, or it may be directed upwards or downwards or obliquely. Convergent strabismus generally is found in hypermetropic conditions, whereas a divergent squint is more common in myopia. Any form of strabismus may be either *concomitant* or *paralytic*.

In **concomitant strabismus** there is no paralysis of any ocular muscle. The affected eye is able to perform its natural movements more or less perfectly, these movements accompanying those of the good eye, only that the direction of its visual axis differs from that of its fellow, this difference remaining relatively the same in whatever direction the eyes are looking.

Paralytic strabismus is caused by a partial or complete paralysis of one or more of the external muscles of the eye, and differs from concomitant strabismus in that the amount of deviation is not constant, but varies according to the direction the patient looks, being greater when the eyes are turned towards the paralysed muscle, and less, or absent, when they are turned in the opposite direction. The two forms of squint also differ in the fact that in *concomitant* strabismus the primary and secondary squint are equal, which means that the deviation of the affected eye when the patient is using the good one (i.e., the primary squint) is equal to the amount the good eye would deviate if it were covered and the patient made to fix an object with the affected eye (i.e., the secondary squint). In *paralytic* strabismus, on the contrary, the secondary squint is greater than the primary.

Concomitant strabismus also differs from paralytic in the patient being very little, if at all, troubled with *diplopia*, which is a very prominent and distressing symptom in the latter. The reason for this is that concomitant strabismus generally comes on in early childhood, before the acquired function of binocular single vision has become developed, and in consequence the child easily gets in the way of taking notice only of the clear image received on the macula of the fixing eye, and to neglect, and afterwards to suppress, the less distinct image which falls on a less sensitive part of the retina in the squinting eye. Whereas paralytic strabismus comes on suddenly, and generally later in life, when binocular single vision has long been established, and the patient has learnt to receive into his brain the perception of both retinal images and to fuse them into one mental impression. The sudden disturbance of this causes troublesome diplopia.

Concomitant convergent strabismus is the form most frequently met with. It may be an *occasional* or a *constant* squint; and in either case it may be *monolateral* or *alternating*; that is to say, may always affect the same eye, or be sometimes in one and sometimes in the other.

Concomitant convergent strabismus generally comes on when the child begins to look at picture books or to learn its alphabet, and thus to bring its accommodation and convergence more into use. If there is no hypermetropia, and the accommodation has not therefore to be used in excess of convergence, there is no incentive to converge excessively, whatsoever the state of the binocular function; but in the presence of hypermetropia the excessive accommodation required is associated with a tendency to excessive convergence, which is at this age unrestrained by a desire for binocular fixation, this being yet undeveloped. Thus an undeveloped binocular function permits the excessive accommodation present in hypermetropia to carry with it an excessive convergence, and this convergence throws the macula of one eye out of place, so that the rays from objects looked at do not fall upon it. The result is that one eye fixes the object while the other does not. Thus one macula becomes developed and its acuity of vision perfected, while the other, from want of use, loses some of its visual acuteness, and *becomes more or less amblyopic.* The consequence is that the desire to fuse the retinal images becomes gradually less, or may be never properly developed.

It is, therefore, very important to commence the treatment of an ordinary convergent strabismus *as early as possible.* The child should be atropised, and the hypermetropia with any astigmatism corrected, and glasses ordered for constant use. The sooner the child can be put into spectacles, the more surely will the squint be cured. It is a good thing to keep the child more or less under atropine for three or four weeks after beginning with glasses, in order to *restrain all efforts of accommodation.* Besides this, the mother or nurse should be directed to cover up the good eye for an hour or two every day, so that the child be **made to use the squinting eye.** This will help to keep up the visual acuity of the bad eye.

Careful persistence in these measures will commonly be successful, if begun within a short time of the commencement of the squinting. It is, however, better to supplement them by certain **stereoscopic exercises.** These are especially useful when the visual acuity of the squinting eye is fairly good. Worth's amblyoscope may be used for these exercises, or an ordinary stereoscope fitted with + 6 D spherical lenses, to prevent any effort of accommodation on the part of the patient, who should also wear his own correction.

For the success of these exercises it is often necessary to **practise the patient in seeing double,** so as to overcome the *habit of suppressing* the retinal image of the squinting eye. One means of doing this is to place a prism of a medium power, base down, before one eye, and direct the patient to look at an object in front of him—say, a candle placed about 6 feet away. He should then see two lights, one higher than the other. If only one object is seen, then cover the good eye repeatedly, until the patient becomes conscious of the *two images.*

Reading with a sheet of cardboard placed vertically between the eyes is another simple way of developing binocular vision.

When these means fail to cure a squint, a **tenotomy** or an **advancement** may have to be done. In order to form an opinion as to the amount of operative interference necessary, it is well to ascertain the *degree* of deviation in the squinting eye. A simple way of doing this is the method devised by Priestley Smith. The patient sits in the dark room, with the light behind and above his head. The surgeon sits one metre in front of him, this distance being maintained by means of a tape one metre long with a ring at each end ; one end is held by the patient just below his squinting eye, and the other hooked on to the ophthalmoscope held by the surgeon.

Suppose the right is the squinting eye, the surgeon, holding his ophthalmoscope in his right hand, reflects the light into that eye from the concave mirror, the patient meanwhile keeping his gaze fixed on the mirror. The surgeon now sees the corneal reflex of the light external to the centre of the right pupil. He now holds the end of a tape measure in the right hand, in which he has the ophthalmoscope, and with the left hand lets the tape slip through between his finger and thumb as he slowly moves that hand to the left, directing the patient to watch the left hand as it moves. The surgeon meanwhile keeps his eyes on the corneal reflex, and as soon as it reaches the centre of the pupil, he stops and reads off the tape the distance between his two hands. He will then register this number in his notes, or calculate from it the number of degrees of the angle of deviation, which would be about one-tenth less than the number of centimetres read off the tape.

A squint not exceeding 15° needs a simple tenotomy of the internal rectus of the squinting eye, with suturing of the conjunctival wound afterwards. One of 20° requires a tenotomy with free division of the subconjunctival tissue, or an advancement without a tenotomy. One of 25° to 35°, a tenotomy of the internal rectus, with an advancement of the external. Lastly, one of over 35° needs a free tenotomy of the internal rectus, an advancement of the external rectus, and probably later a tenotomy of the internal rectus of the good eye.

It is better not to fully correct a convergent squint at the time of the operation, as the effect tends to increase as time goes on. For months or, if necessary, for years after a squint operation, orthoptic exercises should be persevered in, and, of course, glasses correcting any ametropia constantly worn.

In **external strabismus,** which so often accompanies myopia, somewhat similar treatment should be adopted. Appropriate glasses should be worn, and the reading distance put back to about 12 inches, though the chances of glasses benefiting the condition are much less than in convergent strabismus. A tenotomy of the external rectus or an advancement of the internal is generally necessary, as well as exercises to improve binocular vision and increase the power of the converging muscles.

Besides these varieties of definite squint, there may be latent defects in the parallelism of the visual axes (heterophoria). In such cases the defect is discovered by directing the patient to look for a few moments at an object in front of him when one eye is covered by the surgeon's hand or a sheet of paper. By quickly uncovering the eye it is seen to be looking in a wrong direction, either outwards (exophoria), inwards (esophoria), or vertically. On being uncovered it generally at once assumes the right position.

The causes of these defects are the same as of definite strabismus.

A satisfactory way of detecting heterophoria is by means of the Maddox rod, which changes the appearance of an ordinary flame into a long red streak. This is placed before one eye while the other is left uncovered. The patient then sees the natural flame with one eye and a long red streak of light with the other. As these two objects are so different in appearance, there is no effort made to fuse them. If heterophoria be present the images will be separated more or less, according to the degree of deviation. The amount of this deviation is indicated by the power of the prism required to bring the images together, the angle of deviation being half the angle of refraction, or the angle between the two surfaces of the prism (*vide* page 22). Instead of a Maddox rod the muscle cone test may be used, when in place of the flame a circle of light is formed, which so differs from the flame that there is no effort made to fuse the two images, and so heterophoria is manifested. If there is no heterophoria the light will occupy a central position in the circle, but if heterophoria be present, it will be either outside the circle altogether, or at some position within the circle other than the centre.

XIII—ANISOMETROPIA.

If there is a material *difference* in the refraction of the two eyes, the condition is called **anisometropia.** Slight differences are very usually present, but the term anisometropia would not be applied unless the eyes differed considerably.

One eye may be emmetropic, and the other myopic or hypermetropic ; both may be myopic or both hypermetropic, but in different degrees, or one may be myopic and the other hypermetropic. The condition is generally congenital, and may be associated with a difference in the development of the two sides of the cranium, or it may be acquired.

Sometimes, in spite of anisometropia, the *binocular vision* is good. The eyes work together, with fusion of the two retinal images, though these images are unequally distinct. For instance, suppose the right eye is emmetropic and that the left has 2 D of myopia, the retinal image of a distant object will be distinct in the right eye, but blurred in the left ; yet there may be fusion of these two images, and they may be both perceived and carried up to the brain as one mental impression.

More often there is an absence of binocular vision ; and the difference in the refractive errors of the two eyes may be such that one eye is better suited for distant vision and the other for near vision. A patient of sixty with one eye emmetropic and the other with say 4 D of myopia, would use the emmetropic eye for distance, and the other for reading. Any attempt in such a case to try and make the two eyes work together would probably be disappointing.

Again, the patient may be in the habit of always using one eye for everything and neglecting the other ; the visual acuity being perhaps good in the one and deficient in the other. The unused eye often deviates, and has a convergent or divergent squint.

Anisometropia is often a source of difficulty in the treatment of errors of refraction. If the surgeon does the most natural thing, and orders the whole correction of the error which he finds in *each eye*, the result will as often as not be a failure.

When a patient has binocular vision, he is often unable to tolerate the correction of his anisometropia. The correction may give him a clear retinal image in each eye, and with either eye alone he may see clearly and comfortably ; yet when both eyes are uncovered he feels giddy and dazzled and uncomfortable ; however much he perseveres, he may be quite unable to accustom himself to the wearing of the glasses. The reason is, the retinal images, though distinct, are of different sizes, and their fusion is difficult or impossible. Perhaps the patient can stand a partial correction of his anisometropia; perhaps none at all. All these points have to be determined, and such *compromises* made as are found to be necessary in each case.

When it is found that a patient uses only one eye, while the other, which has generally the most error, is not brought into use at all, it is often wiser to correct the good eye only, and to order a plane glass for the other.

XIV.—EXAMINATION OF PATIENTS.

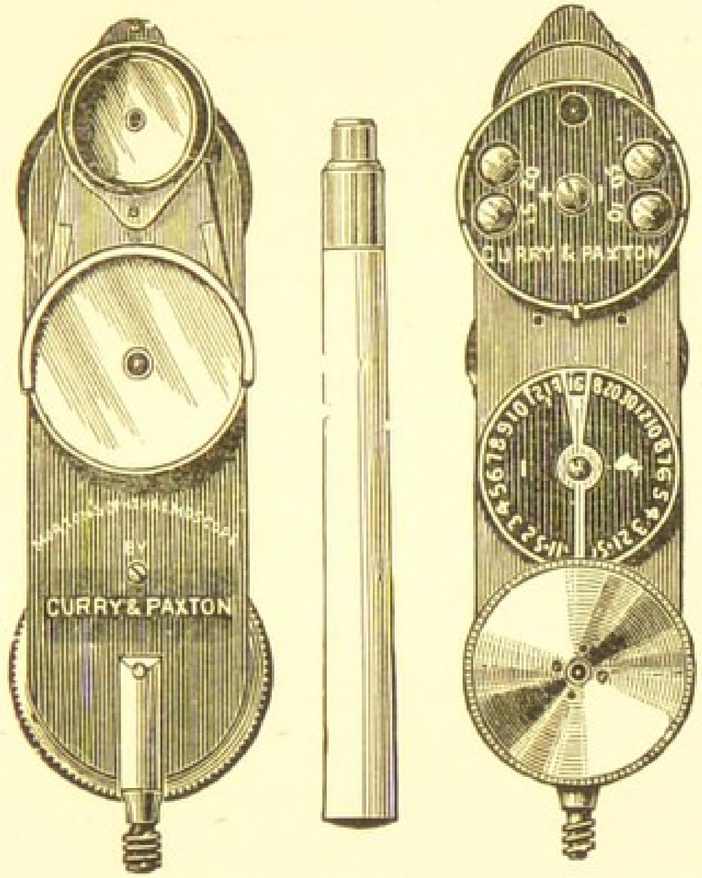

Fig. 3.—Morton's Ophthalmoscope.

In examining ophthalmic cases, it is well to first take notice of any general disease or conditions or peculiarities about the patient, especially such as are known to be *associated* with eye trouble. For instance, any indications of anæmia, syphilis, tuberculosis, kidney or heart disease, diabetes, exophthalmic goitre, locomotor ataxy, paralysis of the cranial nerves, or sympathetic nerves, whooping-cough, lead poisoning, or symptoms suggestive of the over-use of alcohol or tobacco, etc. ; then any peculiarity about the contour of the head and face, whether the eyes are prominent or sunken, whether they are in any way irregular, or differ from one another, or squint.

The different structures of the eyes should then be examined in a systematic manner : First the lids and conjunctiva, then the cornea, especially noting any opacity in the latter or irregularity of its surface. Then see if the pupils are equal, and active to light and accommodation, not tied down by any adhesions to the cornea in front or the lens capsule behind, nor occupied by any organised lymph from old iritis. Also that there is no ciliary injection, or other signs of inflammatory mischief in the cornea or iris, or other structures. Next, have the patient in a dark room, and examine the different media, first by oblique illumination,* and then by means of the ophthalmoscope, and note any opacity or haziness in the cornea, aqueous, lens, or vitreous, and anything abnormal about the fundus, especially the macula and disc. At this stage, while the patient is in the dark room, and in the absence of any condition which would contra-indicate it,

* Oblique illumination is a method of examining the more superficial parts of the eye (namely, the cornea, iris, and lens), by concentrating the light on to these structures by means of a convex lens of about 16 D.

examine the patient by means of retinoscopy without a mydriatic, repeating it later under a mydriatic if found necessary. In the case of children it is generally better to have the accommodation paralyzed by means of atropine before attempting to do a retinoscopy.

Having made this examination, place the patient 6 metres from Snellen's Types, fit him with a pair of trial frames, and proceed to confirm the retinoscopy by placing the correction so found in the frames, and varying it until the best possible result is obtained.

[Snellen's Types are so arranged that a person with normal vision can read the top letter on the board at a distance of 60 metres, and the remaining lines at distances of 36, 24, 18, 12, 9 and 6 metres respectively. These lines are accordingly marked D=60, D=36, D=24, D=18, D=12, D=9, and D=6. (The letter D standing for the word "distance.") For convenience sake, the distance from the board at which the examination is made is always six metres, and the different degrees of vision indicated by the line on the board, which the patient can read. Thus, if a patient placed at six metres from the board is able to read D=6 line, his vision is put down as $\frac{6}{6}$, the figure above the line indicating the number of metres from the board at which the patient is able to read the line, and the figure below indicating the number of metres at which a person with normal vision would be able to read it. If at this distance he cannot read line D=6, but is able to make out the line next above it, namely, the line D=9, his vision is said to be $\frac{6}{9}$. (That is, he can only read the line D=9 at six metres distance, while he ought to be able to read D=6 line.) If he can only read D=12, his vision is $\frac{6}{12}$, and so on up to $\frac{6}{60}$. Thus the vision in each eye is estimated by the line of Snellen's Types which the patient is able to read from a distance of six metres. If the patient is unable to read even the top letter on the board at six metres distance, we try him at a distance of 5 metres, and if he can now read it his vision is noted down as $\frac{5}{60}$. If he can only make out the top letter at four metres, then his vision is $\frac{4}{60}$, and so on up to $\frac{1}{60}$. If he cannot recognize the top letter on the board at a distance of one metre, we see if he is able to count fingers, and at what distance. If he can count them, we note down V=Fingers. If he cannot, we next see if he can make out the hand moving in front of his face, and if so, note down V=Hand-movements. If he cannot even do this, he is taken into the dark room, and placed with his back to the light, and the light reflected by means of an ophthalmoscopic mirror alternately on and off his eye. If he can tell the difference between light and darkness, V=P.L. ("perception of light"). If he is able also to tell from what direction the light comes, then he has "Projection of light." If he cannot tell light from darkness, then his vision is *nil*, the eye is *blind*.

For near vision there are two series of types generally used, one arranged by Snellen, and the other by Jaeger. The latter is mostly used in England, and is composed of different sized prints varying from the Diamond type, which is very small, up to a large type about an inch in size, and numbered from 1 to 20. If a patient can read the smallest, his near vision is put down as J1; if only the next size J2; and so on to J20.]

Having placed the patient at a distance of 6 metres from the Snellen's types, one eye is covered, and with the other he is asked to read the letters from above downwards. If he is able, say with his right eye, to read line D=6 (R.V.=$\frac{6}{6}$) we know that he is not myopic in that eye. He may, however, be hypermetropic, so a weak, convex, spherical lens, say + 0·5 D Sph. is placed before the eye. If he can still read $\frac{6}{6}$ the + 0·5 D Sph. lens is changed for a + 1 D Sph.; if with this he can still see $\frac{6}{6}$, it is replaced by a + 1·5 D Sph., and so on, until the strongest plus lens is reached with which he can still read $\frac{6}{6}$ (any stronger one making the letters indistinct). This will be the amount of his **manifest hypermetropia.** Supposing this lens is + 2 D Sph., the refraction of that eye will be written down thus R.V=$\frac{6}{6}$ Hm 2 D. The left eye should now be tested in the same way, and supposing it gives the same result, it will be also written down L.V. = $\frac{6}{6}$ Hm 2 D. When there is 4 D of hypermetropia or more in a child, or a lower degree in an adult, the accommodation may be unable to overcome it, and the $\frac{6}{6}$ line not be read without the error being corrected. The surgeon should next proceed to test the patient's near vision, and for this purpose would give him a book of Jaeger's or Snellen's types, and note the smallest print which he can read, and the distance at which he reads it.

Suppose, however, that the patient, placed 6 metres from Snellen's types, is only able to read with his unaided eye the fourth line, i.e. $D = \frac{6}{18}$, and that convex lenses do not improve his vision, but make it worse ; we then place a weak *concave* lens, a − 0·5 D Sph. in the trial frame. Suppose that with this lens he can see the next line $\frac{6}{12}$ clearly and partly make out $\frac{6}{9}$, and that a − 1 D Sph. enables him to read $\frac{6}{6}$ distinctly, we would then try if a − 0·75 D Sph. would give an equally good result. If not, we know that − 1 D Sph. is the weakest concave lens which gives the maximum vision. He could of course see equally well with a − 1·5 D Sph., or even with one higher, by using his accommodation ; but the estimate of his myopia is indicated by the *lowest* concave lens which gives the maximum vision.

If, however the patient's vision cannot be brought up to the normal standard, or he suffers from symptoms of asthenopia, or has a strabismus, or a probability of much latent hypermetropia, or spasm of accommodation, and there is no other obvious cause for the defect, we would then make a further examination in a dark room, by means of **retinoscopy** and the **ophthalmoscope,** with the pupils dilated and the accommodation paralyzed by means of a mydriatic. The form of mydriatic used would depend upon the age of the patient, the urgency of the symptoms, and upon whether or no a lengthened mydriasis was specially undesirable. Atropine used three times a day for three or four days, more completely suspends the accommodation than any other form of mydriatic, but its effects last for a week or ten days, during which time the patient is generally unable to read or do close work. A more general rule is to use atropine (2 grains to the ounce) for children, or sometimes young adults ; and some other mydriatic, as hydrobromate of homatropin (4 grains to the ounce), or a combination of this with hydrochlorate of cocaine, for adults. This latter should be instilled three or four times at five-minute intervals, and the examination resumed in about an hour from the first instillation. Always before using any mydriatic, the ocular tension should be noted, any plus tension contra-indicating its use.

When the patient is well under the influence of the mydriatic, indicated by the pupils being widely dilated and inactive to light, and by the accommodation being completely in abeyance, he is again placed in a dark room in front of a good light, and after another look at his lens and structures in front of it by oblique illumination and of the fundus with the ophthalmoscope, an examination by means of retinoscopy is made.

Retinoscopy,* or the shadow test, is a rapid and dependable method of estimating errors of refraction, and being altogether objective, and not dependent on the observations and answers of the patient, is suitable for all cases alike, whether children or adults, educated or illiterate. In this method of examination, the light from a lamp behind the patient's head is reflected by means of a small circular mirror into the patient's eye, and certain phenomena observed by the surgeon through a perforation in the centre of the mirror. The mirror may be either concave or plane ; with the former the resulting shadow in every case moves in the reverse direction to what it does if a plane mirror be used. A description of the results got by means of a *concave mirror* (i.e. an ordinary ophthalmoscopic mirror) will be given here.

The patient is seated in a dark room with a moderately strong light behind and above his head, and a trial spectacle-frame on his face. The surgeon sits facing the patient at a distance of 3 to 4 feet, wearing his own correction if his

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* In describing Retinoscopy the words "image" and "shadow" are used clinically as meaning the same thing. But the image really means the illuminated area, and the shadow the dark edge of that area.

distant vision is at fault. With his ophthalmoscope in his right hand, or a concave mirror specially made for retinoscopy, he reflects the light into the patient's eye in such a way that the pupil becomes illuminated by a fundus reflex, which the surgeon observes through the perforation in the centre of the mirror. He now finds that if he rotates the mirror laterally the illuminated area or "image" moves from side to side across the pupil; and if he rotates the mirror vertically the "image" likewise moves vertically. Now the *direction* in which the image moves, and the *rapidity* of its movement, and other characteristics, are determined by the state of refraction of the eye. It requires considerable practice in retinoscopy to enable one to recognize the different variations of the image, and to understand what these variations indicate.

When an eye is **emmetropic** or **hypermetropic,** the image moves in the *opposite* direction to which the mirror is tilted. In **emmetropia** it moves *rapidly,* and is *distinct* and its edges well defined; that is to say, the image of the lamp stands out bright and clear, and is separated by a distinct edge from the surrounding darkness or "shadow." In **hypermetropia** the image is *less distinct* and moves *less rapidly* across the pupil; and the more hypermetropia there is, the more indistinct is the image and the slower it moves.

In **myopia** of 1 D or higher, the image moves in the *same* direction in which the mirror is turned, being *more defined* and moving *quicker* in low degrees than in high degrees. There is a point, therefore, between 1 D of myopia and emmetropia, at which tilting of the mirror causes no definite movement of the image. This point is a little under 1 D of myopia, and here the image does not move either one way or the other when the mirror is rotated. Thus, not only in hypermetropia and emmetropia, but in the lowest degree of myopia, the image moves " against the mirror." The reason why this turning-point in the movement of the image takes place at nearly 1 D of myopia and not at emmetropia, is that the surgeon for convenience sake observes these phenomena at a distance of 3 to 4 feet, and his eye does not receive parallel rays proceeding from the eye under examination, but rays which converge to a point 3 to 4 feet distant.

When there is **astigmatism** present, the character of the shadow and its movements *vary* in different meridians of the eye ; perhaps one may give a myopic shadow, while the other may give an emmetropic or hypermetropic one ; or both meridians may be myopic, but one more so than the other ; or both hypermetropic, but differing in the same way. Also the image will assume more the form of a *straight band* of light ; the direction of this band indicating the direction of one of the meridians of astigmatism, and giving a rough indication of the direction in which the axis of the cylinder has to be placed which is used to correct the error.

Supposing that the surgeon finds that the shadow moves in the opposite direction to which the mirror is tilted, i.e. against the mirror, he then places in the cell of the trial frame a + 0·5 D Sph., and observes again ; if there is still a reverse shadow, he takes out this lens and puts in its place a + 1 D Sph. ; if still there is a reverse shadow, he replaces this with a + 1·5 D Sph., and so goes on increasing the strength of the lenses until the first is reached which gives a shadow moving with the mirror. He then knows that the last has made the refraction in that meridian myopic about 1 D, because it has just turned the shadow. Supposing the lens is a + 5 D Sph., this has overcorrected the refraction by one dioptre. He therefore goes back to a + 4 D Sph., and finds that this gives a distinct, rapidly moving, emmetropic shadow. If a similar result is obtained in the opposite meridian, the shadow being also corrected by a + 4 D, the case is one of simple hypermetropia of 4 dioptres. The result of the " shadow test " would then be expressed thus :—

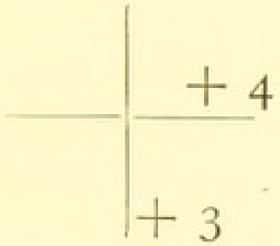
+ 4

+ 4

indicating that in both meridians a + 4 D corrects the error. Next the patient would be placed six metres in front of Snellen's types, and this result confirmed subjectively. In ordering glasses, however, the surgeon would not give this correction, because it is the correction found under atropine, but would order a + 3 D Sph., thus deducting one dioptre on account of a certain natural tonic contraction of the ciliary muscle, which is always present, except when a mydriatic has been used.

Suppose, however, the image is found to move in the same direction in which the mirror is tilted, the surgeon knows that he has to deal with a **myopic** eye. He therefore places in the cell a − 0·5 D Sph., and if it does not change the shadow, replaces it with a − 1 D Sph., and it again for a stronger one, until he gets to the first lens which gives a decided and well-defined reverse shadow, which he recognizes as characteristic of emmetropia. Suppose a − 4 D Sph. give an emmetropic shadow in all directions, this will be the lens which corrects the patient's myopia while under the influence of atropine. When the effect of the atropine has however passed off, it will be found that it takes a rather higher lens than this to fully correct the myopia, in consequence of the involuntary tonic contraction of the ciliary muscle; but as one should err rather on the side of under-correcting than over-correcting myopia, it is generally sufficient to consider this lens as the best correction, and the one to be ordered for distant vision or for constant use.

Suppose again there is **astigmatism** present, and that it takes a + 3 D to correct the image in the vertical direction and a + 4 D to correct it horizontally; the difference between these lenses would represent the amount of astigmatism. This result would be expressed thus :—



which would mean that the ametropia would be corrected by a + 3 D Spherical combined with a + 1 D Cylindrical, with the axis of the cylinder vertical, or shortly,

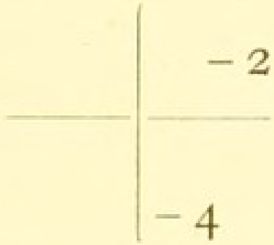
+ 3 D Sph.
+ 1 D Cyl. ax. vert.

and as a rule the combination to be ordered would be

+ 2 D Sph.
+ 1 D Cyl. ax. vert.

that is, one dioptre would be taken off the sphere on account of the examination having been made under atropine. The patient would in this case have **compound hypermetropic astigmatism**.

Suppose, on the other hand, it takes -4 D to correct the shadow in the vertical meridian, and a -2 D to correct it in the horizontal meridian, i.e.,

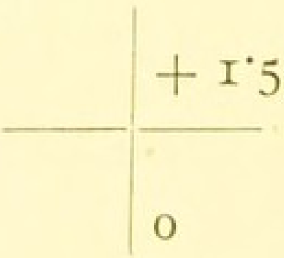


the case would be one of **compound myopic astigmatism,** and the error would be corrected by a -2 D Sph. combined with a -2 D Cyl. axis horizontal, or shortly,

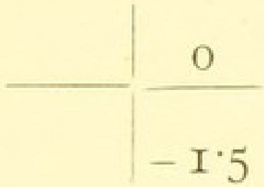
$$\frac{-2\text{ D Sph.}}{-2\text{ D Cyl. ax. hor.}}$$

and this combination would probably be ordered to the patient for distant or constant use.

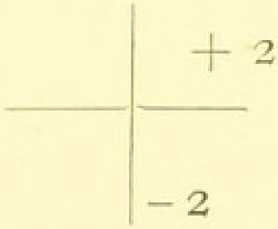
Again, it may be found that in one meridian the refraction of the eye is normal, while in the other it is hypermetropic or myopic. For instance, the horizontal meridian may be corrected by a $+1{\cdot}5$ D, while the vertical meridian is normal, i.e.



This case would be one of **simple hypermetropic astigmatism,** and corrected by a + 1·5 D Cyl. ax. vert. Or the horizontal meridian may be normal, while the vertical, say, has 1·5 D of myopia, i.e.



it being a case of **simple myopic astigmatism,** and corrected by a – 1·5 D Cyl. ax. hor. Or again, one meridian may be hypermetropic and the other myopic, giving an image against the mirror in one direction and with the mirror in the other. Suppose the image is corrected in the horizontal meridian by a + 2 D and in the vertical meridian by a – 2 D, i.e.



the combination of lenses required while under atropine would be either

$$\frac{+\,2\text{ D Sph.}}{-\,4\text{ D Cyl. ax. hor.}} \text{ or } \frac{-\,2\text{ D Sph.}}{+\,4\text{ D Cyl. ax. vert.}}$$

and the case would be one of **mixed astigmatism.**

The shadow in retinoscopy is not always as defined as above indicated. If the surface of the cornea is rendered uneven by nebulæ, the result of old corneal ulcers, the shadow will be broken up and no very definite result be obtained. Also if the cornea be not regularly curved on account of its centre being either a little conical or flattened, two shadows are seen, one central and the other peripheral. In this case it is always the central one which has to be noticed and corrected.

The lens, instead of the cornea, may be responsible for the two shadows, in consequence of the centre of the lens being of a different refracting power to the periphery.

After retinoscopy, the result has generally to be confirmed subjectively before Snellen's types, and modified if necessary. If a cylindrical lens is used, it must be rotated till the best vision is obtained, and the position of its axis carefully noted.

A more rapid but less accurate way of estimating the refraction of the eye is by means of direct ophthalmoscopic examination. This may be done with or without a mydriatic. The patient is seated in a dark room with a light placed behind and on a level with the eye to be examined, and is told to look into the darkness straight in front of him. The surgeon, holding his ophthalmoscope as near as possible to the patient's eye, reflects the light into the eye and observes the details of the fundus, as in ordinary ophthalmoscopic examination, keeping his own accommodation relaxed all the time. If the patient's eye is emmetropic, the surgeon, if also emmetropic, will see the disc and the vessels of the fundus distinctly, without the aid of any of the little lenses of the ophthalmoscope; and these details will be rendered less distinct by turning on a convex lens. If, however, the eye is **hypermetropic,** the details of the fundus may or may not be distinct, according to the completeness of the relaxation of the patient's and of the surgeon's accommodation, but will remain distinct or become more distinct as the disc behind the mirror is revolved and convex lenses are turned on. The highest convex lens which gives a clear view of the fundus is the measure of the hypermetropia.

If, on the other hand, the eye is **myopic,** the details of the fundus will be indistinct, but will become clear by turning on concave lenses. The weakest concave lens, which gives a clear view of the details of the fundus, is the measure of the myopia.

In **astigmatism,** as the refraction in one meridian of the eye is not the same as that in the opposite meridian, no one lens will make the whole fundus altogether clear. For instance, one lens will render the vertical markings of the fundus clear, i.e. the lateral edges of the disc and the vessels which run vertically (that is to say, will correct the horizontal meridian);

and another will clear up the vessels which run from side to side and the upper and lower margins of the disc (that is to say, will correct the vertical meridian). For example, in **compound hypermetropic astigmatism** of say 2 D in the vertical meridian and 4 D in the horizontal meridian, a + 2 D is the highest convex lens which makes the vessels running horizontally distinct, while a + 4 D is the highest with which the vertical vessels can be distinctly seen.

Again, in a case of **simple myopic astigmatism**, in which the horizontal meridian is emmetropic, while the vertical meridian requires a − 2 D to correct it, the vertical vessels will be distinct without the help of a lens, while the horizontal vessels will need a − 2 D to clear them up.

The estimation of refraction by direct ophthalmoscopic examination is much simplified by having the patient under atropine.

Several instruments have been devised for the purpose of facilitating the estimation of errors of refraction, and particularly in retinoscopy. These are called **Optometers** or **Refractometers.** Two of these instruments, designed one by Couper and the other by Doyne, consist of a large revolving disc, in which are mounted numerous lenses. Each instrument stands on a special table arranged in such a way that the patient is able to be so placed behind it, that by revolving the disc, different lenses are with ease and rapidity able to be brought in front of the eye to be tested.

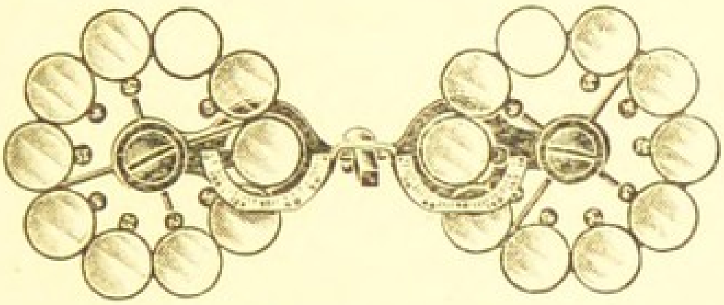


Fig. 4.

The one represented in the accompanying *Fig.* 4, and designed by the author, consists of a reversible frame, which is placed on the patient's face like an ordinary trial frame. Upon this are mounted two revolving wheels containing convex lenses on one side and concave on the other, so that by reversing the frame, the plus or minus side can be brought before either eye. Higher spheres or cylinders may be placed in the graduated cell, so that, by superimposing, any strength or combination can be obtained. It is useful in retinoscopy, but can also be used in ordinary subjective testing.

XV.—SPECTACLES.

It is supposed that lenses were used by ancient races some centuries before the Christian era. The characters of many of the inscriptions found on unearthed record cylinders and other ancient curios are so very minute that it is difficult to understand how they could have been engraved without a magnifying lens. Further, Layard discovered among the ruins of Nineveh a lens of the strength of about + 9 D Sph., and $1\frac{1}{2}$ inches in diameter. The Emperor Nero, who was myopic, is said to have used a concave jewel to assist his distant vision.

There is no record of lenses having been placed in *spectacle frames* until the thirteenth century; and not till the seventeenth century was there any attempt made to treat the subject scientifically. Cylindrical lenses were not used for the correction of astigmatism till seventy to eighty years ago. Lenses are of three kinds,—spherical, cylindrical, and prismatic.

Spherical lenses, used in the correction of hypermetropia and myopia, may be either convex or concave, the spherical surface being ground on one or both sides of the glass.

Cylindrical lenses, used in the correction of astigmatism, are also either convex or concave, the cylindrical surface being ground on one side only. When a combination of a sphere and a cylinder is required, one surface of the lens is spherical and the other is cylindrical.

Prismatic lenses are required in certain cases of muscular asthenopia, and sometimes in diplopia. When they are used in combination with spherical or cylindrical lenses, these latter are ground on the surfaces of the prism instead of on the ordinary piece of glass.

Parallel rays passing through any lens alter their course in such a way that they are deflected towards the thickest part of the lens, e.g. towards the centre of a convex lens, and towards the periphery of a concave lens, and towards the base of a prism.

Lenses are numbered according to the dioptric system, the unit of which is a lens whose focal distance is one metre. A + 1 D Sph. has therefore a focal distance of one metre; and a + 2 D Sph., which is twice as powerful, has a focal distance of half a metre, and so on.

Lenses are nearly universally made of crown glass, which is a combination of silicic acid with a metallic base, generally sodium or calcium. The popular notion of the superiority of rock crystal to crown glass is a delusion. It is harder, but is more likely to have striæ, and its index of refraction is not so constant.

The **frames** are generally made of gold, or plated gold, or steel (often nickelled to prevent rusting). Spectacle frames consist of several parts. The lenses are mounted in "eyewires," which are joined together internally by the "bridge." Externally are the "end-pieces," on to which are fixed by a hinge the "temples" or "sides." These latter may either be straight or may curl round the ear ("straight sides" or "curl sides"). In *pince-nez* frames the bridge is replaced by nosepieces or "placquets" and "spring."

The lenses or "eyes," are of various forms or sizes. They may be oval, or round, or a combination of these, called "round-ovals," in which the upper border of the lens is oval and the lower border circular, and various other shapes.

A **bi-focal lens** is one in which the upper part is of a different power from the lower; the upper being used for distant vision, and the lower for near vision. Either a thin extra lens is cemented on to the lower part of the distance lens, or the lower part is composed of glass of a different refractive index and fused on to the upper distance portion, there being then a scarcely perceptible line between them. Instead of this, additional lenses may be mounted in a frame called "grab fronts," that can be hooked on to the distance spectacles when the patient wishes to read or do near work.

It is very necessary to have the lenses which are ordered, *accurately* mounted in well-fitting frames.

The principal axis of a lens passes at right angles through its optical centre (which is the thickest part of a convex lens or the thinnest part of a concave lens), and the visual axis or line of vision should correspond with the principal axis. In other words, the patient should look straight through his lenses, not obliquely, and through their optical centres. The optical centre is not necessarily in the middle of the lens, i.e., does not necessarily correspond with the geometrical centre, though it generally does.

In certain cases of muscular asthenopia, troublesome diplopia, etc., it is necessary to order prisms. A prismatic effect can be obtained in three ways: (1) By *adding a prism* to the glasses worn; (2) By *decentering* the lenses in their frames; and (3) By *decentering* the lenses together with the frames.

In the first, the optician grinds the spherical or cylindrical surfaces on a prism, instead of on an ordinary plane piece of crown glass. In the second, after the lens is ground, it is cut in such a way that the optical centre of the lens is to one side of its geometrical centre, i.e. not in the middle of the lens. In the third, the lenses are ground and cut and mounted in the usual way, but the spectacles are purposely either *too narrow* or *too wide,* so that the patient does not look through the centre of his glasses, but to one side.

Reading glasses ought always to be a little decentred inwards, because in looking at a near object the visual axes converge; and consequently, in order that they shall pass through the centres of the lenses, the latter must be brought closer together. Each lens should be decentred inwards about two millimetres.

Lenses should always be worn as close to the eyes as possible without touching the lashes. For distance, the lenses should be vertical, with their principal axes parallel. For reading and near work, however, the anterior surfaces of the lenses should look a little down, and also a little in; that is, they should be "angled for reading."

It is sometimes necessary for a surgeon, in the absence of an optician, to **measure the patient** for the frames as well as give a prescription for the lenses. In any case he should know how to do it, and be able to point out any defects. There are several measurements required.

First of all the **pupillary distance** has to be taken. The patient, facing a good light, is directed to look straight in front of him at a distant object. The surgeon, holding a six-inch rule in his right hand, places it across the bridge of the patient's nose, the lower edge of the rule being on a level with the patient's pupils, and reads off the distance between the centres of the pupils.

The next thing is to get the **measurements of the bridge,** and this is most easily done by having a series of specimen frames, and having found one that fits, to take its measurements. The three bridge measurements required are (1) The height of the bridge above the centre of the lenses ; (2) The relation of the top of the bridge to the plane of the lenses ; (3) The width of the base of the bridge. By laying the frame selected on a properly-marked optician's rule, it is readily seen how far the apex of the bridge is above or below the centre of the lenses. Also it is easy to tell whether the top of the bridge stands forward beyond the plane of the lenses, whether it is on a line with the plane of the lenses, or whether it does not reach as far forward as the lenses, and how much behind or in front it is. The third measurement to be taken is the distance across the widest part of the bridge.

The following is a specimen of such a prescription :—

Right + 2 D Sph. ;   Left + 2·5 D Sph.
For reading.
Pupillary distance $2\frac{3}{8}''$
Bridge :—
$\frac{1}{4}''$ above centre of lenses
$\frac{1}{16}''$ forward
Width of base $\frac{3}{4}''$
Straight sides.
Angled for reading.
Gold.

In order to **determine the strength** of any given lens, hold it up about a foot in front of the eye, and move it repeatedly from side to side, looking at a distant object through it. If it is a convex lens, the object is seen to move in the opposite direction to which the lens is moved. By putting progressively stronger concave lenses in apposition with it, and repeating the side-to-side movement, one is at length reached which neutralizes it, so that the object no longer moves with or against the motion of the lens ; say the concave lens which neutralizes the movement is -2 D, the original lens would be a $+$ 2 D. With a convex lens, the object always moves in the opposite direction to the motion of the lens, and with a concave lens the object moves in the same direction.

In order to determine the **direction of the axis** of a cylinder, hold the lens up between one's eye and some straight line, say the vertical bar of a window. Now rotate the lens until the bar assumes an unbroken line, the axis of the lens will be vertical in this position.

To prove whether the **optical centre** is in the middle of the lens, i.e. corresponds with the geometrical centre, hold the lens horizontally above the corner of a rectangular piece of paper, and move it about until the corner seen through the lens appears in the right position in relation to the rest of the sheet, and the sides continuous ; the point of the paper will now be opposite the optical centre of the lens.

Spectacles ought to sit straight on the face ; if one eye is lower than the other, bend down the corresponding " temple," this will raise the lens on that side. The lenses should just clear the eye-lashes. The patient should look through the centres of the lenses.

The " temples " should not indent the skin, and if curled around the ear should fit the concha. The bridge should be flattened, so as not to cut or unduly indent the nose.

EXAMPLES.

CASE I.—*Hypermetropia, with Convergent Strabismus of left eye.* Patient, 8 years of age.

$$\text{R.V. } \frac{6}{6} \text{ Hm. } 2\text{ D} = \frac{6}{6}, \text{ J } 1;$$

$$\text{L.V. } \frac{6}{24} \text{ Hm. } 2\text{ D} = \frac{6}{24}, \text{ J } 4.$$

No apparent changes in left eye to account for defective vision. After atropine for three days, retinoscopy gave :—

R	L
+ 4	+ 4·5
+ 4	+ 4·5

$$\text{R. } \bar{c} + 4\text{ D Sph.} = \frac{6}{6}$$

$$\text{L. } \bar{c} + 4{\cdot}5\text{ D Sph.} = \frac{6}{24}$$

Ordered R + 3·5 D Sph. ; L + 4 D Sph., for constant use. As the left eye was amblyopic, the mother was directed to cover up the good eye for two or three hours every day, so as to try and develop the visual acuity of the left.

CASE II.—*Myopia of the right eye and Compound Myopic Astigmatism of the left.* Patient, 16 years of age, complains of being "short-sighted," is unable to see across the street; has floating specks in front of his eyes; and his left eye has a tendency to turn out.

$$* \text{ R.V.} < \frac{6}{60}\ \bar{c} - 6 \text{ D Sph.} = \frac{6}{6};$$

J 1 at 6″.

$$\text{L.V.} < \frac{6}{60}\ c - 10 \text{ D Sph.} = \frac{6}{24};$$

J 2 with difficulty at 4″.

In right eye media clear and small myopic crescent on outer side of optic disc. In left eye media clear, myopic ring round optic disc with some atropic changes about the macula. Tension normal in both. Retinoscopy after a mydriatic gave :—

R		L	
	−5·5		−9
	−5·5		−11·5

$$\text{R. } \bar{c} - 5{\cdot}5 \text{ D Sph.} = \frac{6}{6}$$

---

* i.e.—The unaided vision of the right eye is less than $\frac{6}{60}$, but with a − 6 D Sph. lens vision is improved to $\frac{6}{6}$.

$$\text{L. } \bar{c}\ \frac{-\ 9\text{ D Sph.}}{-\ 2{\cdot}5\text{ D Cyl. ax. hor.}} = \frac{6}{18}$$

Ordered the above correction for constant use.

CASE III.—*Compound Hypermetropic Astigmatism, Asthenopia, Spasm of Accommodation.* Patient, 17 years of age, a sempstress, suffers from periodic attacks of migraine.

R.V. $\frac{6}{12}\ \bar{c}\ -\ 1$ D Sph. $= \frac{6}{9}$; L.V. Same as right. J 1 with difficulty.

Retinoscopy after homatropin :—

R

+ 2·5

+ 1·5

L

+ 2·5

+ 1·25

$$\text{R. } \bar{c}\ \frac{+\ 1{\cdot}5\text{ D Sph.}}{+\ 1\text{ D Cyl. ax. vert.}} = \frac{6}{6}$$

$$\text{L. } \bar{c}\ \frac{+\ 1{\cdot}25\text{ D Sph.}}{+\ 1{\cdot}25\text{ D Cyl. ax. } 100^\circ} = \frac{6}{6}$$

$$\text{Ordered R. } \frac{+\ 1\text{ D Sph.}}{+\ 1\text{ D Cyl. ax. vert.}}$$

$$\text{L. } \frac{+\ {\cdot}75\text{ D Sph.}}{+\ 1{\cdot}25\text{ D Cyl. ax. } 100^\circ}$$

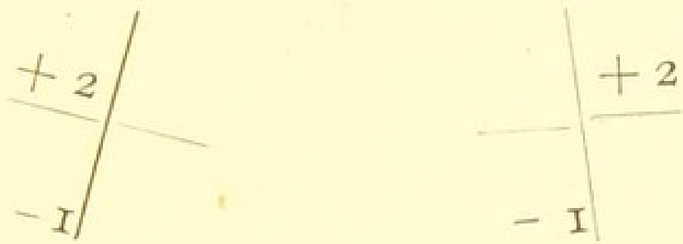
for constant use.

Case IV.—*Mixed Astigmatism.* Patient, 26 years of age, suffers from headache and other symptoms of asthenopia.

R.V. $\frac{6}{18}$ not improved by spheres; L.V. same as right. J 1 with difficulty.

Retinoscopy after homatropin:—

R L



$$\text{R. } \bar{c}\ \frac{+\ 2\text{ D Sph.}}{-\ 3\text{ D Cyl. ax. }20^\circ} = \frac{6}{6}\text{ partly}$$

$$\text{L. } \bar{c}\ \frac{+\ 2\text{ D Sph.}}{-\ 3\text{ D Cyl. ax. }15^\circ} = \frac{6}{6}\text{ partly}$$

$$\text{Ordered R. } \frac{+\ 1{\cdot}5\text{ D. Sph.}}{-\ 3\text{ D Cyl. ax. }20^\circ}$$

$$\text{L. } \frac{+\ 1{\cdot}5\text{ D Sph.}}{-\ 3\text{ D Cyl. ax. }15^\circ}$$

for constant use.

Case V.—*Hypermetropia and Presbyopia.* Patient 50 years of age; complains of difficulty of reading with his present glasses, which are + 2 D Sph.; also his distant vision is not so good as it used to be.

R.V. $\frac{6}{18}$ Hm. 2 D = $\frac{6}{6}$; L.V. $\frac{6}{18}$ Hm. 2 D = $\frac{6}{6}$. Reads J 1 type easily with + 4 D Sph.

Ordered R. and L. + 4 D Sph. for reading, and recommended him to use his old glasses for distance.

CASE VI.—*Myopia of Right Eye and Hypermetropia of Left, Anisometropia.* Patient, 55 years of age, accidentally found that he could not see clearly at a distance with his right eye. Never has had any trouble with his eyes, and never needed glasses for distant or near vision.

R.V. $\frac{6}{60}$ $\bar{c}$ − 3 D Sph. = $\frac{6}{6}$; J 1 without a lens.
L.V. $\frac{6}{9}$ Hm. ·5 D = $\frac{6}{6}$; J 1 $\bar{c}$ + 3·5 D Sph.

With the above corrections patient complained of discomfort and giddiness when he tried to use both eyes together, and no attempt to make the eyes work together was satisfactory. He had always been accustomed, unconsciously, to use only one eye at a time, i.e. his left eye for distance and his right for near vision, and the best course was to let him continue to do so, and order no correction so long as he experienced no difficulty.

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