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ON

LONG, SHORT, AND WEAK SIGHT,

AND THEIR TREATMENT,

BY

The Scientific Use of Spectacles.

Now ready, 8vo., pp. 741, cloth, 24s.,

BY THE SAME AUTHOR,

A TREATISE ON THE DISEASES OF THE EYE,

Illustrated by numerous coloured Ophthalmoscopic Plates and Engravings on Wood.

JOHN CHURCHILL & SONS, NEW BURLINGTON STREET.

ON

LONG, SHORT, AND WEAK SIGHT,

AND THEIR TREATMENT,

BY

The Scientific Use of Spectacles.

BY

J. SOELBERG WELLS,

PROFESSOR OF OPHTHALMOLOGY IN KING'S COLLEGE, LONDON; OPHTHALMIC SURGEON TO KING'S COLLEGE HOSPITAL; AND ASSISTANT SURGEON TO THE ROYAL LONDON OPHTHALMIC HOSPITAL, MOORFIELDS.

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PREFACE.

I HAVE endeavoured in these pages to lay before the reader, in an easy and practical form, the modern theories of the affections of the Accommodation and Refraction of the Eye, so as to enable him at once to grasp the most salient and important points in the symptoms, diagnosis, and treatment of these diseases. I have purposely abstained from mathematical calculations, and have confined myself to such simple formulæ as I have found most serviceable in practice.

I have chiefly followed the views of Von Graefe and Donders in treating of these affections; indeed, it is to their admirable and important researches that we are mainly indebted for the scientific elucidation and treatment of this class of eye diseases.

The favourable reception accorded to the former editions of this work, has encouraged me to add considerably to the present, in the hope of making it as complete a synopsis as possible of the group of diseases of which it treats.

The following symbols are frequently employed in the course of the work: $\frac{1}{A}$, means range of accommodation; r, punctum remotissimum (far point); p, punctum proximum (near point); ∞, infinite distance; ′, foot; ″, inch; ‴, line.

The test types of Jaeger may be obtained from the Secretary of the Royal London Ophthalmic Hospital, Moorfields; and those of Snellen from Messrs. Williams and Norgate, Henrietta Street, Covent Garden.

16, Savile Row, W.
January, 1869.

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ON

LONG, SHORT, AND WEAK SIGHT,

AND THEIR TREATMENT BY THE

SCIENTIFIC USE OF SPECTACLES.

CHAPTER I.

THE ACCOMMODATION OF THE EYE.

THE affections of the refraction and accommodation of the eye are daily assuming more importance, and are engaging more and more the attention of some of our most able and scientific ophthalmologists. For it is now known that certain forms of asthenopia and amblyopia, which had in former times set all remedies at defiance, are not due, as was generally supposed, to serious lesions of the inner tunics of the eyeball, but are in reality dependent upon some anomaly of the refraction of the eye, or a peculiar asymmetry of the organ (astigmatism). Since the discovery of these important facts, a considerable group of cases has

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We are all well acquainted with the anxious tale so often told by the over-worked student and literary man, or by the distressed and careworn artisan or sempstress. They complain that their eyes, which are to all appearance perfectly healthy, soon fail to fulfil their task, and speedily become wearied and fatigued during continuous employment at near objects, as, for instance, in reading, sewing, or engraving; thus necessitating a more or less prolonged cessation from work. This weakness of sight naturally renders these patients peculiarly anxious and nervous, leading them to fear that they are afflicted with some grave and dangerous affection, which threatens either great impairment of vision, or even complete loss of sight. We are chiefly indebted to Donders for the important discovery that this troublesome affection (asthenopia) is, in the majority of cases, due to hypermetropia, and easily cured by the proper use of glasses.

The greater the strides which have been made in the investigations of the affections of the refraction and accommodation, the more evident has it become how essentially necessary it is, that they

should be thoroughly and carefully studied, and scientifically treated. I would, therefore, impress upon the student that, after he has made himself conversant with the theoretical portion of the subject, it is only by a practical and oft-repeated examination of a considerable number of cases, that he can acquire the requisite facility in the examination of the range of accommodation, the state of refraction, and in the choice of spectacles. To those who may consider these subjects somewhat abstruse and difficult, I would reply, that the difficulties lie only on the surface, and that a little perseverance and practice will soon enable them to unravel the knotty points.

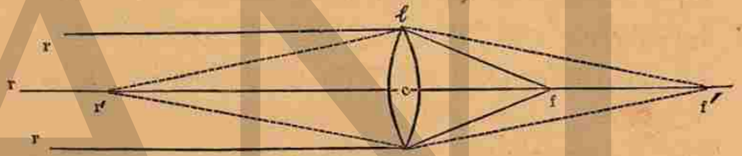
The selection of spectacles is of great importance; and I have no hesitation in saying that the empirical, haphazard plan of selection generally employed by opticians, is but too frequently attended by the worst consequences; and that eyes are often permanently injured which might, by skilful treatment, have been preserved for years. For this reason, I must strongly urge upon medical men the necessity, not only of examining the state of the eyes and ascertaining the nature of the affection, but of going even a step further than this, and determining with accuracy the number of the required lens. For this purpose they must possess a case of trial-glasses, containing a complete assortment of concave and convex lenses;—glasses of corresponding number being kept by the optician. The focal distance of the required glass is then to be written on a slip of paper, and the optician should supply the patient with the lens prescribed thereon. It is, in fact, only writing a prescription for spectacles. By so doing, we are assured that the patient is furnished with suitable and proper glasses.

Before we enter upon the subject of the refraction and accommodation of the eye, we must very briefly consider the properties of optical lenses. For spectacles, the spherical biconvex and biconcave lenses are almost solely used, and I shall, therefore, confine myself to their description. In the article upon astigmatism, the properties of cylindrical lenses will be explained.

The biconvex lens is formed by the apposition of a segment of two spheres, the radii of curvature of the two surfaces being equal. Such lenses are often also termed *converging* lenses, as they possess the power of deflecting a ray of light, passing through them, towards the axis. The line drawn through the centre of the lens (Fig. 1 *c*) is termed the axis, and any ray passing through it (axial ray) is not deflected.

(1.) If parallel rays (emanating from a luminous object at an infinite distance)* fall upon a biconvex lens, they are united at a certain point behind the lens, and this point is called the *principal focus* (or simply the focus) of the lens. The distance of this point from the optic centre of the lens (which equals the radius of curvature of the lens), is termed the focal length of the lens. Thus, if in Fig. 1 *l* is a biconvex lens of 6 inches focus, parallel rays (*r r*) will be united at *f*, 6 inches behind the lens. (2.) If the

Fig. 1.



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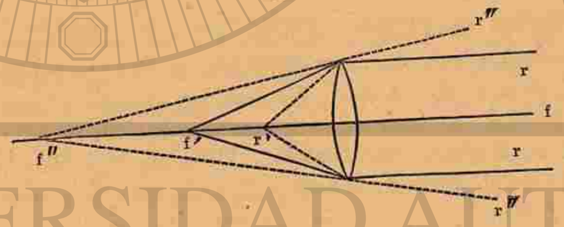
* As the term infinite distance will necessarily be of frequent occurrence in these pages, it will be well to explain its signification at the outset. We consider an object to be at a finite distance, as long as rays emanating from it fall in a divergent direction upon the eye. Of course rays from even a very distant object do in reality diverge, but this divergence (which naturally decreases in extent the further the object is removed), is already so slight when the object is placed at a distance of 18 or 20 feet, that the rays from it impinge, to all intents and purposes, parallel upon the eye. We therefore consider rays coming from an object situated further than 18 feet as parallel, and as emanating from an object at an *infinite* distance. Rays coming from a nearer object are divergent in proportion to its proximity, and are considered as coming from a *finite* distance.

object be now brought closer to the lens, to r', so that the rays emanating from it assume a divergent direction, they will be brought to a focus at f', lying at some distance behind the principal focus (f) of the lens. (3.) If the object is situated at twice the focal length of the lens, the rays from it will be united at a point placed twice the focal length behind the lens, and hence the distance of the object and of its focus from the lens will be the same. (4.) If the object be placed at the principal anterior focal point, *i.e.*, 6″ in front of the lens (Fig. 2 f') the rays will emerge from the lens parallel to its axis, $r\ r$. (5.) If the object is placed *inside* the principal focus (Fig. 2, r') the rays from it will be so divergent that the lens will not be able to render them even parallel, and they will, therefore, emerge from it still somewhat divergent. This divergence will of course be less than before they entered the lens, and if the rays ($r''\ r''$) are prolonged back to the point at which they would cut each other, this point would lie at f'', being situated further from the lens than the object r'. The focus (f'') of these rays is therefore imaginary, and situated on the same side of the lens as the object. (6.) If convergent rays (rendered so by some other lens) fall upon the lens, they will be brought to a focus on the other side of the lens, at a point lying nearer than the principal focus.

Fig. 2.



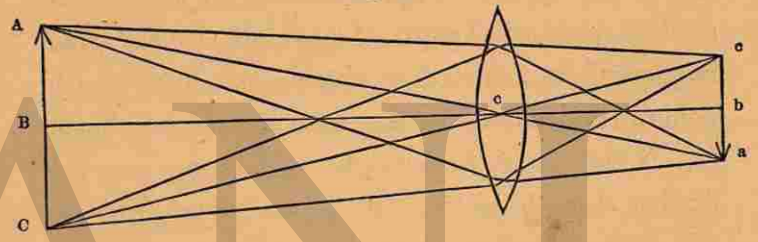
It has been shown above, that the further the object, from which divergent rays fall upon the lens, is removed from the latter, the nearer will the focus of such rays approach the principal focus of the lens; whereas, the closer the object is brought (provided that it remain further off than the principal focus) the more will its focus recede from the lens. On account of this dependence of these two points (the position of the object and its focus) upon each other, they are termed *conjugate foci.* Moreover, if the position of the object and its focus are changed, so that the object is placed at f' (Fig. 1), the rays from it would be brought to a focus on the other side of the lens at r', the point where the object was situated before; hence f' and r' are *conjugate foci.* Again, if the object be placed at f, its rays will emerge parallel from the lens.

Hitherto we have only spoken of the refraction of rays which are parallel to the axis of the lens, and whose focus is situated upon the axis. We must now consider the focus of rays, the axes of which pass through the centre of the lens, but which are inclined to the axis. Such are termed *secondary axes.* The inclination must not, however, be too considerable, otherwise, the rays will not be brought to an exact focus, on account of the great spherical aberration which occurs. Thus in Fig. 3 let *A B* be the principal axis of a lens, *r* a luminous point situated on this axis, and *f* the focus at which the rays from *r* are united. Now let *r′* be another luminous point situated at the same distance from the lens as *r*, but not on the principal axis, but at a certain inclination towards it. The secondary axis *A′ B′* will pass straight through the centre (*c*) of the lens without undergoing any deflection, and the rays from *r′* will be brought to a focus at *f′*, which will be situated on the secondary axis *A′ B′*, at the same distance behind the lens as *f*. Just as *f* is the conjugate focus of *r*, will *f′* be the conjugate focus of *r′*.

Fig. 3.

We shall now be able to understand the manner in which a biconvex lens forms an image of any luminous object situated in front of it. Let *A B C* (Fig. 4) be an object situated in front of the lens.

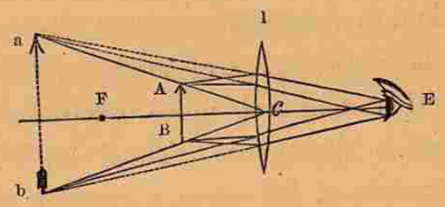
Fig. 4.



The rays emanating from *A* will be united at a point *a* situated on the secondary axis, drawn from *A* through the centre (*c*) of the lens; *a* is consequently the image of *A*; in the same manner *c* is the image of *C*, and the rays from *B*, situated on the principal axis of the lens are united at *b*, likewise placed on this axis, hence *b* is the image of *B*. A reverse and smaller image of the object *A B C* is, therefore, formed behind the lens at *a b c*. The rays which pass through the centre (*c*) of the lens are not deflected; and *a b c* are the conjugate foci of *A B C*. The distances *c B* and *c b* are also conjugate, for if the object be placed at *a b c*, its inverted and enlarged image would be formed at *A B C*.

Now the size of the image formed by the lens will depend upon the distance at which the object is situated. (1.) If the latter is placed at an infinite distance, the smallest inverted image will be formed behind the lens at its principal focus. (2.) If the object be approximated so as to lie at double the focal length of the lens, its inverted image will be situated at double the focal length behind the lens and be the same size as the object. (3.) If the object be brought still closer, but yet further than the anterior focus, the inverted image will move further away from the lens and be larger than the object. (4.) If the latter be placed at the anterior focus no real image will be formed, for the rays will issue from the lens in a parallel direction. (5.) If the object is placed inside the focal length, the rays will still issue in a divergent direction from the lens, and the latter will act as a magnifying glass, the image will not be inverted and situated behind the lens, but will be erect, magnified, and situated in front of the lens, *i.e.*, on the same side as the object. Fig. 5 will explain this. If *A B* be an object situated closer to the lens *l* than its anterior focus *F*, the rays from *A* will still diverge after their passage through the lens, and in such a direction as if they came from

Fig. 5.

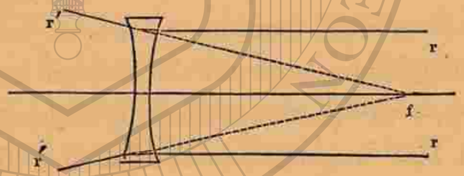


a, and the rays from *B* will diverge as if they came from *b*. If the eye *E* is placed on the other side of the lens, it will see instead of the object *A B*, its magnified, erect image, *a b*.

This magnifying power of the lens will be greater according to the shortness of its focal length, thus a 4-inch lens magnifies more than a 5-inch, and the latter more than a 6-inch lens. In order, therefore, to give the correct magnifying power, and to demonstrate at once that a 6-inch lens magnifies less than a 5-inch, we designate the magnifying power of a lens by fractions, the numerators of which are one, the denominators, the focal length of the lens. Thus one-fourth is stronger than one-fifth, the latter fraction being less than the former. Moreover, this way of expressing the strength of the lens is also correct, as indicating its power of refraction, for a lens of one-fifth will deflect rays of light impinging upon it more than a lens of one-tenth.

If parallel rays fall upon a biconvex lens, they are united into a real focus behind the lens. It is different, however, with a biconcave or "diverging" lens, for this does not unite parallel rays, but renders them divergent. Thus (1), if parallel rays (Fig. 6, *r r*) fall upon a concave lens they will be rendered divergent, assuming a direction as if they had proceeded from *f*, in which the prolongation backwards of the divergent rays *r′ r′* would cut one another, hence this point is called the negative virtual focus of the lens, and is an imaginary one, being situated upon the same side as the object. The distance of this point for parallel rays from the lens, gives the focal distance of the lens. Thus a concave lens of 10 inches focus renders parallel rays so divergent, as if they came from a distance of 10 inches in front of the lens.

Fig. 6.



(2.) If the object is brought closer to the lens, so that the rays emanating from it will diverge, they will be rendered still more divergent by the concave lens, and their focus will lie closer to the lens than its principal imaginary focus.

We have now to consider the manner in which the eye receives upon the retina a clear and sharply-defined image of an object placed in front of it.

We may regard the eye as a camera-obscura, upon the screen (retina) of which is formed a diminished and inverted image of the object. The impression of the object will be formed upon the bacillar layer (rods and cones) of the retina, be conveyed thence through the fibres of the optic nerve to the brain, be there received, and then projected back again in an inverted direction outwards to the object. The most sensitive portion of the retina being situated at the yellow spot, this point is always directed towards any object at which we are looking. The sensibility of the retina, which diminishes rapidly from the yellow spot towards the periphery, may be excited by the undulations of rays of light, or by mechanical means. The former excitation occurs when rays emanating from a luminous object impinge upon the retina; the latter, when the eyeball is slightly pressed by the point of the finger, which will produce the appearance of luminous rings (phosphènes), situated apparently in a direction opposite to that of the pressure. Thus, if the outer portion of the sclerotic be pressed upon, the luminous ring will appear at the nasal side, and *vice versâ.*

The refractive power of the normal, emmetropic eye is such, that rays which emanate from a distant object, and impinge in a parallel direction upon the cornea, are brought to an exact focus upon the retina, and the eye receives a distinct image of such an object. The dioptric system of the eye which causes this refraction of the rays of light, consists of certain media, which, taken conjointly, act as a biconvex lens. These refractive media are the cornea, aqueous humour, crystalline lens, and vitreous humour. On account of the slight thickness of the cornea, the parallelism of its two surfaces, and the fact that the refracting power of the cornea and aqueous humour are nearly equal, we may assume that the two form only one refracting surface. The index of the refraction of the vitreous humour is almost the same as that of the aqueous. But the refraction of the cornea and of the aqueous and vitreous humours would not suffice to bring parallel rays to a focus upon the

retina in an emmetropic eye, for the focus would lie considerably behind it, and the lens is required to render the rays sufficiently convergent. The axis of the dioptric system is called the *optic axis,* the anterior extremity of which corresponds to the centre or apex of the cornea, and the posterior extremity to a point situated between the yellow spot and the entrance of the optic nerve. By the term *visual line* is meant the line of direction drawn straight from the object (through the nodal point) to its image formed at the yellow spot. It was formerly supposed that the optic axis and visual line were identical, but this is not so, for according to Helmholtz,* the visual line outside the eye lies somewhat above and to the inner side of the optic axis, and its posterior extremity on the retina consequently lies a little to the outer and lower side of the axis. This fact will be found of practical importance with regard to the question of real and apparent strabismus.

If we now apply to the eye the principles laid down above, as to the properties of biconvex lenses, we can easily understand the mode in which the reverse image of an object is formed upon the retina. Thus, if *A B C* (Fig. 7) be an object placed at the proper distance from the eye, a

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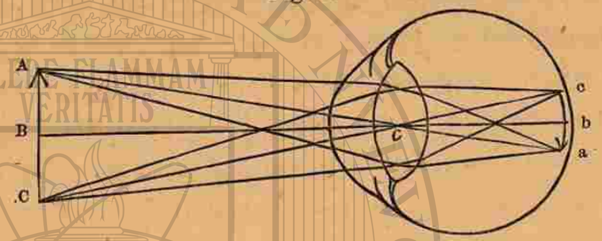
* Helmholtz's Physiologische Optik., p. 70.

distinct inverted image of it will be formed upon the retina at *a b c.* Let *B b* be the axial ray passing through the nodal point (*c*) to the retina. Through this nodal point draw a straight line from *A* to *a.* This line *A a* will be a secondary optic axis, and all the rays emanating from *A* will be united upon the retina at *a.* The straight line *C c*, passing through the nodal point, will be another secondary optic axis, and all the rays from *C* will be united upon the retina at *c.* Hence *a b c* will be the inverted diminished image of *A B C.*

Fig. 7.

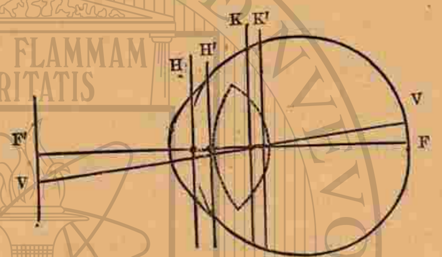


Now the question, whether or not the rays from the object will be brought to a focus upon the retina, and the latter thus receive a clearly-defined image, will depend upon the situation of the object, and the distance for which the dioptric system of the eye is accommodated. The same principles as were laid down with respect to biconvex lenses apply to this case. Thus, if an eye

is adjusted for parallel rays, these will be brought to a focus upon the retina. If the object is now brought nearer to the eye, so that its rays become divergent, they will no longer be united upon the retina, but behind it. The eye will consequently not receive a clearly-defined image, but the latter will be blurred and indistinct, on account of the "circles of diffusion" formed upon the retina. As the focus of the rays lies behind the retina, each luminous point from the object is no longer represented by a point upon the retina, but by a circle (the section of each conical pencil of rays), and as these circles overlap each other, the image is rendered indistinct. These are called circles of diffusion, and take the form of the pupil, consequently their size diminishes with that of the pupil, and *vice versâ.*

For the more exact calculation of the passage of rays of light through the eye, Listing constructed a diagrammatic eye (Fig. 8) having six cardinal points, corresponding to those of optical lenses and situated on the optic axis. 1. The focus *F* (Fig. 8) situated upon the retina, in which rays falling parallel upon the cornea would be united. 2. The anterior focus *F′*, at which rays coming from the retina, and whose course is parallel in the vitreous humour, would be brought to a focus. 3. The two "principal points" *H H′* which lie on the optic axis in the anterior chamber close behind the cornea (in Fig. 8 these two points lie somewhat too far from the cornea). 4. The two "nodal points" *K K′*, in which the lines of direction cut each other, and which are situated near the posterior surface of the lens.

Fig. 8.



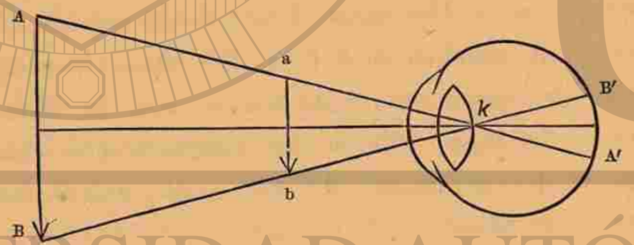
On account of the extremely small distance (less than ¼ of a millimètre) between the two principal points and the two nodal points, this diagrammatic eye may be simplified, and the four cardinal points be reduced to two, viz., a principal point situated in the anterior chamber, and a nodal point, situated somewhat in front of the posterior surface of the lens. The two focal points remain the same. For the method of calculating the course of the rays of light according to the cardinal points, I must refer the reader to Helmholtz's Physiologische Optik, and Donders' work on the Anomalies of Refraction and Accommodation.

A glance at Fig. 8 will also explain the relative positions of the optic axis (*F F′*) and of the visual line (*V V′*). The latter is an imaginary line drawn from the yellow spot to the object point. They were formerly supposed to be identical, but Helmholtz has found that this is not the case, but that in front of the eye the visual line lies inwards and generally somewhat upwards of the optic axis, its posterior (retinal) extremity consequently lying to the outer side of the optic axis and slightly below it. Thus in Fig. 8 (which represents a horizontal section of the diagrammatic eye, the upper side of the figure being the temporal, the lower the nasal side) *V V′* is the visual line and *F F′* the optic axis. At the cornea, the former lies to the inner side, at the retina, to the outer side of the optic axis. At the nodal point *K* they cross each other.

In the normal or emmetropic eye the visual line impinges upon the cornea slightly to the inner side of the optic axis, forming with it an angle of about 5°. But Donders has shown that in the hypermetropic eye it lies still more to the inner side, so as to form an angle of 8° or 9°; whereas, in myopia the visual line may correspond to the optic axis, or even lie to the outer side of it. These differences in the relation between the optic axis and visual line often give rise to an apparent strabismus.

The Visual Angle.—The apparent size of an object depends upon the size of its retinal image. If, for instance, the eye is adjusted for the object *A B* (Fig. 9) and the lines of direction, *A A′* and *B B′* are drawn through the nodal point *k*, the angle *A k B* will be the visual angle under which the object is seen, and this angle will equal the angle *A′ k B′*. The visual angle stands in direct relation to the size of the object, for the larger the latter is, the greater will be the visual angle, and consequently the image, and *vice versâ*. Moreover, the visual angle will also increase in size according to the proximity of the object, and diminish as the latter is further removed from the eye. If, however, the size of the object increases in due proportion with its distance, it will be seen under the same visual angle. Thus *A B* (Fig. 9) and *a b* are seen under the same visual angle, although the former is considerably further from the eye than *a b*. From this it will be easily understood, that the mere fact of a patient being able to read the smallest print does not exclude a certain degree of amblyopia. In deciding upon this point, we must always take into consideration the distance at which he can read it, and the state of refraction and accommodation.

Fig. 9.



The smallest visual angle under which an object can be distinctly seen by the eye is one of 5°. Hence, this has been taken as the standard for determining the acuteness of vision, and the test types of Snellen and Giraud-Teulon have been devised upon this principle, each type being seen under an angle of 5° at the distance in feet corresponding to its number. Thus No. 1 is seen at an angle of 5 minutes at one foot, No. 2 at 2 feet, etc.

We have now to turn our attention to the nearer consideration of the subject of refraction and accommodation.

The beginner often experiences some difficulty in realizing the difference in the meaning of the terms "refraction" and "accommodation;" and he, consequently, does not clearly comprehend the distinction between the affections of the refraction and those of the accommodation. In the former group are embraced hypermetropia, myopia, and astigmatism, for in them the refraction of the eye is altered, whilst its power of accommodation is, in pure cases, unimpaired. Amongst the affections of the accommodation we must include presbyopia, paralysis, atony, and spasm of the ciliary muscle. In presbyopia and paralysis of the ciliary muscle the power of accommodation is impaired, but the state of refraction is unaltered; whereas in spasm of the ciliary muscle the accommodation is not only affected, but the eye has also become more or less short-sighted.

By the term "accommodation" is meant the power which every normal eye possesses of adjusting itself almost imperceptibly and unconsciously for different distances. At one moment, looking at something but a few inches from the eye, at the next, regarding some far distant object, or taking in at a glance the vast expanse of miles of scenery.

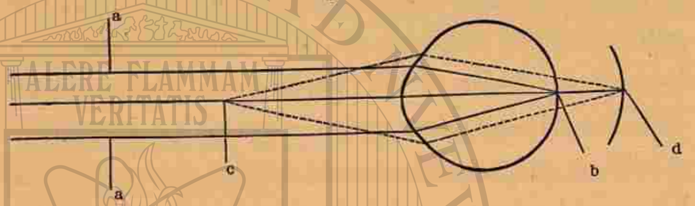
In a normal eye, the whole apparatus of accommodation is so beautifully balanced, and its functions are performed with such ease and accuracy, that, although in reality a voluntary act, its duties are from early childhood fulfilled intuitively, unconsciously. No wonder, then, that this power of adjustment of the eye to different distances has been a favourite study with some of the most eminent physiologists and natural philosophers.

That such a power is essentially necessary will become at once apparent by a consideration of the following fact, and a glance at Fig. 10.

Let us assume that the normal eye, when in a state of rest, is adjusted for objects at an infinite distance (rays from which may be considered as being parallel), *i.e.*, rays emanating from such an object are brought to a focus upon the retina without any effort of accommodation. But when the object is brought much nearer, the rays from it will become divergent, and will now no longer come to a focus upon the retina, but behind it, if the eye does not undergo some change which will increase its refraction and unite these divergent rays upon the retina.

The accompanying figure will explain this: it represents a normal eye in a state of rest, so that parallel rays (*a*), emanating from an object at an infinite distance (at or beyond 18 feet from the eye), are brought to a focus upon the retina (*b*), without any effort of the accommodation. If the object be now gradually approximated much nearer to the eye, to *c*, say 12 inches from the eye, the rays from it will be strongly divergent, and will be brought to a focus behind the retina at *d*, if the eye does not accommodate itself for them and undergo some change in form (becoming proportionately longer), or if its power of refraction be not increased by some change in its apparatus of accommodation, so that the rays will be united upon the retina. For if this is not the case, and the rays are united *behind* the retina, circles of diffusion will be formed upon the latter, and the object appear blurred and indistinct. If the accommodation of the eye is paralysed, rays from the object *c*, 12″ in front of the eye, would be brought to a focus upon the retina by the aid of a biconvex lens of 12 inches focus, for this would render the rays parallel, and enable the eye to unite them upon the retina.

Fig. 10.



It is very necessary carefully to distinguish between the meaning of the terms refraction and accommodation, as they signify two perfectly different things.

By refraction is understood the passive power which every eye possesses, when in a state of rest, —*i.e.*, adjusted for its far point—of bringing certain rays to a focus upon the retina without any active effort or participation of the muscular apparatus of accommodation. This power of refraction is due to the form of the eye and to its different refractive media.

We have just seen (Fig. 10) that the state of refraction of the normal eye is such that, when it is in a state of rest, parallel rays are brought to a focus upon the retina without any effort of the accommodation. Its furthest point of distinct vision lies at an infinite distance. Donders terms this condition "Emmetropia." He says,* "The refraction of the media of the eye at rest can be called normal in reference to the situation of the retina, only when parallel incident rays unite on the layer of rods and bulbs. Then, in fact, the limit lies precisely at the measure; then there exists emmetropia (from ἔμμετρος, modum tenens, and ὤψ, oculus). Such an eye we term emmetropic.

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* Donders "On the Anomalies of Accommodation and Refraction of the Eye," p. 81. New Sydenham Society, 1864.

"This name expresses perfectly what we mean. The eye cannot be called a *normal* eye, for it may very easily be abnormal or morbid, and nevertheless it may be emmetropic. Neither is the expression *normally constructed eye* quite correct, for the structure of an emmetropic eye may, in many respects, be abnormal, and emmetropia may exist with difference of structure. Hence the word emmetropia appears alone to express with precision and accuracy the condition alluded to."

The state of refraction may deviate from the emmetropic condition in two ways.

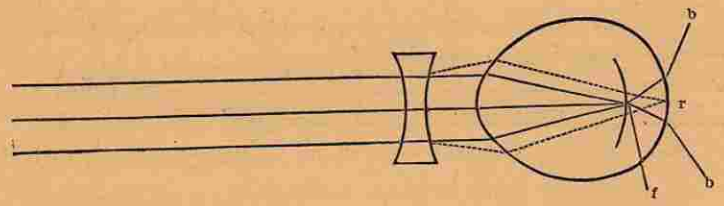
1. The principal focus of the eye, when adjusted for its far point, lies in front of the retina (myopia).

2. The principal focus lies behind the retina (hypermetropia).

In the myopic eye, parallel rays are not united upon the retina, but in front of it, when the eye is in a state of rest. The eyeball, in fact, is either too long, or the state of refraction too high, so that when the eye is adjusted for its far point only those rays which come from a finite distance, and impinge in a sufficiently divergent direction upon the eye, are united upon the retina.

Fig. 11 represents a myopic eye, in which parallel rays are brought to a focus, not upon the retina (*r*), but before it (*f*); circles of diffusion (*bb*) are formed upon the retina, and the object,

Fig. 11.

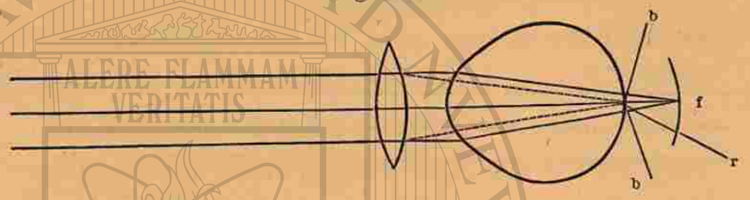


consequently, looks indistinct and blurred. In order to render the myopic eye capable of seeing distant objects (rays from which impinge in a parallel direction upon the eye), we must place that concave lens before it which will give the parallel rays such a divergent direction that they are united upon the retina.

In hypermetropia, on the other hand, the refractive power of the eye is too low, or the antero-posterior axis of the eyeball too short, so that when the eye is in a state of rest, parallel rays are not united upon the retina, but behind it, and only convergent rays are brought to a focus upon the latter.

Fig. 12 represents a hypermetropic eye, in which, either on account of its being too short in the antero-posterior axis, or its possessing too low a power of refraction, parallel rays are brought to a focus, not upon the retina (r), but behind it at f; circles of diffusion (bb) are formed upon the retina, and the object appears indistinct. To remedy this, the eye undergoes a change in its accommodation, so as to increase its power of refraction sufficiently to unite parallel rays at r. The less the power of refraction of the hypermetropic eye, the greater must be this effort of the accommodation; and it must increase, of course, proportionately as the object is brought nearer to the eye. By placing a suitable convex lens before the eye, the parallel rays are rendered so convergent that they are united upon the retina (r) without any effort of the accommodation; and we thus place the hypermetropic in the same condition as the emmetropic eye, upon the retina of which parallel rays are united without any effort of the accommodation.

Fig. 12.



On comparing these three figures, the reader will at a glance observe the difference between the emmetropic, the myopic, and the hypermetropic eye.

In the *emmetropic* eye, rays from an infinite distance are united upon the bacillar layer of the retina without any effort of the accommodation. The limit lies at the measure, hence the name emmetropia. When the eye is in a state of rest, the posterior principal focus of its dioptric system falls on the external layer of the retina.

In a state of rest, the myopic eye is not adjusted for parallel, but for more or less divergent rays, and the parallel rays are, therefore, brought to a focus *before* the retina. The posterior principal focus lies, consequently, in front of the retina; the furthest limit lies within the normal measure: the measure is too short, and hence Donders has proposed the name brachymetropia (βραχὺς, brevis, μέτρον, modus, ὤψ, oculus). He thinks it however preferable to retain the old term myopia.

The *hypermetropic* eye, when in a state of rest, is, on the contrary, adjusted for convergent rays, parallel rays being brought to a focus *behind* the retina. The posterior principal focus lies behind the bacillar layer of the retina: its limit lies *beyond* the measure, and he has therefore termed it hypermetropia (ὑπερ, super, μέτρον, modus, ὤψ, oculus).

In order to express that the eye is not emmetropic, Donders proposes the term *ametropia* (from ἄμετρος, extra modum, and ὤψ, oculus); and he observes that brachymetropia and hypermetropia are both, therefore, referrible to it. Formerly, presbyopia and myopia were supposed to be opposite conditions. This is, however, erroneous. In myopia there is an abnormal position of the far point, whereas, in presbyopia the position of the far point is normal, but that of the near point is changed, being removed further from the eye. Indeed, we may have the two conditions co-existing. Presbyopia is not, therefore, an anomaly of refraction, but a diminution in the range of accommodation.

It has long been a keenly debated question in what the changes of accommodation of the eye consist, and various opinions have been advanced. Some have thought that the cornea undergoes some alteration during accommodation for near objects, so that its power of refraction is increased, and the eye enabled to adjust itself for reading, writing, &c.; but, apart from other reasons against this theory, Helmholtz has shown, with his ophthalmometer, that there is no alteration in the curvature of the cornea during accommodation.

Others have supposed that the muscles of the eyeball play an important part in bringing about, in conjunction with the ciliary muscle, the adjustment for near objects. But that this is not the case has been incontrovertibly proved by a case of Von Graefe's, in which all the recti and obliqui muscles of both eyes were paralysed, so that the eyeballs were completely immoveable; and yet the power of accommodation was perfect.

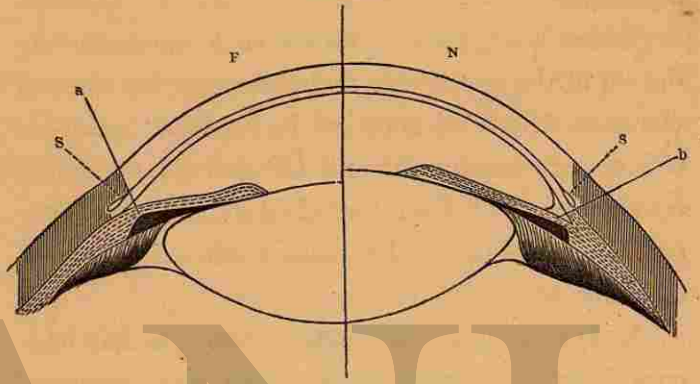
It has at length, however, been definitely settled, chiefly by the experiments of Cramer and Helmholtz (conducted independently of each other), that the necessary change in the refraction of the eye during accommodation is due to an alteration in the form of the crystalline lens. Helmholtz found, by means of his ophthalmometer, that the lens did not change its position during accommodation for near objects, but that this was brought about by a change in the curvature of the anterior and posterior surfaces of the lens, which become more convex (the lens itself thicker from before backwards), so that the lens acquires a higher power of refraction, and consequently a less focal distance, by which means rays from even very near objects are brought to a focus upon the retina. He found, with the ophthalmometer, that the eye undergoes the following changes during accommodation for near objects :—

1. The pupil diminishes in size. 2. The pupillary edge of the iris moves forwards. 3. The peripheral portion of iris moves backwards. 4. The anterior surface of the lens becomes more convex (arched), and its vertex moves forwards. 5. The posterior surface of the lens also becomes slightly more arched, but does not perceptibly change its position. The lens, therefore, becomes thicker in the centre.*

As the volume of the lens must remain the same, he thinks that we may, moreover, assume that the transverse diameter of the lens becomes diminished. He finds, from calculation, that these changes in the lens are quite sufficient for all accommodative purposes.†

Fig. 13 illustrates the changes which the eye undergoes during accommodation. The anterior portion of the eye is divided into two equal parts. The one half, F, shows the position of the parts when the eye is adjusted for distance, the other, N, when it is accommodated for near objects. When the eye is in a state of rest, the iris forms a curve (*a*) in the vicinity of Schlemm's canal (*s*); but when accommodated for near objects, the fibres of the iris undergo contraction, the periphery of the iris

Fig. 13.



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* Otto Becker has found that in albinotic eyes the space between the ciliary processes and the edge of the lens becomes increased in size during accommodation for near objects. He thinks it probable that the volume of the ciliary processes varies in the different conditions of the accommodation, and supposes that this is due to the difference in the blood supply to the iris, which he thinks varies with the dilatation and contraction of the pupil.

† It was found, with the ophthalmometer, that the position of the reflection images of a candle, produced by the cornea and the anterior and posterior surfaces of the lens, undergoes a change during accommodation for near objects. Whilst the reflex image from the cornea remains unchanged, that from the anterior surface of the lens approaches the corneal image and diminishes in size; the image from the posterior surface of the lens also diminishes very slightly in size, but undergoes no appreciable change of position.

becomes straightened (*b*), and the anterior chamber lengthened, so that its diminution in depth is compensated for by the advance of the anterior surface of the lens.

There being now no doubt that the accommodation of the eye is due to a change in the form of the lens, the next question is, by what means is this change produced? and this brings us to the consideration of the much-debated, but yet unsettled question of the mechanism of accommodation.

This change in the form of the lens has been considered to result chiefly from the combined action of the iris and ciliary muscle, some physiologists giving the pre-eminence to the iris, others to the ciliary muscle. Before entering into this question, it will be well just to glance at the anatomical position of the parts involved, by referring to the accompanying plate (copied from Ecker's "Icones Physiologicæ").

Fig. 14.

Section of the parts of the human eye concerned in accommodation × 15.

C. Cornea.

c c. Its anterior elastic lamina passing over

Fig. 14

from the layer of connective tissue (*s c*) of the sclerotic.

c c'. Epithelium of the anterior surface of the cornea.

C D. Membrane of Descemet; its homogeneous lamella.

C D E. Its epithelium.

S. Sclerotic.

S c. Vascular layer of connective tissue of the sclerotic conjunctiva.

s. c'. Its epithelium.

The tissue of the cornea passes over into that of the sclerotic without any well-defined boundary. The place of the caudated corneal corpuscles is gradually supplied by elastic meshes, and that of the homogeneous corneal plates between them, by layers of fibrous connective tissue. The elastic meshes are particularly close together in the vicinity of Schlemm's canal, running here also, by preference, in a circular direction.

c s l. Canal of Schlemm.

In the vicinity of this canal, (at *C D**) the homogeneous lamina of the membrane of Descemet splits up into a number of fibrous plates, which appear first at the outer side, so that the membrane of Descemet seems to terminate with its edge bevelled off towards the inner side. These fibres, whose character appears to lie midway between the elastic and the fibrous connective tissue, are thus distributed: (1), the external (a) pass over into the elastic meshes of the sclerotic, and particularly, into the external wall of Schlemm's canal; (2), the middle fibres (m) serve as an origin for the ciliary muscle; (3), the most internal (i), forming the ligamentum pectinatum (pillars of the iris), are connected with the iris.

Ch. Choroid.

C p. Its pigment layer.

P c. Ciliary process (a longitudinal section).

On account of its uneven, nodulated surface, the section of the tissue is at one place edged with pigment, and at another, deeper portions of the surface appear not touched by the section.

m c i. Ciliary muscle; its fibres run in a wavy manner. The greater portion of them lie in the direction of the meridians, and can be easily peeled off. When these have been removed, other fibres are also seen to run in a transverse direction (*m ci*).* It is probable that the one set bend round and pass over into the other, thus forming arcades. This has not, however, yet been ascertained with certainty.†

I. Iris.

i p. Pigment layer.

In the substance of the iris radiating fasciculi of connective tissue are seen.

R. Retina.

R o. Ora serrata.

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* Circular fibres of Müller.

† The following is Kölliker's description of the ciliary muscle: "The ligamentum ciliare of anatomists, called also musculus ciliaris or tensor choroideæ, was recognised as being of a muscular nature, almost simultaneously, by Brücke and Bowman; it is a tolerably thick lamina of radiating, smooth, muscular fasciculi, which pass from the most anterior border of the sclerotic to the corpus ciliare, and are lost in the anterior half of that body, at the spot corresponding to the situation of the ciliary processes internally. More accurately described, the ciliary muscle arises at that part of the sclerotic where it is furrowed for the formation of the venous sinus of Schlemm (vide Fig. 4, *c s l*); indeed, it is from a special dense, smooth tract, which, whilst forming the inner wall of the above-mentioned canal, coalesces with the sclerotic, receiving at the same time a part of the fibrous network prolonged from the membrane of Desmours; the last-mentioned fibres coalesce perfectly with the similar elements of the special tract, which are, however, finer, anastomose more densely, and have a circular direction. The termination of the ciliary muscle is at the attached part of the ciliary processes, but not in these structures themselves. The muscular elements are somewhat shorter (0·02‴) and broader (0·003‴ to 0·004‴) than the ordinary fibre cells, and are finely granular and very delicate; they are, indeed, so perishable, that they cannot be easily isolated in the human subject. Very lately, H. Müller has discovered a circular muscular layer, quite anteriorly, beneath the radiating fibres of the ciliary muscle; and this I call the circular muscle of Müller. The latter forms the deepest and most anterior layer of the ciliary muscle close to the insertion of the iris."

H, Hyaloid.
*H**. Place of its division.
H′. Zonula.
Z. Its free portion.
H″. Posterior lamina of the hyaloid.
c. p. Canal of Petit.
L. Lens.
L. c. Capsule of lens.
v. a. Anterior chamber.
h. a. Posterior chamber.

Cramer supposed that the arching forward of the lens is caused by the iris, its dilatator and sphincter being simultaneously contracted, the peripheral portion of the iris at the same time moving backwards. By this means a certain amount of pressure is exerted upon the peripheral portion of the lens which is covered by the iris, in consequence of which pressure, the anterior surface of the lens must become more arched. The simultaneous tension of the radial and circular fibres of the iris have the effect of decreasing the pressure in the anterior chamber, and increasing that in the vitreous. He thinks that the ciliary muscle acts in so far, that it prevents the lens being pushed backwards under the pressure of the iris, and that it defends the retina from deleterious pressure.

Donders agrees on the whole with these opinions, but thinks, also, that the ciliary muscle, by drawing the peripheral edge of the iris backwards against the wall of the canal of Schlemm, forms a fixed point for the action of the dilatator pupillæ. This would form the posterior fixed point, the anterior being formed by the contracted sphincter pupillæ. Donders, moreover, vindicates the importance of the ciliary muscle during accommodation, for he says, "I consider this muscle (ciliary muscle) just as important for the change in the form of the lens as the muscular fibres of the iris. Without it, the iris would not be able to exert a pressure of any importance upon the lens."

Helmholtz, however, shows that, although these theories of Cramer and Donders suffice to explain the arching forward of the anterior surface of the lens, they do not suffice for the explanation of the whole change in the form of the lens which occurs during accommodation for near objects. Heinrich Müller gives the following very clear *résumé* of Helmholtz's views :—"Finally, Helmholtz thinks with Donders that the iris, in conjunction with the ciliary muscle, is the chief organ of accommodation. He, however, believes that the recession of the peripheral portions of the iris may also be explained by the tension of the dilatator, the latter levelling the iris, which was before slightly bent (vide Fig. 13), by the action of the elastic fibres of the ligamentum pectinatum (pillars of the iris), and laid along the whole breadth of the canal of Schlemm against the inner wall of the latter. Besides this, Helmholtz also assumes that the ciliary muscle not only draws the insertion of the iris backwards, but also draws the posterior ends of the ciliary processes forwards, thus causing a relaxation of the zonula, which in its turn again favours the increase in the thickness of the lens."

Heinrich Müller attaches far greater importance to the action of the ciliary muscle than to the iris. He, moreover, discovered that the ciliary muscle consists of two different sets of fibres—a radiating longitudinal and a circular. (Vide Fig. 14, *m c i*, and *m c i'*.)

He ascribes a different action to each set of fibres, and has come to the following conclusions as to the probable action of the different parts concerned in accommodation. He thinks that*—

1. "The circular fibres of the ciliary muscle exert a pressure upon the edge of the lens, by means of which the latter becomes thicker.

2. "The longitudinal fibres of the muscle cause

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* Von Graefe's Archiv. iii, 1, 23.

an increase of tension in the vitreous humour, on account of which, the posterior surface of the lens is prevented from shifting, and the action of the peripheral pressure is chiefly confined to the anterior surface.

3. "The pressure of the tense iris on the peripheral portion of the anterior surface of the lens assists in increasing the convexity (arching forward) of the latter, and in preventing the arching of the posterior surface.

4. "The arching forward of the centre of the anterior surface of the lens is rendered possible and favoured by the recession of the peripheral portion of the iris, which is accompanied by a contraction of the deeper (circular) layer of the ciliary muscle and the iris.

5. "The contraction of the ciliary muscle causes finally a relaxation of the anterior portion of the zonula, by which means, again, the increase in the thickness of the lens is promoted."

We have shown how Cramer, Donders, Helmholtz, Müller, as well as many other observers, have considered the iris to play a more or less important part in the mechanism of accommodation. It was difficult, indeed impossible, to determine with accuracy the relative amount of importance of the iris or ciliary muscle, even after the most careful dissections and most elaborate investigations. This question as to the importance of the iris in accommodation has, however, been definitely set at rest by a case which occurred in Von Graefe's clinique, in which, together with a total absence of the iris (the latter was removed after an accident) the power of accommodation remained perfect. Moreover, on the application of a strong solution of atropine it became completely paralysed.*

NEGATIVE ACCOMMODATION.

We have assumed that when the normal eye is in a state of absolute rest, parallel rays (emanating from objects at an infinite distance) are brought to a focus upon the retina, and that a positive change of the accommodative apparatus within the eye is only required for objects at a finite distance. But it is thought by some (particularly Weber and Von Graefe) that the eye, when in a state of rest, is adjusted neither for its far nor for its near point, but for a distance between the two, and that adjustment for either nearer or more distant objects necessitates an effort of accommodation. Now, if we call the adjustment for near objects the *positive* accommodation,

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* Vide "Archiv. f. Ophthalmologie," vii, 2, 26.

that for distant objects may be designated the *negative.*

Von Graefe thinks that, by the help of certain accessory powers (chiefly the external muscles of the eyeball), which exert a slight pressure upon the eye, and flatten the cornea a little, the refraction of the eye is somewhat diminished, and the far point removed still further than when the eye is in a state of absolute rest.

Henke has, however, advanced the theory that the negative and positive accommodation are produced by the action of the ciliary muscle, which he would divide into two, according to the direction of the fibres, viz., the "musculus circularis" and the "musculus radialis." He considers their action to be different and antagonistic, and thinks that in accommodation for near objects the circular muscle is contracted, the radial extended, whereas in accommodation for distance the reverse occurs—the radial muscle being contracted, the circular extended.*

The discovery of the circular fibres in the ciliary muscle is undoubtedly of great importance, although some think that their action is almost completely neutralized by the longitudinal fibres.

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* "Der Mechanismus der Accommodation für Nähe und Ferne." Henke. "Archiv. f. Ophthalmologie," vi, 2, 53.

The mechanism of the accommodation could be, indeed, more easily explained if we might assume that the radial and circular fibres are supplied by branches from different nerves, and that they stand in a similar antagonistic relation to each other as the dilatator and sphincter pupillæ.

The chief argument against the theory that the eye accommodates itself actively for distant objects is in the action of a strong solution of atropine, which paralyses the power of accommodation, but does not interfere with the distant vision of the emmetropic eye, and does not change the position of the far point.

CHAPTER II.

RANGE OF ACCOMMODATION.

BEFORE we speak of the mode of examining the range of accommodation, it will be well to consider what test-types are the best for the purpose of determining the acuteness of vision, and the position of the near and far point. Formerly Jaeger's test-types were chiefly in use, but they did not afford us a perfect clue to the acuteness of vision; for a person might be able to read No. 1 of Jaeger, and yet not enjoy a normal acuteness of sight. Snellen has, however, devised a set of test-types which fulfil this desideratum. The letters are square, and their size increases at a definite ratio, so that each number is seen at an angle of 5 minutes. Thus, No. 1 is seen by a normal (emmetropic) eye up to a distance of 1 foot, at an angle of 5 minutes; No. 2 up to 2 feet, and so on. These numbers cannot, as a rule, be seen distinctly beyond these distances.*

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* At Professor Longmore's suggestion, Dr. Snellen has given, in his later editions of the Test-types, some tables containing a series of figures and single numbers, for the examina-

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Now, if the eye is suffering from any diminution of acuteness of vision, it will require to see the letters under a larger angle than that of 5 minutes, in order to gain larger retinal images. No. I cannot be read at a distance of 1′, but only, perhaps, No. IV. or V. We may easily calculate the degree of the acuteness of vision thus :

"The utmost distance at which the types are recognised (d) divided by the distance at which they appear at an angle of 5 minutes (D), gives the formula for the acuteness of vision (V).

$$V = \frac{d}{D}$$

"If d and D be found equal, and No. XX be thus visible at a distance of 20 feet, then $V = \frac{20}{20} = 1$; in other words, there is normal acuteness of vision. If, on the contrary, d be less than D, and if No. XX is only visible within 10 feet, No. X only within 2 feet, No. VI only

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tion of such recruits for the British army as are unable to read. For further information as to the examination of the sight of recruits, I must refer the reader to Professor Longmore's excellent "Ophthalmic Manual," which I would also recommend to the special notice of the surgeons of the Militia and of Volunteer corps. These test-types may be obtained from Messrs. Williams and Norgate, Henrietta Street, Covent Garden.

within 1 foot, these three cases are thus respectively expressed :—

$$V = \frac{10}{20} = \frac{1}{2}$$

$$V = \frac{2}{10} = \frac{1}{5}$$

$$V = \frac{1}{6}$$

d may sometimes be greater than D, and No. XX be visible at a greater distance than 20 feet. In such cases the acuteness of vision is greater than the normal average." (Snellen.)

It must, however, be confessed that some patients (more especially amongst the lower classes) often experience a difficulty in fluently reading type composed of these square letters. They have always been accustomed to ordinary type, the letters of which are of unequal thickness, and differ both in dimension and definition. I, therefore, generally employ Jaeger's test-types for ascertaining the fluency with which small print can be read, and those of Snellen, for testing with accuracy the acuteness of vision.

When the eye has assumed its highest state of refraction, it is accommodated for its nearest point of distinct vision; when its state of refraction is, on the other hand, relaxed to the utmost, it is adjusted for its furthest point.

The power of the ciliary muscle is, however, limited; and consequently the lens is only capable of a certain increase in its convexity, and the accommodation for near objects has, therefore, also its limit, and the near point cannot be brought nearer than a certain distance from the eye. In normal eyes the nearest point of distinct vision lies at about 3½ or 4 inches from the eye; this varies, however, according to the age of the patient, for, as we shall afterwards show, the near point recedes further and further from the eye with advancing years. For continued work at near objects—engraving, &c.—the near point lies at about 5 inches. Few eyes, indeed, can bear to work for any length of time with the object nearer than this. The furthest point of distinct vision in the normal eye is at an infinite distance (parallel rays).

The distance between the furthest point (r), *and the nearest point* (p) *of distinct vision is called the territory or range of accommodation.* The extent of this range must vary, of course, according to the strength and efficiency of the ciliary muscle, the elasticity of the lens, and the age of the patient.

The distance of p from the eye (measured from the nodal point) is expressed by P, the distance of

r from the eye by R; and we may easily find the range of accommodation $(\frac{1}{A})$ by the following formula:—

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$$

The distances P and R may, according to Donders, be calculated from the nearest point, p, and from the furthest point, r, of distinct vision, to a point situated about 3‴ behind the anterior surface of the cornea in the eye, called the anterior nodal point, k'. He says, further:—

"The meaning of the formula for the range of accommodation—

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$$

is easily understood. In this formula A is the focal length of a lens, which gives a direction to the rays from the nearest point of distinct vision, p, as if they come from the farthest point, r. The subjoined Fig. (15) illustrates this. The eye in the condition of rest, is accommodated for the distance $r\,k' = R$; in the strongest tension of accommodation for the distance $p\,k' = P$. In the former case, the rays diverging from r are united on the retina; in the latter those diverging from p. In accommodation, therefore, the eye must be so altered, that the rays proceeding from p, in the vitreous humour,

Fig. 15.

acquire a direction equal to that of the rays proceeding from r in the non-accommodated eye. This can be effected by placing an auxiliary lens in k', and we may thus imagine the eye away, and suppose that the auxiliary lens in k' is in the air. The lens now represents the accommodation of the eye, and its power the range of accommodation. The focal distance, A, is found by the formula mentioned :—

$$\frac{1}{P} - \frac{1}{R} = \frac{1}{A}$$

Consequently, A is the focal distance of the auxiliary lens, of which the eye avails itself in accommodation, and as the power of a lens is inversely proportional to its focal distance, $\frac{1}{A}$ or 1 : A, expresses the range of accommodation. It is convenient to represent the value of A in Parisian inches, especially as the focal distance of lenses is usually stated in the same, and

this applies also more particularly to spectacles."* (Donders, p. 30).

To render this still easier of comprehension, let us suppose that the eye is emmetropic and accommodated for an object placed at its far point (parallel rays), if the object is now moved up to 5″ from the eye, and the latter does not exert its power of accommodation, the rays from the object will be brought to a focus behind the retina. In order to unite them upon the latter a biconvex lens must be placed before the eye, which shall render the rays coming from the object (placed at 5″) parallel, *i.e.*, give them the same direction as they had when the object was situated at an infinite distance. A 5-inch lens would be required for this purpose, for the rays from an object situated at its anterior focus would issue parallel from the lens. If we now suppose this auxiliary lens placed within the eye, it represents the accommodation of the eye, and its power the range of accommodation, the latter would, therefore, in this case = $\frac{1}{5}$.

Let us illustrate Donders' way of determining the range of accommodation by a few examples ;

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* The lenses in the boxes of Paetz and Flohr of Berlin are defined in Prussian inches, which are very nearly the same as the English inches, and less than the Parisian.

first again, however, explaining the meaning of the following expressions :—*A* signifies range of accommodation; *r*, far point; *p*, near point; ∞ (= 0), infinite distance; ′, foot; ″, inch; ‴, line.

1. Normal eyes, which can see from an infinite distance up to 5″ from the anterior surface of the crystalline lens, have their far point (*r*) at an infinite distance (∞), their near point (*p*) at 5″. In order to find the range of accommodation of such an eye, we apply the above formula, $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$. In our case r = ∞, p. = 5″ therefore $\frac{1}{A} = \frac{1}{5} - \frac{1}{\infty} = \frac{1}{5}$.

The range of accommodation is here represented by an auxiliary lens of 5 inches.

2. Let us test the range of accommodation of a short-sighted, or myopic eye. Let us suppose that its far point (*r*) lies at 8″ from the eye, its near point (*p*) at 4″, $\frac{1}{A}$ therefore $= \frac{1}{4} - \frac{1}{8} = \frac{1}{8}$.

3. If a presbyopic, or far-sighted eye, has its far point (*r*) at an infinite distance, and its near point at 10″, $\frac{1}{A}$ will be $\frac{1}{10}$, for $\frac{1}{10} - \frac{1}{\infty} = \frac{1}{10}$.

I shall afterwards, when speaking of hypermetropia, mention the best plan of examining the range of accommodation of a hypermetropic eye.

The following is also a very good method for testing the range of accommodation, and for quickly discovering whether the eye is myopic, hypermetropic, or presbyopic :—

A convex lens of 6″ or 10″ focus is placed before the eye.* With this lens the patient then reads No. 1 of Snellen, and his far and near point are noted. The far (*r′*) and near point (*p′*) thus found, stand in such a relation to his real far (*r*) and near point (*p*), that the rays coming from *r′* are refracted by the lens as if they came from *r*, those from *p′* being also refracted as if they emanated from *p*. With convex 6, *r′* (in the normal eye) lies at 6″ from the eye, for rays from an object at 6″ distance falling on this lens would be rendered parallel by it, and would, consequently, impinge upon the eye as if they came from an infinite distance (the normal far point). The near point (*p′*) would lie at about $2\frac{2}{3}$″. This varies, however, with the age of the patient.

The range of accommodation is, therefore, easily found by the formula $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$. The lens and its distance from the eye (about $\frac{1}{2}$″) are omitted in the calculation.

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* The lens must be strong in order that the patient may really command his far point, and that the latter may be approximated so much that the minimum of the angle of distinction no longer exerts any influence, and amblyopia is therefore excluded.

If (with convex 6) the far point (r') lies at 6″, the near point (p') at 3″, $\frac{1}{A} = \frac{1}{3} - \frac{1}{6} = \frac{1}{6}$.

Let us illustrate this proceeding by the following examples :—

I. *Myopic eye.* We find that with convex 6 $r' = 5''$, $p' = 3''$. The eye is consequently myopic, for it is not adjusted for the normal far point (6″), but for a nearer one, the rays from which impinge in a divergent direction upon the eye :—

$$\frac{1}{A} = \frac{1}{3} - \frac{1}{5} = \frac{1}{7\frac{1}{2}}.$$

Now, what glasses will this patient require for infinite distance ? By means of our strong convex lens we have changed this eye into a very myopic one, in fact, into a myopia of $\frac{1}{5}$, for we should have to place a concave glass of 5″ focus before convex 6 in order to enable it to see at a distance; for this concave glass would render parallel rays so divergent as if they came from 5″ distance. In order to find the proper concave glass for distance, we deduct concave 5 from convex 6. Hence the proper concave glass will be No. 30 for

$$\frac{1}{6} - \frac{1}{5} = -\frac{1}{30}$$

II. *Hypermetropic eye.* With convex 6, $r' = 8$, $p' = 3''$. The eye is, therefore, hypermetropic, for its far point lies beyond the normal far point (6″).

Its range of accommodation $= \frac{1}{4\frac{4}{5}}$ for

$$\frac{1}{A} = \frac{1}{3} - \frac{1}{8} = \frac{1}{4\frac{4}{5}}$$

Although we can thus very quickly determine the fact that the eye is hypermetropic, and also its range of accommodation, we cannot find with exactitude the requisite convex glass for distance by the same calculation as in the myopic eye; for, as we shall, hereafter, show, the amount of hypermetropia before and after the paralysis of the ciliary muscle by atropine sometimes varies greatly.

Above, we have only spoken of the *absolute* range of accommodation which exists when each eye is tried separately. Donders* has, however, pointed out that we must distinguish two other kinds of ranges, viz., the *binocular* and the *relative*. The *binocular* comprises the accommodation from the furthest point r_2 to the nearest point p_2, when both eyes are tried together. The formula is $\frac{1}{A_2} = \frac{1}{P_2} - \frac{1}{R_2}$.

Although a certain connection exists between

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* Op. cit., 110. Full explanations, with explanatory diagrams of this subject, will be found in Donders' work.

the accommodation and the convergence of the visual lines, yet this connection is not absolute and definite, for we find that the position of the visual lines may be changed, yet the accommodation remain the same; for if a prism of moderate strength be placed with its base outwards before one eye, the convergence of the visual lines will be greatly increased to overcome the diplopia, and yet the object can be distinctly seen at the same distance with both eyes. Again, the accommodation may be altered, and yet the state of convergence remain the same, for if we place weak concave or convex lenses before the eyes, an object can still be distinctly seen at a definite distance. This proves that the accommodation may be modified without any change of the convergence of the visual lines. These experiments show that there exists a certain independence between the convergence and the accommodation, and the range of accommodation over which we have control at a given convergence of the visual lines is termed the *relative* range, and is found by the formula $\frac{1}{A_1} = \frac{1}{P_1} - \frac{1}{R_1}$. It consists, moreover, of two parts, the *positive* and the *negative*. The positive being the part which is disposable for a distance closer than the point of convergence, whereas the negative is the portion

which is required to see an object lying beyond the point of convergence of the visual lines. Now the relation between these two parts of the relative range of accommodation is of much practical importance, for it is found that, in order that the eyes may be employed comfortably for some length of time at near objects (reading, etc.), it is absolutely necessary that the positive part of the accommodation should bear a certain proportion to the negative (it should at the very least be equal to $\frac{1}{2}$).

The best objects for testing the range of accommodation are Snellen's test types or Von Graefe's wire optometer. But as the latter requires some exactitude and intelligence on the part of the patient, I find it more practical, especially with hospital patients, to use the test types. If, whilst they are reading No. 1, we move the type a few times alternately nearer to and further from the eye, the nearest and furthest point of distinct vision can be readily ascertained. Von Graefe's optometer consists of a small square steel frame, across which a number of delicate, parallel, vertical wires are stretched. This frame may be attached to a brass rod (graduated in inches and feet) upon which it is moveable; or it may be fastened to a graduated tape. One end of the rod or the bobbin of the tape is placed against the forehead of the patient, and the frame moved to the nearest point at which the individual wires still look clearly and sharply defined; the distance of this point from the eye is read off from the graduated scale, and put down as the near point (*p*). The frame is then removed to the greatest distance at which the individual wires still appear sharply defined, and this is noted as the far point (*r*). The distance between *p* and *r* gives the range of accommodation. The wires only appear sharply defined when the eye accommodates itself perfectly for them, directly there is the slightest deviation from this perfect accommodation (the frame being too far from or too near to the eye), the wires seem indistinct, thickened, or as if surrounded by a halo; or coloured double images of them may even appear in the transparent intervals. With the test types, the examination is still easier, the nearest point at which No. 1 (Snellen) can be distinctly and comfortably read is ascertained, and noted as the near point, and then the furthest point (in an emmetropic eye No. 1 of Snellen should be read up to 1′, No. xx up to 20′), is measured and noted.

CHAPTER III.

MYOPIA.

SHORT-SIGHTED persons generally apply to us with the complaint that, although they are able to distinguish the very finest objects near at hand, they cannot see well at a distance. This depends upon the fact, that the refracting power of the eye is increased in myopia, or that the antero-posterior axis of the eyeball is too long, so that parallel rays (emanating from objects at an infinite distance), or even not sufficiently divergent rays, are brought to a focus before the retina; circles of diffusion are formed upon the latter, and in consequence of this, the distant object does not appear clear and sharply defined, but indistinct and blurred. Such patients notice, for instance, that the stars, the moon, or a gas-lamp in the streets, do not present a clear and well defined outline, but appear irregular, enlarged, and as if surrounded by a halo. In order, therefore, to improve their vision for distant objects, they often acquire the habit of nipping their eyelids together. The reason for of the tape is placed against the forehead of the patient, and the frame moved to the nearest point at which the individual wires still look clearly and sharply defined; the distance of this point from the eye is read off from the graduated scale, and put down as the near point (p). The frame is then removed to the greatest distance at which the individual wires still appear sharply defined, and this is noted as the far point (r). The distance between p and r gives the range of accommodation. The wires only appear sharply defined when the eye accommodates itself perfectly for them, directly there is the slightest deviation from this perfect accommodation (the frame being too far from or too near to the eye), the wires seem indistinct, thickened, or as if surrounded by a halo; or coloured double images of them may even appear in the transparent intervals. With the test types, the examination is still easier, the nearest point at which No. 1 (Snellen) can be distinctly and comfortably read is ascertained, and noted as the near point, and then the furthest point (in an emmetropic eye No. 1 of Snellen should be read up to 1′, No. xx up to 20′), is measured and noted.

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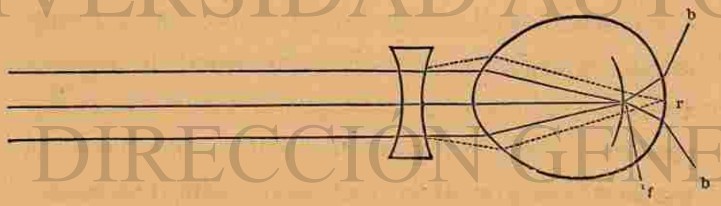
We have already stated that in the short-sighted eye the principal focus of the dioptric system does not lie, as is the case in emmetropia, upon the bacillar layer of the retina, but in front of it. Hence, only such rays as come from a finite distance, and impinge in a sufficiently divergent direction upon the eye, are united upon the retina.

Fig. 16 represents a myopic eye, in which, either on account of its being too long in the

Fig. 16.



antero-posterior axis, or its possessing too high a power of refraction, parallel rays are not brought to a focus upon the retina (*r*), but in front of it (*f*); circles of diffusion (*bb*) are, consequently, formed upon the retina, and the object looks blurred and indistinct. In order, therefore, to enable the myopic eye to see distant objects (the rays from which impinge upon it in a parallel direction), we place that concave lens before it which will give the parallel rays such a degree of divergence that they are united upon the retina.

Myopia is frequently congenital, and often hereditary. We may sometimes trace its existence back through several generations, and may meet with it in several members of the same family. It may also show a tendency to increase in degree in each successive generation, but this will depend greatly upon individual circumstances.

The most frequent cause of myopia is an abnormal increase in the length of the eyeball in its antero-posterior axis. This extension chiefly occurs at the posterior portion of the globe, and may here produce a more or less considerable ovoid bulging (posterior staphyloma), which is accompanied by thinning and atrophy of the choroid and sclerotic. This prolongation of the visual axis of course varies greatly in extent in different cases, and thus gives rise to very varying degrees of short sight. In cases of considerable myopia, we find that this peculiar atrophy of the choroid (posterior staphyloma, sclerotico-choroiditis posterior) is almost always present. Von Graefe lays it down as a general rule, that when the far point lies nearer than 5 inches from the eye (the myopia exceeding $\frac{1}{5}$), we may almost with certainty foretell the presence of sclerotico-choroiditis posterior. But we very frequently meet with it in much slighter degrees of myopia; indeed, I have often seen it in cases where the myopia did not exceed $\frac{1}{12}$ or $\frac{1}{18}$. But even if the eye is but slightly short-sighted, we may often observe a thinning and atrophy of the choroid round the optic nerve entrance, even although there may be no defined crescent. It is of consequence, therefore, that all short-sighted persons should be examined with the ophthalmoscope, in order that the presence and extent of the posterior staphyloma may be carefully and accurately noted, for it is always a more or less serious complication, more particularly if the affection is extensive and progressive. But even if the presence of sclerotico-choroiditis posterior be not suspected, the ophthalmoscopic examination should not be neglected, in order to ascertain whether the condition of the optic nerve and retina be normal

or whether they are hyperæmic and congested; a condition which is frequently met with in short-sighted eyes that are overworked, and which demands careful treatment.

There is no doubt that continued tension of the accommodation for near objects is a very frequent cause of myopia. This is the reason why this affection is so much more frequently met with amongst the higher and literary classes, amongst those who employ their eyes much in reading, writing, sewing, &c., than amongst the lower orders.

The production and increase of myopia by continuous use of the eyes at near objects appears to find its explanation chiefly in the fact that the inner tunics of the eyeball become congested. The near approach of the object necessitates a strong convergence of the optic axes, which causes an accumulation of blood in, and congestion of, the inner tunics of the eyeball, these conditions being increased still more by the stooping position generally indulged in during such employment. We can easily understand that this congestion and this augmentation in the pressure of the ocular fluids must, if long continued, necessarily lead to an extension of the tunics at the posterior pole, and thus give rise to posterior staphyloma.

Again, long-continued working at near objects may probably also produce myopia in the following manner :—Persons thus employed continually accommodate for a very near point, their crystalline lens has, therefore, constantly to assume a more convex form, and after a time it may not be able quite to regain its original form, even when the necessity for adjusting itself for near objects no longer exists. This occurs particularly when the lens possesses but a slight degree of elasticity, for then, after it has been for some length of time accommodated for near objects, it gradually, like a bad watch-spring, loses the power of springing back to its original form; it remains too convex, even when the pressure upon its periphery ceases. In consequence of this, the focal point of the dioptric system becomes shorter, and, when the eye is in a state of rest, lies in front of the retina, and the eye has thus become myopic. This form of acquired myopia is generally, however, only slight in degree.

The seeds of short-sightedness are frequently sown in childhood, either through a premature over-exertion of the eyes at near objects, or through some affection of the refractive media (the cornea or lens). The cornea may, for instance, be clouded, and then the patient often brings the object very close

to the eye, in order to obtain larger and more distinct retinal images, and thus myopia may be soon induced. The same thing may occur when the lens is somewhat opaque; thus it is well known that lamellar cataract frequently becomes complicated with short sight.

There can be no doubt that the degree of myopia is often greatly increased during childhood by long continued study, more especially by insufficient illumination, and a faulty construction of the tables or desks at which the pupils read and write. An insufficient illumination necessitates a close approximation of the object, which gives rise to straining of the accommodation and congestion of the eyes. A faulty construction of the tables, or an inconvenient distance between them and the seats, is also injurious, by forcing the children to stoop. An interesting and valuable monograph has been written by Dr. Cohn* upon this subject. He examined the eyes of 10,060 school children, and could distinctly trace the increase in the proportion of the myopia according to the construction of the desks and the lighting of the school-rooms.

It was formerly supposed that increased convexity of the cornea was the cause of myopia, but

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* Dr. Cohn, Untersuchung der Augen von 10,060 Schulkindern. Leipsic, 1867.

this is erroneous, for Donders has found that the cornea is, as a rule, less convex in myopic persons than in the emmetropic. Increase of the curvature of the cornea (as in conical cornea) may, however, give rise to myopia. We sometimes also find that persons suffering from incipient cataract become somewhat myopic, and see better at a distance with concave glasses. The real explanation of this fact is still uncertain, but, it may perhaps be due to a slight swelling (?) of the lens, and a consequent increase in its power of refraction.

The diagnosis of myopia is generally a matter of no difficulty. The far point of distinct vision is more or less approximated to the eye, in consequence of which, distant objects cannot be clearly distinguished, and a suitable concave lens is required to render them distinctly perceptible. We must be upon our guard, however, not at once to pronounce a person short-sighted because he holds small objects (such as small print) very close to the eye, or because he cannot see well at a distance, for we shall hereafter find that this may likewise occur in hypermetropia, in which case, convex and not concave glasses are required to remedy this defect.

Myopia might also be confounded with weak sight (amblyopia), for we find that weak-sighted

persons likewise approximate small objects very closely to the eye, in order to obtain larger and more clearly-defined retinal images; but they are unable to distinguish very small objects, and in this they differ from the short-sighted. Concave glasses, moreover, do not enable them to see further off, indeed they see worse through them, as they diminish the size of the retinal images too much. If a person has to hold small print very near the eye, he may be suffering either from short sight or from amblyopia (I purposely pass over the possibility of the presence of hypermetropia). Now if we have no concave lenses at hand, the following will be found a ready method of distinguishing between weak sight and myopia: if it be a case of amblyopia, and the patient can see No. 2 of Snellen's test-types at 5″, he should be able to see print of double this size at twice this distance, for the size of the retinal images increases in proportion to that of the print, and all that the weak-sighted require are large retinal images. In myopia, however, it is different, for although the short-sighted eye will be able to see large print further off than small, the proportion between the distance and the size of the print is far less.

We find that myopia and amblyopia often coexist. Persons suffering from sclerotico-choroiditis posterior are generally somewhat amblyopic. Again, I have already pointed out that affections which produce weakness of sight, such as opacities of the cornea and lens, often lead to myopia, by necessitating the close approximation of very small objects. We may easily distinguish simple myopia from myopia complicated with amblyopia, by the fact that the former can be completely corrected by suitable concave glasses. A person suffering from simple, uncomplicated myopia should, with the aid of the proper concave lens, be able to read the same sized print as the normal eye, and at the same distance. Thus, No. XX of Snellen should be read at a distance of 20 feet. If, with the most carefully selected glasses, only No. XXX or No. XL can be read at this distance, the eye is not only myopic, but its acuteness of vision is also impaired, it is amblyopic. The less the concave glasses correct the myopia, the greater is the degree of the co-existing amblyopia, and *vice versâ*.

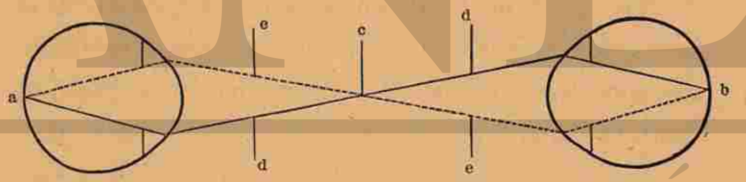
Ophthalmoscopic diagnosis of Myopia.—We may also recognise the existence of myopia, and ascertain its approximative degree by means of the ophthalmoscope, and this will often be found very useful in practice, particularly when the patient's statements are not very trustworthy. We can

diagnose the existence of myopia by the following appearances:—

I. If we examine a highly myopic eye in the erect image (that is, merely with the mirror, without any convex lens before it), we are at once struck by the fact that we can see the details of the fundus at some distance from the eye. If we regard one of the retinal vessels or the optic disc, and move our head slightly to one side, we notice that the image moves *in the contrary direction*; if we move to the right, it moves to the left, and *vice versâ*, so that we obtain a reverse image of the background of the eye.

Fig. 17 will at once explain the reason of this. Let *a* be a very short-sighted eye ($m = \frac{1}{4}$), and *b*, the eye of the observer: *a* being in a state of rest is adjusted for its far point (*c*), which lies 4″ in front of the eye. The rays from the fundus, therefore, pass out of the eye in a strongly convergent direction, and meet at *c*, and, crossing there, fall in a divergent direction upon the eye of the observer.

Fig. 17.



If the latter be myopic (accommodated for divergent rays when his eye is in a state of rest), they may be united upon his retina (*b*) without the aid of any correcting lens behind the ophthalmoscope. But if his eye is emmetropic he will, if adjusted for his far point, require a suitable convex lens behind the mirror, in order to render the divergent rays parallel. If he, however, accommodates himself for a sufficiently near point, he will be able to unite the divergent rays upon his retina without any correcting lens. The reversed image of the eye represented in Fig. 17 (the myopia of which $= \frac{1}{4}$) will be seen at a distance of about $7''$—$8''$, because as the rays from it cross at *c*, the upper ray, *e*, becomes the lower ray after they have crossed, and the lower ray, *d*, becomes the upper.

II. In order to examine a myopic eye in the erect image, it will be necessary to place a suitable concave lens behind the mirror, so as to obtain a distinct image of the fundus; the greater the myopia the stronger must this concave glass be, and the nearer must the observer approach to the eye. The strength of this correcting concave lens will also enable us approximately to estimate the degree of the myopia,* which will be always somewhat less than the strength of the correcting lens. The field of vision will appear smaller, and the image nearer the eye of the observer, than in the emmetropic eye. The image is also less bright in colour and less illuminated, but apparently larger, for we cannot, as in the emmetropic eye (the size of the pupil being equal) overlook the whole expanse of the optic disc at a glance, but only a portion of it. In the indirect mode of examination, the image of the disc will be less than that of the emmetropic eye, on account of its being formed nearer to the object lens.

Myopia may run a very variable course. In some cases its progress is marked and rapid, in others slow and insidious; in the most favourable cases it remains stationary at the adult age. It is generally, however, somewhat progressive, especially between the ages of 15 and 25, and often markedly so in hereditary myopia, or if the patients employ their eyes a great deal in reading, sewing, etc. A moderate degree of stationary or but slowly progressive myopia causes but little annoyance to the patient; but it is very different if its degree is very considerable and its progress marked and rapid, for in the latter case it is almost always

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* For a very full and valuable explanation of the determination of the state of refraction by the aid of the ophthalmoscope, I must refer the reader to Mauthner's Lehrbuch der Ophthalmoscopie.

accompanied by symptoms of irritation and inflammation of the inner tunics of the eyeball, giving rise to redness, heat, and ciliary neuralgia during prolonged work at near objects. We must, however, be upon our guard not to confound these symptoms with those of muscular asthenopia, dependent upon weakness of the internal recti muscles.

It is of great consequence in the prognosis and treatment of short-sightedness that its progress should be carefully watched, and that the degree of the myopia should from the first be accurately ascertained and noted; so that we may, hereafter, be able at once to determine whether the disease has remained stationary, or whether it has progressed, and, in the latter case, note the extent and rate of such progress.

The popular idea that myopia diminishes in old age is erroneous. This error is partly due to the fact that it was formerly thought possible to determine the degree of myopia by the position of the near point, and not by the far point, as is now done. It will be evident at once, that if the myopia be but slight (say $\frac{1}{16}$) the near point may, with advancing years, remove further from the eye, perhaps to 10″ or 12″, and the eye will thus have become presbyopic and the patient suppose

that his myopia has decreased. The increasing diminution in the size of the pupil, which occurs in old age, also tends to improve the distant vision of the myopic eye, by diminishing the circles of diffusion upon the retina, and thus rendering the image more distinct and well defined. Again, the senile changes (sclerosis) which the lens undergoes with advancing years, may suffice in a very slightly myopic eye greatly to diminish the short sight, or even perhaps almost to neutralize it.

There is nothing to be feared from a slight, stationary myopia. But it is very different indeed if the disease is progressive, for then it is always a source of danger to the eye. Upon this important point Donders speaks with great decision and earnestness. He says, "The same causes which give rise to myopia are still more favourable to its further development. I have always with great care watched the course of myopia. I attach to it a special importance. The well-known fact that myopes, with little light, can recognise small objects, and especially the circumstance that, at an advanced period of life, they need no glasses to enable them to see near objects, procured almost general acceptance for the prejudice, that near-sighted eyes are to be considered as particularly strong. Many medical men even participate in this error. But the oculist has only too often been convinced by sad experience of the contrary. I have no hesitation in saying, that a near-sighted eye is not a sound eye. In it there exists more than a simple anomaly of refraction. The optical characteristic of myopia may consist in this, the anatomical is a prolongation of the visual axis, and the latter depends upon a morbid extension of the membranes. If this extension has attained to a certain degree, the membranes are so attenuated, and the resistance is so diminished, that the extension cannot remain stationary, the less so, because in the myopic eye the pressure of the fluids is usually increased. In this progressive extension progressive myopia is included, which is a true disease of the eye.

"From what has here been said, it will easily be understood that high degrees of myopia are less likely to remain stationary than slight degrees are; at a more advanced time of life they even continue to be developed, with increasing atrophy of the membranes. In youth, almost every myopia is progressive; the increase is then often combined with symptoms of irritation. This is the critical period for the myopic eye: if the myopia does not increase too much, it may remain stationary, and may even decrease in advanced

age; if it is developed in a high degree, it is subsequently difficult to set bounds to it. At this period, therefore, the above-mentioned promoting causes should be especially avoided. On this point I cannot lay sufficient stress. Every progressive myopia is threatening with respect to the future. If it continues progressive, the eye will soon, with troublesome symptoms, become less available, and, not unfrequently, at the age of fifty or sixty, if not much earlier, the power of vision is irrevocably lost, whether through separation of the retina from the choroid, from the effusion of blood, or from atrophy and degeneration of the yellow spot."

It is of great consequence in myopia that the glasses should be selected with accuracy and care, and that we should be guided in their choice by the individual peculiarities of each case. For if they are unsuitable, more particularly if they are too strong, they may prove most injurious to the eyes.

In selecting spectacles for short-sighted persons, we should, in the first place, determine with exactitude the degree of myopia, by ascertaining the position of the far point. We find, for instance, that the patient cannot see at a distance, being unable to decipher No. *cc* at a distance of 20′. We next ascertain the furthest distance up to which he can read No. 1 with ease and comfort.

Let us suppose that he is able to do so up to 10″ from the eye, his far point (*r*) consequently lies at 10″, and his myopia = $\frac{1}{10}$. With a concave lens of 10″ focus he would be able to unite parallel rays upon the retina, as this glass would render parallel rays so divergent as if they came from 10″ in front of the eye. The position of the far point at the same time affords us a clue as to the number of the glass which the patient will require for distant objects. In this case it would be about concave 10. But although, theoretically, a glass of 10 inches focus would be the proper one, we find that, practically, it would be somewhat too strong. The reason of this is to be found in the convergence of the optic axes, which prevents the eye from accommodating itself for its far point, the latter being only attainable when we look at distant objects with parallel optic axes. We, therefore, find that the patient in our supposed case, would require about concave 12 for distance.

We may easily determine whether or not the glass thus found accurately suits the patient's sight. In order to ascertain this fact, we try whether

with this lens he can read No. XX distinctly at a distance of 20 feet. In the case before us, the trial lens would be about concave 12. We find that with it he can read each letter of No. XX with fluency and ease. We next alternately place very weak concave and convex lenses before the spectacles, and try their effect. If slightly concave glasses improve the vision, the original glasses (No. 12) are too weak; if, on the other hand, convex glasses improve it, they are too strong. If neither the one nor the other render any improvement, the spectacles suit exactly. Let us illustrate this proceeding by the following simple examples :—

A comes to us with a myopia = $\frac{1}{10}$. We give him concave glasses of 10″ focus, and desire him to read No. XX at 20′ distance. He can do so, although the letters are not quite distinct and sharply defined. We then place No. 60 convex before the spectacles, and find that this renders the letters clearer; convex 50 improves vision still more, with it he can see the individual letters most distinctly; but convex 40 renders them more indistinct. The original glass (concave 10) is consequently somewhat too strong, and, in order to suit the patient's sight exactly we must deduct 50 from it. The glass required is therefore

$\frac{1}{10} - \frac{1}{50} = \frac{1}{12\frac{1}{2}}$. We then try concave 13, and now find that neither concave nor convex glasses render any improvement. He is, therefore, accurately suited.

B also appears to be suffering from a myopia $= \frac{1}{10}$. He is tried in the same way as A with concave 10. In his case, however, we find that convex glasses render his vision more indistinct, but that concave glasses improve it—concave 50 most of all; we have, therefore, to add this number to the original glass (No. 10), which was too weak. The glass required will therefore be found thus, $\frac{1}{10} + \frac{1}{50} = \frac{1}{8\frac{1}{3}}$. We then try concave 9, and find that vision is not further improved by the addition of any concave or convex glass. It is, therefore, the proper lens. It may be laid down as a rule that the *weakest* glass with which the patient can see distinctly at a distance should be given.

A short-sighted person may desire to have spectacles which enable him to see objects at a distance of about two feet (for instance, the music whilst he is playing the piano). Let us suppose that he requires concave 12 for distant objects. How are we to find the right number for objects at 2′ distance? Simply thus: If his myopia equals about $\frac{1}{12}$, the number required for objects at 24″ will be found thus: $-\frac{1}{12} + \frac{1}{24} = -\frac{1}{24}$. Hence concave 24 will suit him for seeing at 2′ distance.

In the same way we can find what glasses are required for reading at 1′ distance in a myopia $= \frac{1}{6}$; $-\frac{1}{6} + \frac{1}{12} = -\frac{1}{12}$. Concave 12 would be required for this purpose. We shall, however, find that the patient requires a somewhat weaker glass, because the convergence of the optic axes to a point 12″ distant, already necessitates an accommodation for a nearer point.

As the amount of the range of accommodation which the patient possesses very materially influences our choice of spectacles, and the question whether or not they are to be used for near objects, we must, in the next place, shortly consider how the range of accommodation is to be tested in a myopic eye, we may do this in two ways:—

1. We let the patient read No. 1 of the test-types, and by alternately moving it nearer and further from the eye, we ascertain his near (p) and far (r) point. Let us suppose that $p = 3''$, and $r = 6''$. His range of accommodation is found by the formula—

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}, \text{ therefore } \frac{1}{A} = \frac{1}{3} - \frac{1}{6} = \frac{1}{6}.$$

2. Donders has lately, however, preferred the following plan :—He gives the patient those glasses which neutralize the myopia, and enable him to see distant objects distinctly (by means of which he can, therefore, unite parallel rays upon the retina). Let us again suppose that No. 10 (concave) is the weakest glass with which he can read No. XX quite distinctly and sharply at 20′ distance. His far point will therefore, with concave 10, lie at infinite distance (∞). With the same glass we now try how near he can read No. 1 comfortably, and with ease; let us suppose that this be at 5″, $\frac{1}{A}$, therefore, $= \frac{1}{5}$, for $r = \infty$, $p = 5$, $\frac{1}{A} = \frac{1}{5} - \frac{1}{\infty} = \frac{1}{5}$.

The great advantage of this method is, that the patient really accommodates for his far point which is not the case in the former plan; for owing to the amount of convergence at 6″, the patient cannot sufficiently relax his accommodation to accommodate for his far point.

In determining the degree of myopia, and in examining the range of accommodation, both eyes may be at first examined together, but they should then be always tested separately. For although we find in the majority of cases that the myopia is nearly the same in degree in both eyes, we occasionally meet with a very marked difference, which may demand glasses of different focus for the two eyes. This question will, however, be fully considered in the article upon spectacles.

Short-sighted persons often inquire whether they may wear spectacles for distant objects, or whether this would injure their sight and tend to a rapid increase of the myopia. Now, there cannot be any harm in giving them suitable glasses for distance. By so doing, we neutralize the myopia and change their eyes into emmetropic ones, and thus enable them to unite parallel rays upon the retina. We should, however, prescribe the weakest glass with which the patient can see clearly and distinctly at a distance, so that he may only require to make use of a minimum of his power of accommodation, and not have to strain it unduly when he is observing near objects. For we must remember that he will but seldom have to look for any length of time at a distance, but will alternately observe near and distant objects; one moment looking at something on the opposite side of the street, the next into a shop window, or at some object near at hand. Now if the glasses are too strong, he is already obliged to use more than a minimum of his power of accommodation when he is observing distant objects, and will consequently have to make use of a still greater amount (perhaps almost the whole) when he is looking at things but a short distance from him. This would soon lead to an increase of the myopia.

If the myopia is only moderate in degree, and if the range of accommodation is good, we may permit the use of glasses which entirely neutralize the myopia, such in fact as enable the patient to see as well at a distance as a normal eye, and render his eye emmetropic. If the patient is young, if the range of accommodation is good, and the degree of myopia moderate, such glasses should be worn not only for distance, but even for near objects, as in reading, writing, sewing, etc. Donders has indeed found that the myopia is, under such circumstances, remarkably little progressive, and he thinks that the use of glasses in myopia should be commenced early in life.

But when the degree of myopia is considerable ($\frac{1}{5}$ or $\frac{1}{6}$), the range of accommodation diminished, and the acuteness of vision impaired, it is not advisable completely to neutralize it. We should then give the patient weaker glasses, and permit him the use of a double eye-glass to hold before the spectacles when he desires to see a distant object very distinctly.

If persons desire spectacles to enable them to see objects at a distance of 18″—24″, as for

instance, the music in playing the piano, it is generally best to furnish them with glasses that bring their far point to this distance, for if the myopia is at all considerable, and they use completely neutralizing glasses, these are sometimes found to inconveniently diminish the size of the music, and render it somewhat indistinct and difficult to decipher.

It is still a somewhat debated question whether myopic persons may be allowed the use of glasses in reading, writing, etc. Where the myopia is but slight in degree, so that the person is not obliged to approximate the work very closely to the eye, they may be dispensed with. But just in these cases we find that the myopia may be completely neutralized, and the glasses used with advantage for all purposes. Where the short sight is considerable, so that the far point lies very near the eye, and necessitates a close approximation of the object, it is advantageous to give glasses which will remove the far point to a distance of 14—16 inches, so as to prevent the necessity of stooping, more particularly if the patient is tall and much engaged in writing. This habit of stooping gives rise to an increased flow of blood to the eye, and to an increase in the tension of the fluids within the eye. And this undoubtedly greatly tends to promote the development of sclerotico-choroiditis posterior, effusions of blood, and detachment of the retina, which are so apt to occur in short-sighted persons. On this account, we should, therefore, always direct myopes to read with their head well thrown back, and to write at a sloping desk.

But the strong convergence of the optic axes, which takes place when the object has to be held close to the eye, is also a source of great danger, for it is always accompanied by an increased tension of the eyeball and of the accommodation. The latter is an associated action, not arising from the mechanism of the convergence, but existing within the eye itself, and may, consequently, easily give rise to an increase of the myopia. But besides this, the pressure of the muscles upon the eyeball is greater when the optic axes are convergent than when they are parallel, and this increase of pressure must tend to give rise to the development of posterior staphyloma, and to hasten its progress. The increase in the tension of the eyeball is particularly marked when the internal recti muscles are weak, and thus render the convergence of the optic axes more difficult.

Now if we afford such very short-sighted persons the use of glasses which enable them to read and write at a distance of 14—16 inches from the eye, we do away with the necessity of a considerable convergence of the optic axes, the stooping position, and the evils to which these give rise.

But it may, on the other hand, be urged that it is just in looking at near objects that myopic persons have an advantage, as they can see them remarkably distinctly. The great danger is, moreover, that after reading for some time with spectacles, the patient, on getting somewhat fatigued, is apt, instead of laying the book aside, to approach it nearer to the eye in order to gain larger retinal images, and thus to strain and overtax his power of accommodation. If, for instance, we give a patient, whose far point lies at 8″, a pair of spectacles which enable him to read at 12″—14″, he will, if not very careful, after a short time, almost insensibly bring the book nearer to his eyes, and thus be forced to make use of a greater amount of his accommodative power. If he does this frequently, the myopia will soon increase in degree.

Spectacles may also be used for near objects in those cases of myopia which are accompanied by muscular asthenopia (depending upon an insufficiency or weakness of the internal recti muscles), which manifests itself as soon as the patient has worked at near objects for a short time.

Whilst these forms of myopia may, with advantage, be permitted the use of spectacles for near objects, they must be forbidden if the range of accommodation is very limited, and if the patients suffer from such a degree of amblyopia (generally depending upon sclerotico-choroiditis posterior), that they are unable to read No. 2 or 3 of Snellen's types. The glasses will diminish the size of the letters, and, in order to see them under a larger visual angle, the patient will bring the object very close to the eye, which will cause the accommodation to be greatly strained, the intra-ocular pressure to be increased, and serious mischief will but too surely ensue. Hence spectacles should not be permitted for near objects when much amblyopia exists.

If the myopia is very considerable, we find that generally only one eye is employed for near objects, and the convergence of the optic axes therefore annulled. Donders says with reference to this point, "This appears to me to be often a desirable condition: in strong myopia binocular vision loses its value, and the tension which would be required for it cannot be otherwise than injurious. Now, in such cases, for reading no spectacles are given; in the first place, because the acuteness of vision has usually somewhat decreased, and the diminution

of concave glasses is now troublesome; in the second place, because, with the retrocession of r, injurious efforts at convergence and at binocular vision might be excited. In any case the spectacles should be so weak as to avoid these results."

The question as to the shape of the spectacles, and whether they are preferable to single eye-glasses, etc., is treated of in the chapter upon spectacles.

CHAPTER IV.

SCLEROTICO-CHOROIDITIS POSTERIOR.

We have already stated that this affection is but seldom absent in the more considerable degrees of myopia, and that it must be regarded as a grave complication, which, if progressive, may lead to very serious consequences. It is of very frequent occurrence, indeed Von Graefe states that out of a thousand cases of amblyopia, four hundred and twenty were due to it.

Symptoms.—The eyeball often appears larger, more prominent, and of an ovoid shape; the eyelids are more widely apart, which is particularly noticeable when only one eye is affected. The shape of the eyeball is changed, it appears lengthened in its antero-posterior diameter, it is more oval, and the infundibulum, or hollow, which appears in the normal eye between the outer canthus and the globe (when the eye is much turned inwards), has disappeared, so that the posterior segment of the eyeball looks lengthened and square, showing often also a bluish tint. If the disease is considerable,

the lateral movements of the eyes are often somewhat curtailed. The patients frequently complain of a sensation of tension and fulness in the eye, as if, as they often express it, the latter was too large for the socket; they also, at times, experience more or less circum-orbital and intra-ocular pain.

We can, however, only diagnose the disease with certainty by means of the ophthalmoscope, for a considerable posterior elongation of the eyeball (staphyloma posticum) may exist without any appearance of sclerotico-choroiditis posterior.

The ophthalmoscopic appearances are generally most marked and unmistakeable. The characteristic symptom is a brilliant white crescent at the edge of the optic nerve entrance, generally at the outer side (in the reverse image it will of course appear towards the nasal side of the patient). This crescent varies much in size, from a small white arc to a large zone, extending, perhaps, all round the optic nerve, and embracing even the region of the macula lutea; its greatest extent being always in the direction of the latter.* Its edges

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* We must, however, be careful not to call every little white rim at the edge of the disc sclerotico-choroiditis posterior, for this may be caused simply by the choroid receding somewhat from the papilla, and permitting the light to fall at this spot through the retina upon the denuded sclerotic, and thus affording the appearance of a white glisten-

may be either sharply and distinctly defined, or may be irregular, and gradually lost in the surrounding healthy structures; irregular patches of pigment are strewn about its margin, and also, perhaps, on its surface, so that little dark islets of varying size and form appear in its expanse. The crescent itself is of a brilliant white, so much so indeed, that the disc, by contrast, appears to be abnormally pink. On account of the white background, the small retinal vessels can be traced more distinctly, and their minute branches more easily followed, over this patch than in the neighbouring fundus. This white crescent is due to a thinning or atrophy of the stroma of the choroid (indeed, the latter has occasionally been found quite wanting in this situation); the pigment cells are not necessarily destroyed, but there is an absence of the pigment molecules, for the irregular black patches mentioned above, are pathological agglomerations of pigment. On account of the loss of pigment, and the atrophy or thinning of the stroma of the choroid, the glistening sclerotic shines through the latter, and lends the brilliant white appearance to the figure. The want of pigment also gives rise to

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ing rim. But this arc is very narrow, and there are no appearances of atrophy of the choroid, irregular patches of pigment, &c., at its edges.

the sense of glare which the patient experiences in a bright light. The amblyopia which frequently exists in this disease, is, undoubtedly, also partly due to this fact, for we find that the sight of such patients is often remarkably benefited by blue spectacles. As a rule, however, the amblyopia depends chiefly upon the disturbance in the intra-ocular circulation produced by the state of chronic congestion of the venous system of the eye. Hence, we find that the sight is generally greatly improved by depletion, and more especially by artificial leeches.

The retina generally suffers only in so far from this loss of pigment in the choroid, that a slight diminution in the distinctness of perception is produced. The "blind spot," answering to the optic disc, is somewhat enlarged, but this increase does not correspond at all to the size of the crescent, and vision is only impaired, not destroyed, in this extra portion of the blind spot. But sometimes there arises a state of great irritability of the retina, producing considerable amblyopia and disturbance of vision, together with photopsia and a feeling of pain and tension within the eye on the slightest exertion in reading, etc.

The disease may remain stationary or progress. In the former case, the myopia does not increase, the circum-orbital and intra-ocular pains diminish or cease, and, with the ophthalmoscope, we find that there is no increase in the size of the crescent, and that, perhaps, a regular deposit of pigment again takes place.

Far different is it if the disease progresses, which is generally the case when the atrophy is at all advanced. The myopia is then found to increase more or less rapidly, vision becomes dimmed or greatly impaired, the patients are often continually haunted by "blacks" floating before their eyes, which may assume all kinds of fantastic shapes, and are due to opacities in the vitreous humour. At other times, they are greatly disturbed by showers of bright stars and flashes of light, which are due to a state of irritation of the optic nerve and retina; and they become more and more dazzled by the light, on account of the increasing atrophy of the choroid and loss of the pigment. But the progress of the affection is best watched with the ophthalmoscope. The edges of the crescent show symptoms of hyperæmia and irritation, and become irregular and ill-defined. Small white patches show themselves around it (symptomatic of the progressive atrophy of the choroid), and these, gradually increasing in size, coalesce with each other and with the original

crescent, so that the latter may in time extend completely round the disc, which thus becomes embedded in a more or less broad, white, glistening ring, which extends chiefly in the direction of the yellow spot. In such cases, a superficial observer might suppose that the optic entrance was greatly enlarged, or even that the optic nerve (from the white appearance) was atrophied. On closer examination, however, the distinction between the entrance and the white zone is easy, for the entrance of the optic nerve looks abnormally pink, on account of the contrast with the bright white of the surrounding ring, and its vessels are more easily traceable over the latter than in the disc.

A similar process may also occur in the region of the macula lutea. Little white patches appear, which increase in size and coalesce, giving the whole an appearance of alternate white and dark reticulated spaces, the white spots being due to the sclerotic shining through the atrophied stroma and pigment layer of the choroid. Von Graefe thinks that the retina may, in this situation, participate more rapidly in the disease than otherwise, on account of its being thinner at this spot. If the atrophy of the choroid in the region of the macula lutea, as well as that around the optic entrance, progress, the two separate processes may gradually extend towards each other, (leaving less and less healthy structure between them), until they finally pass into each other and form one large white figure.

The occurrence of the disease at the macula lutea generally causes great impairment of vision, and the patients then also complain of the constant appearance of one or more central fixed blind spots (scotomata). It should be remarked, that these may be apparent to the patient, long before we are able to detect with the ophthalmoscope any corresponding changes in the region of the yellow spot.

Von Graefe has noticed the important fact, that the amaurosis in sclerotico-choroiditis posterior may be due to excavation of the optic nerve through increased intra-ocular pressure. Glaucoma has then supervened upon the original disease.

* "The eye then presents the following symptoms: it is abnormally hard, the sclerotic vessels perhaps somewhat injected, the anterior chamber of normal size, the pupil wide. On ophthalmoscopic examination, the optic nerve shows symptoms of excavation. The edge of the optic disc, contiguous to the arc, which was before indistinct, so that it was perhaps difficult to determine where the margin of the optic disc really began, now again becomes sharply defined. But there is no considerable change in the position of the vessels, they are only somewhat displaced and curved at the edge of the excavation, but the latter extends quite up to the margin of the nerve, which distinguishes it from the physiological cup, this being confined to the centre of the disc. Von Graefe at first only met with this glaucomatous condition, supervening upon sclerotico-choroiditis, in elderly persons, who were suffering from very considerable myopia, which had increased rapidly during their youth, but had afterwards remained nearly stationary. In elderly persons, this complication may be due to the fact that when the sclerotic becomes thickened with advancing years, it loses some of its elasticity, and cannot, as heretofore, yield to the increased intra-ocular pressure and bulge backwards (at the posterior staphyloma), and therefore the optic nerve entrance, which is the next least resisting part, will yield before the pressure and become excavated. In old persons the excavation is not generally of a deep form. He has lately, however, seen some cases of glaucoma following sclerotico-choroiditis posterior in young

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* Vide the author's work "Glaucoma and its Cure by Iridectomy," p. 40.

individuals; in all these the eyes appeared very prominent, the myopia varying from $\frac{1}{8}$ to $\frac{1}{24}$, the symptoms of increased tension were slight, and less than in the cases observed in older individuals, in two there was, indeed, no perceptible increase of tension. The excavation was deep and abrupt. Both eyes were generally attacked simultaneously.

"Iridectomy proves also most beneficial in these cases, saving the sight of eyes which would otherwise have become completely blind. But the operation must be performed very early, as no other remedy will stay the progress of the affection. Great care must, however, be taken that the aqueous humour flows off very slowly indeed, as there is in these cases (on account of the primary disease) great tendency to intra-ocular hæmorrhage, detachment of the retina, etc."

COMPLICATIONS. — *Vitreous Opacities.*— The vitreous humour almost always undergoes some changes in sclerotico-choroiditis posterior; indeed, Von Graefe thinks that two-thirds of the affections of the vitreous are due to this disease. Although it generally becomes fluid only at its posterior portion close to the retina, the synchysis may, though rarely, extend to the whole of the vitreous humour.

It is of much practical importance to distinguish between the pathological opacities of the vitreous humour, and the subjective physiological muscæ volitantes which are met with in perfectly healthy eyes (*Myodesopia*). These assume the most various shapes and appearances. Sometimes they look like small transparent discs or circles, which may be isolated or arranged in groups; or they may resemble strings of bright beads, or filamentous bands, which float about in all directions through the field of vision. They are generally due to minute beaded filaments or groups of granules in the vitreous humour, and are quite physiological, occurring more or less in all eyes. They are so minute that they are perfectly invisible with the ophthalmoscope, and this instrument is therefore of the greatest use in enabling us to distinguish between the physiological and pathological *muscæ volitantes*, for directly it reveals to us the presence of opacities in the vitreous, however slight they may be, we must regard them as pathological products. I must, however, mention in passing, that certain changes in the choroid and retina may give rise to fixed dark spots in the visual field (so-called "scotomata"). No careful observer could, however, confound these with the opacities in question.

Muscæ become very evident when the person regards some light and highly illuminated object, as, for instance, the bright clear sky, a very white wall, or the brightly illuminated field of the microscope, whereas, in a subdued light the floating bodies may be hardly, if at all, observable. They are also increased by fatigue of the eye from overwork, or when the retina is very sensitive and irritable ; the same often occurs if there is any disarrangement of the nervous system or of the digestive organs. The situation of the muscæ may be approximately ascertained, as was shown by Listing, by making the patient look through one of the minute apertures of the stenopaic apparatus, or a pin-hole in a card. Now, if the card is moved in a certain direction (*e.g.*, upwards), and the objects also move upwards, they are situated behind the pupil, whereas, if they move in the opposite direction, they lie in front of the pupil. The greater the degree of movement, the further does the object lie from the pupil.[*] The position of the objects can be estimated with still greater accuracy by Donders's mode of examination *à double vue.* He employs a diaphragm pierced by two small apertures, situated about one line from each other, so that two shadows are thrown upon the retina, and

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[*] Helmholtz Physiologische Optik., 150.

cover one another by nearly one half.[*] We must distinguish the muscæ which have their seat in the vitreous humour from the appearances produced by eyelashes, muco-lachrymal drops on the conjunctiva and cornea, and the radii and spots situated in the lens. For full information upon this interesting subject of Entoptics, I would refer the reader to Dr. Jago's admirable and exhaustive treatise.[†]

Short-sighted persons are especially troubled by muscæ, for even the physiological motes are rendered peculiarly marked and distinct by the size of the circles of diffusion upon the retina. In consequence of this, they often prove a source of the greatest anxiety and trouble to the patient. Already, perhaps, in constant dread that his myopia should rapidly increase, and lead eventually to great impairment of sight, or even total blindness, the appearance of these muscæ often frightens him greatly, and causes him to yield undivided attention to his eye sight, and to watch every symptom with anxiety. This is more particularly the case with those persons who are dependent upon their sight for their livelihood, or are naturally of a

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[*] Donders's "Anomalies of Accommodation and Refraction," 201.

[†] "Entoptics, with its use in Physiology and Medicine," by James Jago, M.D., 1864 (Churchill).

nervous and anxious temperament. Even although we may earnestly and repeatedly assure them that these physiological motes are not of the slightest importance, and are a source of no danger, we but too frequently fail to alleviate their mental distress. They seek advice from others who, in their opinion, are more competent and willing to understand the nature of their complaint. Amongst such patients the charlatan finds his most fervid and profitable followers. I have met with several most distressing cases, in which advertising quacks have greatly frightened patients who complained of their motes, assuring them that they depended upon some secret disorder, and if not speedily and properly treated, that they would lead to amaurosis, of which, indeed, they were the sure precursory symptoms. Such patients must be cheered up, and prevented as much as possible from thinking of their ailments. Their general health must be strengthened, and any irregularities of the circulation or digestive organs removed. Much benefit is often also produced from the use of dark blue or neutral tint eye-protectors, as they diminish the intensity of the light, and thus render the muscæ less visible.

The presence of opacities in the vitreous humour may be best ascertained by examining the eye in

the direct method. The patient should be told to move his eye repeatedly in various directions, which will cause the moveable opacities to float about, and will enable us to judge of their size and number, and to distinguish between them and those that are fixed.

We should always regard opacities in the vitreous humour with anxiety, if they are numerous or very diffuse, and if the myopia is progressive. The opacities may be of various kinds. The patient at first, perhaps, only notices a dark speck, which he cannot wipe away; afterwards, thin, flaky membranes may appear, which float about before the eye, assuming different forms and positions with its every movement. These opacities generally throw a shadow upon the retina, the more so in proportion to their proximity to the latter; if they lie further off, they may not throw individual shadows, but only cause a general dimness of vision. With the ophthalmoscope, we can readily distinguish them as dark, fixed, or floating bodies of varying size and shape. Sometimes, however, they are so delicate and fine that we cannot individualize them, the whole fundus only appearing more or less hazy and indistinct.

A more dangerous form of opacity is that in which the vitreous becomes suddenly and diffusely clouded, so that we cannot thoroughly illuminate any portion of the retina with the ophthalmoscope; the whole looks clouded and indistinct. These sudden attacks of haziness may recur several times; and then, when the dimness at length disappears, and we can again examine the fundus with the ophthalmoscope, we but too often find that the retina has become detached.

Pigmentation of the Retina.—As the sclerotico-choroiditis posterior progresses, the retina may become infiltrated with pigment from the choroid, and thus a considerable impairment of vision may result.

Detachment of the Retina.—This is but a too frequent complication; indeed it occurs more often in myopic eyes, particularly those affected with sclerotico-choroiditis posterior, than in any others. The extent and the degree of detachment may vary very considerably. In some cases, it is only very slightly detached from the choroid, and would easily escape the notice of any but a skilled and close observer. In others, it is apparent at a glance, a considerable portion being detached and floating loosely about like a bluish grey cloud.

It chiefly arises in two ways.

1. On account of the retina not following the traction of the choroid and sclerotic (which bulge

posteriorly), a serous, or hæmorrhagic effusion may occur between the retina and choroid, and the former be partially or entirely detached. The detachment generally occurs at the lower portion of the retina, owing to the gravitation of the fluid. It may, however, be at first slightly detached at the upper or any other part; but in the course of a few days or weeks we invariably find that the detachment has extended to the lower portion. Our attention should be particularly directed to this complication, if we find that the upper or lower half of the field of vision has become indistinct, or if the patient complains of a cloud, like the "peak of a cap," hanging before his eyes, and if he sees objects broken or notched.

The effusion may, however, burst through the retina into the vitreous without detaching the former.

2. Heinrich Müller has pointed out[*] that detachment of the retina may not only occur through the pressure of fluid from behind, but also through traction from before. The latter is thus produced:—when the exudations in the vitreous humour shrivel up and contract, they, being also attached to the retina, draw the latter forward and detach it from the choroid.

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[*] Von Graefe's Archiv. iv, i, 372.

Opacity at the posterior pole of the lens sometimes occurs in the later stages of sclerotico-choroiditis posterior: this opacity, as it is situated generally very close to the "turning-point" of the eye, retains its position in whichever direction the eye is moved. Cataracta accreta and atrophy of the globe may close the scene.

Causes.—The origin of the affection is still a matter of controversy. Without doubt, there generally exists a congenital (and often hereditary) tendency to elongation of the eyeball in the optic axis; and this must necessarily cause a stretching of the choroid in this direction, which is generally soon followed by consecutive atrophy of this membrane. The development of this prolongation of the visual axis is greatly favoured by the strong convergence of the optic axes, and the state of congestion of the eye which is produced during accommodation for near objects, more particularly if these are small and insufficiently illuminated. For during such accommodation, a certain pressure upon the eye always occurs, accompanied by increased intra-ocular pressure; the venous circulation within the eye becomes retarded, and a more or less considerable state of mechanical congestion is produced. Instances of such intra-ocular congestion are furnished by cases of amblyopia due to

opacities of the cornea or lens, in which the myopia is caused by the patients bringing small objects very near to the eye, in order to gain larger retinal images. A similar thing may occur if the patient, whilst using spectacles for reading, gradually approaches the book too near to his eyes. We occasionally find that vitreous opacities, and even detachment of the retina, occur in such cases soon after continued reading or working with spectacles.

This state of congestion and increased pressure of the intra-ocular fluids leads to softening and extension of the tunics of the eyeball. As the eyeball receives no support at the posterior pole from the muscles, the prolongation occurs chiefly at this point, the choroid is stretched and generally undergoes consecutive atrophy.

This secondary atrophy of the choroid, which gives rise to the crescentic white patch at the margin of the optic disc, has been considered by Von Graefe to be most likely due to a chronic inflammatory process of the sclerotic and choroid, and he has, therefore, designated it sclerotico-choroiditis posterior. Others, again, have thought that it depends upon a circumscribed staphylomatous bulging of the sclerotic at this part, and hence they have termed it staphyloma posticum.

But against both these opinions exception might be taken.

We find that this choroidal atrophy often exists without any posterior staphyloma. Indeed Schweigger states that a real staphyloma posticum, *i.e.*, a more or less sharply defined local ectasia of the walls of the eyeball, does not take place in the majority of cases of myopia. The presence of a posterior staphyloma may be diagnosed by means of the ophthalmoscope, particularly with the binocular, for we then see that the white, shining portion of the sclerotic, exposed through the thinning of the choroid, is not of normal curvature, but is peculiarly cupped backwards, giving rise at this point to a slanting position of the optic disc. Schweigger, moreover, thinks that the acuteness of vision is diminished to an unusual degree in cases of myopia in which posterior staphyloma exists beside the optic nerve. This is the more likely to happen, as he has observed that in cases in which the existence of a posterior staphyloma was proved anatomically, the retina in the expanse of the bulging portion was generally found to be more or less changed in structure, and even atrophied and adherent to the remains of the choroid and sclerotic.

In opposition to Von Graefe's view, it has been urged that all symptoms of irritation and inflammation are frequently completely absent, at least at the commencement of the affection, and that the latter may even attain a considerable degree without their presence. But there is no doubt that such symptoms are almost always developed when the disease becomes considerable, and the myopia is high in degree. In the slightest forms, they may be easily overlooked, but even in moderate degrees of myopia, and in youthful individuals, we not unfrequently observe symptoms of irritation, such as hyperæmia of the optic nerve, retina, and choroid, and it appears probable that a state of irritation, if not of inflammation, exists prior to the atrophy. Donders thinks, "that almost without exception, the predisposition to the development of staphyloma posticum exists at birth; that it is developed with symptoms of irritation, which, in a moderate degree, do not attain any great clinical importance; but that in the higher degrees an inflammatory state almost always occurs, at least at a somewhat more advanced time of life, as a result, and as a co-operative cause of the development of the distension and of the atrophy."

It has also been urged, that either no inflammatory products, or only very few, are to be met with after death.

Von Graefe freely admits that exception may be taken to his opinion, that the disease is due to a chronic inflammation, for he says :—" In opposition to this view it might certainly be objected that in reality inflammatory products are wanting in both tunics (sclerotic and choroid), but the considerable hyperæmia of the choroid itself, the changes in its pigment, the obliteration of the ciliary vessels, and the atrophy in the posterior portion of the tunic, the deranged nutrition of the vitreous humour, the frequent combination with hæmorrhagic processes, and, finally, the beneficial action of antiphlogistics, all these furnish reasons why the affection should not be regarded only as the result of a simple passive distension, but as a chronic state of inflammation."

Jaeger considers that this crescent or posterior staphyloma, as he terms it, is almost always congenital and often hereditary. It may, indeed, exist for many years, or even throughout life, without increasing in size, or without the occurrence of any choroidal changes in its vicinity, its margin remaining distinctly and sharply defined. But we more frequently find, if the eyes are much used and the myopia increases at all considerably in degree, that the edge of the crescent becomes somewhat irregular and broken, and gradually augments in size; this being evidently due to

inflammatory changes in the choroid. Indeed it may well be questioned whether even the congenital crescents may not be of inflammatory origin.

Prognosis.—This should be always very guarded when the disease is at all advanced, when the myopia is progressive, and when the opacities in the vitreous humour are considerable. It becomes still more questionable if the vitreous opacities are diffuse, or large and numerous; if the upper or lower portion of the visual field becomes clouded, which is premonitory or symptomatic of detachment of the retina; and, lastly, if the choroidal changes make their appearance in the region of the yellow spot. They show themselves in the form of small, isolated, whitish spots, around the edges of which there are little accumulations of pigment; these small whitish spots increase in size, coalesce, and then the atrophy of the choroid becomes very apparent. During this process the retina is more or less irritated, and this produces dimness of vision, which however disappears again when the retinal irritation subsides. These atrophic changes in the region of the yellow spot give rise to fixed black spots, which, if considerable, may render working at small objects completely impossible. These changes in the macula lutea generally commence first in one eye, and may for a time be confined to it, but they almost always extend, sooner or later, also to the other eye. The amblyopia dependent upon general irritation of the retina, which has already been mentioned, is often greatly relieved by careful treatment, and by strictly guarding the eyes against everything that may give rise to, or increase such a state of irritation.

The prognosis to be made in detachment of the retina, must depend upon its situation and extent. If it is far removed from the yellow spot, and only slight in degree, it may remain stationary for a length of time, and vision be but slightly impaired. I can recall to memory one case of extreme myopia in which a slight separation of the retina remained nearly completely stationary during a period of more than three years, the patient being able to read No. 2 of Jaeger. But if the detachment occurs in the region or vicinity of the yellow spot, or if it be very considerable and progressive, we must expect a very rapid deterioration of vision.

Treatment.—Patients suffering from sclerotico-choroiditis posterior should be particularly warned against working for any length of time at near objects, or with their head bent forward, for venous congestion within the eye is thus easily produced.

It is also very injurious to read in a recumbent position. The best posture for reading is, to sit with the head well thrown back, and to have the light falling on the book from behind, so that the page may be well illuminated, but the eye not exposed to the direct glare of the light. In writing, it is advantageous to use a sloping desk, so that the person need not stoop. If such patients are permitted the use of spectacles for reading and writing, we must particularly point out the danger of bringing the object too near when the eye becomes sometimes fatigued, as this will cause a strain of the accommodation. The work or book should then be laid aside until the eyes have been thoroughly rested. In extreme cases, we should strictly forbid all work at near objects, either with or without spectacles.

The irritation of the optic nerve and retina, which gives rise to the appearance of flashes of coloured light, or showers of bright stars, etc., is best relieved by the application of flying blisters to the temples or behind the ear. They may be with advantage repeated at intervals of six or eight days.

The feeling of glare and dazzling, of which many of these patients complain when in a bright sunlight or at the sea-side, may be effectually alleviated by cobalt blue spectacles. It was formerly supposed that the red rays of the spectrum were the most annoying and trying to the eye, and consequently green glasses (which exclude the red rays) were much in vogue. Now, however, it is a well known fact that it is not the red but the orange rays which are irritating to the retina ; and as blue excludes the orange rays, this is the proper colour for such spectacles. Another explanation of the benefit of blue glasses in such cases is that the blue colour makes less impression upon the retina, on account of its more eccentric position in the sun spectrum. London smoke-glasses are now much worn and highly recommended in England. They are undoubtedly very serviceable in those cases in which we desire to subdue and diminish, more or less, the whole volume of light and colour, as they produce about the same effect as if we place the patient in a somewhat darkened room. But this is not generally necessary in sclerotico-choroiditis posterior, or even in fact desirable, for we only want to cut off the irritating orange rays, which appear to contribute but very little, if indeed at all, to our power of distinction, for we can read just as far with blue spectacles as with the naked eye, which is by no means the case with smoke-glasses. The tint of the blue spectacles should not be too dark.

In very windy or dusty weather the patient should be directed to wear curved blue eye-protectors. These are bent in such a manner that they fit closely everywhere except at the temporal side, where they permit a sufficient amount of air to enter and to come in contact with the eye, to keep up the absorption of the conjunctival moisture. They are greatly to be preferred to the goggles with wire or silk sides, which keep the eye far too hot and close. These may be indicated if the patient is exposed to the atmosphere very soon after a severe operation, when the eye is still inflamed and very susceptible to cold, but for all other purposes the curved glasses are to be preferred.

If the parenchymatous changes in the choroid are at all considerable, we should always subject the patient to a prolonged course of small doses of bichloride of mercury ($\frac{1}{20}$—$\frac{1}{24}$ of a grain twice or thrice a day). In this, as in all the inflammatory changes in the choroid, its beneficial effects are generally very marked. Iodide of potassium is indicated if there is any syphilitic or scrofulous taint. As the patients frequently suffer from biliary and venous congestions, their general health must be particularly attended to, for we generally find in this disease that the state of the eyes is much affected by that of the general health. Derivatives acting on the skin and kidneys, hot stimulating foot-baths at night, &c., often also prove very beneficial.

If the eye is very irritable, if the external tunics of the eyeball are injected, if the optic disc appears reddened and hyperæmic, and if the patient experiences pain in and around the eye, together with a feeling of weight and heaviness in the eyeball, as if he can hardly keep his eyelids open, we must insist upon a complete rest of the eyes, and complete cessation for some length of time from all working at near objects. We must be extremely stringent in the enforcement of such directions, as the patients are too apt to resume work as soon as their eyes feel a little better, and then at once call up again all the symptoms of irritation and congestion, which may cause a rapid increase of the myopia and of any existing sclerotico-choroiditis posterior. Such cases are also much benefited by the use of stimulating lotions to the closed eye and its vicinity, by the eye-douche, and by the application of artificial leeches.

The best and cheapest form of eye-douche is the one commonly used abroad. This consists of a piece of india-rubber tubing about 4½ feet in length carrying a rose at one end, and at the other

a curved piece of metallic pipe, which is to be suspended in a jug of water placed on a high shelf. The fine jet of water thrown up through the rose will be about 12 or 15 inches in height, and the force with which it plays upon the eye may be regulated by approximating or removing this from the rose. This form of eye-douche is to be preferred to that which is applied by means of a cup to the eye itself, as the jet is in this case far too powerful and often increases, instead of allaying, the irritation. It is to be employed night and morning, or oftener, if the eyes feel hot, for two or three minutes at a time. The eyelids are to be closed and the stream is to play gently upon them. The water should not be too cold.

But of all remedies, I have found the most benefit from the application of the artificial leech (Heurteloup's) to the temples. I have often been able to relieve the irritation of the eye, and the peculiar feeling of heaviness and aching in the eyeball by its use, when leeches and other forms of treatment had proved of no avail. In order to act upon the intra-ocular circulation, it is necessary that the depletion should be rapid; for we find depletion by leeches to be perfectly useless in chronic inflammations of the inner tunics of the eye, whereas the effect of the artificial leech is very considerable. The instrument should be applied to the temple, and a tolerably deep incision made, so that the blood may flow freely and rapidly, without the necessity of any excessive "suction." One or two cylinders full (about one or two ounces) are to be abstracted, according to the requirements of the case. The screw should not be turned too quickly, as this often produces excessive pain. With a little practice the operation may be gently, yet effectually performed without any suffering. Hot fomentations should be applied afterwards, so that there may be free after-bleeding. As the abstraction of blood near the eye always causes considerable increase in the flow of blood to that part and its vicinity, the depletion should always be made late in the afternoon, so that the patient may retire to rest directly afterwards, and he should be kept in a darkened room till the next afternoon. At first, he will see a little dimly, but after 30—36 hours the beneficial effect of the bleeding will generally be very marked. But when the disease is very considerable in extent, and when there is any fear of detachment of the retina, its use is often dangerous, for the sudden relief of the intra-ocular circulation is followed by a severe reaction and temporary hyperæmia of the vessels of the choroid and retina, and hence an effusion of blood may take place and produce detachment of the retina.

CHAPTER V.

MUSCULAR ASTHENOPIA.

For the purpose of illustrating the symptoms presented by this affection, let us suppose that a short-sighted person (whose myopia = $\frac{1}{7}$) applies to us with the complaint, that after he has been reading without glasses for a short time, the letters become confused and blurred, and appear to run into each other, and that one line overlaps the other. These symptoms are caused by the weakness of the internal recti muscles, which are not sufficiently strong to maintain the requisite degree of convergence of the optic axes for 6″. This unsteadiness of fixation gives rise to more or less marked diplopia, and hence the lines of type look confused and double. At the same time, the patient experiences pain in and around the eyes, which, if he persists in reading, become red and watery, so that he is forced to lay the book aside. After resting for a short time, the reading may be resumed, to be, however, again interrupted by the same train of symptoms. These symptoms of muscular asthenopia, indeed, last longer after the cessation from work than those dependent upon the accommodative form. Upon examination, we find that the eyes look quite normal, that the acuteness of vision is perfect, and that the range of accommodation is good; but as the far point lies at 7″ from the eye, the patient will, if reading without spectacles, be obliged to hold the print nearer than this point (at about 6″). This will necessitate so considerable a degree of convergence of the optic axes, that the internal recti muscles may not be sufficiently strong to maintain it for any length of time, without becoming greatly fatigued, and at length giving way. In order to judge if such insufficiency of the internal recti muscles is present, we direct the patient to look steadily at an object (a pencil, or our uplifted forefinger), and then gradually approximate this to the eye. If the muscles are too weak, we find that when the object is brought to about 6″, one eye becomes a little unsteady and wavering in its fixation, and then gradually, or else suddenly and spasmodically, deviates outwards. The same deviation occurs when we cover one eye, so as to exclude it from participation in the act of vision, even perhaps if the object be some feet distant. Now, this deviation shows that the internal recti muscles are not sufficiently strong to keep up the

necessary amount of convergence (for 5″—6″) during reading. As soon as we exclude one eye (by covering it) from the act of vision, it follows its natural impulse, and deviates outwards, thus proving the weakness of its internal rectus. In order to avoid diplopia, this tendency to deviation is, however, suppressed by the patient when he looks at an object, as long as this is not approximated too closely. After a time, if he continues to work much at near objects, one eye moves outwards, and a permanent divergent squint is produced, the patient learning at the same time to suppress the image of the squinting eye, in order to avoid diplopia; but this active negation of the pseudo-image soon leads to weakness of the sight of the squinting eye. Other patients avoid the disagreeable symptoms of asthenopia by closing one eye whilst looking at near objects.

By means of prisms, we can in such cases easily satisfy ourselves of the diminished strength of the internal recti muscles, and the increased power of the external recti. Before explaining this mode of examination, it will be well to describe the different kinds of diplopia which are met with, and also to say a few words as to the action of prismatic glasses, as some of my readers may not be quite conversant with these subjects.

In explanation of diplopia and the action of prisms, I give the following extract from my Lectures on Strabismus.—"Med. Times and Gazette," 1862–3 :—

"An object only appears single when both optic axes are fixed upon it; any pathological deviation of either optic axis must necessarily cause diplopia, as the rays from the object do not then fall upon identical portions of the retina. The slightest degree of diplopia is that in which the double images are not yet distinctly defined (are masked), but seem to lie slightly over each other, so that the object appears to have a halo round it.

"We meet with two kinds of double images.

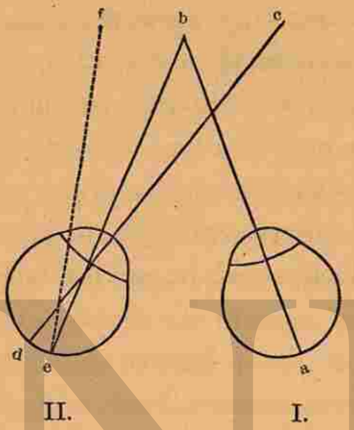
"1. *Homonymous* (or *direct*) diplopia in which the image to the right of the patient belongs to his right eye, the left image to the left eye.

"2. *Crossed* double images, in which case the image to the right of the patient belongs to his left eye, that on his left to his right eye.

"Homonymous diplopia is always produced in convergent squint, for if the eye deviates inwards from the object, the rays coming from the latter will fall upon the inner portion of the retina, and the image will (in accordance with the laws of projection) be projected outwards as in Fig. 18.

"Let I. be the right eye, whose optic axis is fixed upon the object (*b*). II. The left eye, whose

Fig. 18.

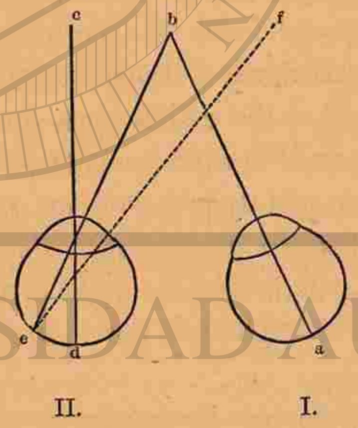


optic axis (*c d*) deviates inwards from the object, the rays from *b* therefore fall upon *e*, a portion of the retina internal to the macula lutea (*d*), and the image is consequently projected outwards to *f*; *b* and *f* are, therefore, homonymous double images, the image *b*, which is to the right of the patient, belonging to his right eye, the image *f* to his left eye.

"Crossed double images arise in divergent squint, for the one eye deviating outwards from the object, the rays from the latter fall upon a portion of the retina external to the macula lutea, the image is projected inwards, and crosses that of the other eye, as in Fig. 19.

"I. The right eye, whose optic axis (*a b*) is fixed upon the object (*b*). II. The left eye, whose optic axis (*c d*) deviates outwards from the object; the rays from the latter, therefore, fall upon *e*, a portion of the retina external to the macula lutea (*d*), and the image is projected to *f*, crossing the image *b*; the image *f*, which would lie on the patient's right hand, would, therefore, belong to his left eye, the image *b*, which would lie on his left side, to the right eye.

Fig. 19.



"If one eye squints upwards, the rays will fall upon the upper portion of the retina, and the image be projected *beneath* that of the healthy eye.

The reverse will be the case if the eye squints downwards, for then the rays fall upon the lower portion of the retina, and the image will be projected *above* that of the healthy eye."

We should never forget to ascertain whether the diplopia be monocular or binocular; if it be the latter, it will of course disappear upon the closure of the healthy eye.*

Let us now glance at the action of prisms. When a ray of light falls upon a prism, it is refracted towards its base. If, for instance, whilst we look at an object (*e.g.*, a lighted candle) at 8′ distance with both eyes, a prism, with its base towards the nose, is placed before the right eye, the rays from the candle will be deflected towards the base of the prism, and fall upon a portion of the retina internal to the yellow spot, and be consequently projected outwards, giving rise to homonymous diplopia. As we are, however, very suscep-

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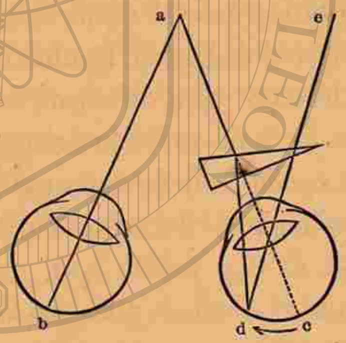
* "In examining the double images of a patient, it is convenient to place a slip of red glass before the sound eye, for we thus enable him readily to distinguish the two images by their colour, and we also weaken the intensity of the image of the sound eye, and approximate it more to that of the affected one, whose image, owing to the rays from the object falling upon an eccentric portion of the retina, will be less intense in proportion to the distance of the spot, upon which the rays fall, from the macula lutea."—Ophthalmic Hospital Reports, No. 9, p. 139.

tible of double images, the eye will endeavour to unite them by an outward movement (its external rectus becoming contracted), which will again bring the rays upon the yellow spot, but at the same time of course cause a divergent squint. Fig. 20 will explain this.

Fig. 20.



Let *a b* be the optic axis of the left eye, fixed (with the other) upon a candle 8′ off. Now, if a prism (with its base towards the nose) be placed before the right eye, the rays are refracted towards the base of the prism and do not, as in the other eye, fall upon the yellow spot, but on a portion of the retina (*d*) internal to the latter, and the image is projected outwards to *e*; homonymous diplopia therefore arises, and to avoid this the external rectus muscle contracts and moves the eye outwards, so as to bring the macula lutea *c* to that spot *d*, to which the rays are deflected by the prism. As the rays from the object will now fall in both eyes upon the macula lutea, single vision will result, accompanied, of course, by a divergent squint of the right eye.

The reverse will occur if we turn the prism with its base to the temple, for the rays will then be deflected to a portion of the retina to the outer side of the macula lutea, and the image will be projected inwards across that of the left eye, and crossed diplopia will be the result. In order to remedy this, the internal rectus will contract and move the eye inwards, so as to bring the macula lutea to that spot to which the rays are deflected by the prism. There will consequently be a convergent squint.

As the internal recti muscles are far more constantly used than the external, they gain a greater degree of strength than the latter, and can overcome far stronger prisms by a voluntary inward squint. In a normal eye, the internal rectus can generally overcome a prism of from 14° to 28°, whereas the external rectus cannot, as a rule, overcome one stronger than 5°—6°.

Prismatic glasses are of great value in ophthalmic practice, for they not only enable us to free a patient from the annoyance of diplopia, to exercise and strengthen a partially paralysed or insufficient muscle, but also to ascertain whether or not a person enjoys binocular vision (Gemeinschaftlicher Sehact), *i.e.*, sees with both eyes at the same time,—a fact which is of great importance with regard to the prognosis of the result of an operation for squint. If binocular vision exists, we may guarantee a perfect cure, without it, we can but promise an approximative one; for in the latter case there will not, of course, be any diplopia, and the perfect cure of squint depends, as we shall show hereafter, upon the presence of double images.

We should, therefore, in all cases of squint carefully ascertain whether there is binocular vision or not. Its presence is of course at once proved by binocular diplopia, for this cannot exist if the person only sees with one eye at a time. A person may see perfectly with either eye singly, or when both are open there may be no deviation of either optic axis, and yet he may not see with both eyes at the same time. In the majority of cases of squint, particularly if the affection has existed for some time, there is no binocular vision, the one image being suppressed, and there is consequently no diplopia; the sight of the squinting

eye is generally considerably impaired; occasionally, however, it is almost or even quite normal.

We may readily ascertain whether or not a person enjoys binocular vision by simply placing a prism before one eye. We should first, however, examine each eye separately, so that its degree of vision, range of accommodation, and state of refraction, may be accurately ascertained, notice being also taken whether its optic axis is fixed upon the object, or whether the eye "fixes" the latter with an eccentric portion of the retina and not with the macula lutea. The patient being ordered to look (with both eyes open) at a lighted candle placed at a distance of from six to eight feet, a prism with its base outwards is to be placed before one eye.

Let us now suppose it held before the right eye, —one of three things will occur:—

1. *Diplopia.*—The rays from the object will be deflected by the prism towards its base, and will consequently impinge upon a portion of the retina external to the macula lutea, and be, therefore, projected inwards, giving rise to crossed double images.

2. *Corrective Squint.*—Now, if the prism be not too strong, the right eye will, in order to overcome the annoyance of the diplopia, squint inwards, thus bringing the deflected rays once more

upon the yellow spot, and uniting the double images. We may, therefore, be certain that binocular vision exists, if, on holding a prism before one eye, diplopia or a corrective squint arises. If the base of the prism is turned outwards, the squint would be convergent, if inwards, divergent.

3. But the prism may have no effect whatever; it neither gives rise to diplopia nor to a squint, indeed the eye does not move at all. This proves at once the absence of binocular vision, and shows moreover, that the prism has been held before the eye which the patient does not use (although its sight may be perfect), for if we place it, still with its base outwards, before the other eye, the latter will move inwards, in order to bring the deflected rays once more upon the macula lutea; the other eye making at the same time an *associated* movement outwards, so that, although the one eye moves inwards, there will be no corrective squint, the other eye counterbalancing the inward by an associated outward movement. The eye which, when a prism is interposed, moves towards the refracting angle of the latter, is the one commonly used, whereas the other eye, which makes an associated movement, is the one excluded from binocular vision.

Binocular vision is frequently only lost in certain portions of the retina, particularly in those which, though not identical with, are constantly excited simultaneously with the central portion of the retina of the other eye.

Thus in convergent strabismus we find that in the squinting eye, the portion of the retina which lies internal to the yellow spot is the first to suffer a loss of binocular vision, for it is directed towards the object, and is, therefore, (though not identical with it) constantly excited simultaneously with the central portion of the retina of the other eye, which is fixed upon the object. The reverse occurs in divergent squint, for there the external portion of the retina is the first to fail. At first, this loss of binocular vision only extends horizontally, so that if we turn a prism with its base upwards or downwards (or place it even in a diagonal position), we at once produce double images, which show not only a difference in height, but also, if there is any squint, a lateral difference. We may thus determine, with the greatest nicety, which part of the retina has lost the power of binocular vision. Sometimes, it extends over the whole retina, so that we fail to produce diplopia even with the strongest prisms turned in any direction; at others, this loss of binocular vision is tolerably circumscribed, being confined to a very small portion of the retina. In convergent strabismus, for instance, only a small portion of the retina internal to the yellow spot may have suffered, so that on placing a prism with its base towards the nose before this eye, and deflecting the rays still more inwards, double images are at once produced, although the deflected rays now impinge upon a more eccentric, and, naturally, less sensitive portion of the retina. Occasionally, we may in such a case also produce diplopia, if we bring the rays nearer to the macula lutea by means of a prism. Thus, through a sudden alteration of the position of the optic axis of the affected eye, diplopia may be at once induced; as, for instance, after the operation for squint, or in cases of paralysis or spasm of the other muscles of the eyeball.

Prismatic glasses, therefore, afford us an excellent test of the relative strength of the internal recti muscles. Now, in insufficiency of these muscles we find that their strength is greatly diminished, so that they may perhaps only overcome a prism of 4° or 5°, instead of, as in the normal eye, one of 16° or 24°, or even 30°. The external recti, on the other hand, gain unusual strength in such cases, on account of the diminished force of their opponents, and may now be able to overcome prisms of 14°, 16°, or even 20°.

In testing the relative strength of the muscles with prismatic glasses, the object (a lighted candle is the best) should be placed at a distance of 7—8 feet. If the patient is short-sighted, he should be furnished with the concave glass which will enable him to see the object distinctly and clearly defined. Von Graefe has pointed out the interesting fact, that the power of overcoming prisms by the action of the external rectus (voluntary abduction) increases as the object is brought nearer to the eye. He himself is able (the object being placed at a distance of 6′) to overcome a prism of 30° through adduction (action of the internal rectus), and one of 6°, through abduction (action of the external rectus). When the object is, however, brought to 1′ he can overcome a prism of 16° through abduction, and at 8″ one of 22°. The power of the internal rectus appears to remain about the same up to a distance of 8″, but it becomes somewhat diminished when the object is brought nearer than this.

The diagnosis of insufficiency of the internal recti muscles may be made either by approaching an object close to the eye and watching whether the fixation remains steady, or whether one eye becomes unsteady and moves outwards. Or, whilst the patient is regarding an object at 10″—12″ distance, we may cover one eye with the palm of our hand, so as to exclude it from participation in the act of vision, and the same outward deviation will then occur in the covered eye, if its internal rectus is insufficient; for as there is now no longer any visual impulse to regulate the position of the optic axes, the covered eye follows the action of the stronger muscle.

This test is applicable in marked cases of insufficiency, where the deviation is considerable enough to be at once apparent; but in slight cases it may be so small as to be inappreciable by the eye, although the double images may be very evident to the patient. It is, therefore, far better to make use of a prism to detect these slighter cases. This should be placed with its base upwards or downwards so as to produce diplopia; the double images will then not be fused into one, as the eye cannot unite double images which show a difference in height.

We have seen that the normal eye may be able to overcome a prism of 20°—30° with its base turned outwards, and one of 6°—8° with its base turned inwards, but very few persons can overcome more than a prism of 1° with its base turned upwards or downwards. In consequence of this, double images will, therefore, be produced, the visual impulse will be annulled, and the eye yield to the prepondering influence of the strongest muscle. In the normal eye the muscles are equally balanced, and the double images will only show a difference in height, standing straight one above the other. But if either the internal or external rectus considerably exceeds the normal standard of strength, the double images will not only show a difference in height but also a lateral difference. If the internal rectus is insufficient, the eye will move outwards when a prism is held with its base upwards or downwards, and there will, consequently, be not only a difference in the height of the double images, but they will also be crossed, on account of the divergent squint. We may then easily express the degree of insufficiency by the degree of the prism (base turned inwards) which is required to bring the double images one above the other. This mode of examination is particularly recommended by Von Graefe, who proposes the following plan:—A dot is drawn on a piece of paper, and is then bisected by a fine vertical line (Fig. 21). This paper is placed at the usual distance of reading or writing, and the patient is directed to regard the dot with both eyes. A prism of 14° (with its base upwards) is then to be placed in front of one eye. This will at once produce diplopia, and the image of the eye before which the prism is held will be beneath that of the other eye. If the eyes are normal, the double images will only show a difference in height, but not any lateral difference, they will lie straight above one another. But if the internal rectus is insufficient, the eye moves outwards, and consequently the double images will not only show a difference in height, but also a lateral difference, and they will be crossed. We next try what prism (with its base inwards) is required to neutralize the effect of this deviation, and bring the images straight above each other. In order to ascertain whether the images are crossed or homonymous, we place a slip of red glass before the other eye, and this will enable us at once to distinguish which image belongs to the left and which to the right eye. After the presence and degree of insufficiency have been thus determined, we should proceed to test the relative strength of the internal and external rectus of each eye, by ascertaining the strongest prism which they are able to overcome.

Fig. 21.

Although insufficiency of the internal recti muscles occurs chiefly together with myopia, it is occasionally also met with in emmetropic and hypermetropic eyes. Indeed it is far more common than is generally supposed. It will be self-evident that a short-sighted person will have to approximate small objects more closely to the eye than an emmetropic individual, and that the internal recti muscles will, therefore, have to maintain a greater degree of convergence; if the myopia is very considerable, they may be unable to do so for any length of time without becoming over fatigued and symptoms of asthenopia arising. This constant fatigue will soon weaken them and lead to still greater insufficiency. Diseases which greatly weaken the general system, such as severe fevers, diphtheria, &c., may also produce a temporary insufficiency, which disappears, however, when the patient has regained his strength.

Cases of insufficiency of the internal recti muscles may be treated in different ways, according to whether our purpose is merely to alleviate, or to cure the affection. We may alleviate this muscular asthenopia in two ways:

1st. By permitting the use of concave glasses (if the patient is myopic) for reading and working at near objects. For if we give a patient, suffering from myopia = $\frac{1}{6}$, a pair of spectacles which enable him to read at a distance of from 12″ to 14″, the amount of convergence of the optic axes (and the consequent action of the internal recti) will be proportionately diminished, and he will now be able to read with more ease and comfort. But the spectacles act only as a palliative; indeed the internal recti muscles become weaker instead of stronger, for they will now have much less than their accustomed work. We must remember also the danger in using concave glasses for near objects, viz., that the patients are apt after a time, when their eyes get somewhat fatigued, to approach the object too near the eye, and thus to strain their power of accommodation. These spectacles should be slightly blue, as such eyes often suffer from photophobia.

2. The asthenopia may be alleviated by the use of prisms with their base turned inwards. Let us presume, for instance, that the tendency of the eye is to deviate outwards to about 1‴ during work at near objects; now, if we place a prism with its base inwards, of sufficient strength to exactly neutralize this deviation (by bringing back the retinal image to the macula lutea), we should enable the person to read with comfort, for we thus diminish the action of the internal recti and remove the

symptoms of asthenopia. It is not always necessary to neutralize the whole of the deviation, for weaker prisms will often suffice. It is always better to divide the prism between the two eyes, more particularly if it be stronger than 8°. If a prism of 10°, is required, we should order one of 5° for each eye. In myopia it should be combined with the requisite concave lens, whereas in hypermetropia, or in emmetropia if the range of accommodation is diminished, it is advisable to combine it with a convex lens, as the diminution in the convergence of its optic axes is accompanied by a diminution of the power of accommodation.

These prismatic glasses are particularly indicated in slight cases of insufficiency, or in those in which there is but a very limited power of abduction for distance, and hence the fear that a convergent squint might arise after division of the external rectus.

It has been thought that this affection may be cured by strengthening the internal recti muscles through constant exercises with prismatic glasses held with their base outwards before one eye, so that the rays from the light (to be placed at a distance of about 8′) will impinge upon a portion of the retina slightly to the outer side of the macula lutea. In order to avoid the diplopia arising from this, the eye will then move inwards, so as to bring the rays again upon the yellow spot.* By gradually increasing the power of the prism we exercise the internal rectus more and more, and it will soon acquire greater strength.

But this treatment requires great patience and accuracy, both on the part of the medical man and of the patient, and the latter generally soon gets wearied of these exercises, which, in order to secure anything like success, would have to be continued for a length of time. If the prism is chosen at all too strong, it will rather tend to weaken the muscle by over-exertion, than to strengthen it.

The best plan of treatment is division of the external rectus muscle. Our object in doing this is to strengthen the abnormally weak internal rectus by a division of its opponent muscle, so that the former will have a less resistance to overcome. Our primary object must always be to enable the patient to read, write, and work at near objects without any difficulty, and we must, of course, be chiefly guided in this by the state of refraction. If he is myopic, he will have to hold

the object much closer to the eye than if he is emmetropic or hypermetropic. If, for instance, he suffers from myopia = $\frac{1}{7}$, he will require to read at about $5\frac{1}{2}''$, and should be able to converge his optic axes steadily, and for some time, upon an object at $4''$. We must, above all things, endeavour to obtain this result, and it will not matter much if there should be a slight tendency to convergent squint when he is looking at distant objects; for in order to escape the diplopia consequent upon this, the external rectus will contract, and, by moving the eye slightly outwards, correct the squint, and once more bring both optic axes to bear upon the object. Of course the amount of convergence which may be safely permitted for distance, must depend upon the relative strength of the internal and external recti, and more particularly upon the power of abduction. If in a myopia of $\frac{1}{7}$, the internal rectus could, before the operation, only overcome a prism of 4° or 5°, but the external rectus one of 14° or 16°, it would be perfectly safe to permit a convergence of $\frac{1}{2}'''$ or $1'''$ for distance, more particularly if the excluded eye had, before the operation, deviated outwards $\frac{3}{4}'''$ or $1'''$ when covered. In such a case, even after its division, the external rectus would remain sufficiently strong to rectify the convergent squint.

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* Short-sighted persons must be furnished with concave spectacles during these exercises, so that they may see the object distinctly.

The following considerations must guide us as to the extent of the tenotomy:—

1. The degree of the myopia, and the consequent distance for which the optic axes must converge in reading, etc.

2. The strength of the prisms which can be overcome by the internal and external rectus. The strength of the prism which can be overcome for distance by the external rectus gives us a clue as to the extent of the tenotomy, for we may correct with safety the deviation outwards which corresponds to the strength of this prism. Von Graefe has found that the primary effect of the operation may even exceed this by $\frac{2}{3}$ or $\frac{3}{4}'''$, so that, at a distance, homonymous double images arise in the middle line, which require a prism of 10° to unite them. As long as this is not exceeded, we need not fear that the homonymous diplopia will remain permanently. In order not to be misled by the temporary insufficiency of the external rectus, it is better not to hold the object in the median line, but 15° or 20° to the nasal side of the operated eye (Von Graefe).

3. The degree of deviation outwards (in looking at distant objects), which occurs when the affected eye is covered. The less this power of abduction is, the more careful must we be with

the tenotomy. If the degree of insufficiency exceeds the prism which the eye can overcome at a distance by abduction, we must only partially correct the insufficiency, and limit the effect of the operation by a conjunctival suture. We may also assist the effect of the operation by using prismatic glasses, with the base inwards, for reading, etc. Where the power of abduction is extremely slight, and the insufficiency at a distance almost nil, tenotomy is contra-indicated, for it would be sure to be followed by a convergent squint, and consequent diplopia for distance. In such cases, the asthenopia must be alleviated by prismatic glasses.

4. The mode of deviation when the object is approximated to the eye. This test is, however, less accurate than the preceding ones. Von Graefe thinks that a considerable correction is indicated, if the eye moves suddenly and spasmodically outwards at the moment when the insufficiency of the internal recti shows itself; whereas we must be more guarded in the extent of the operation, if, as the object is brought gradually nearer to the eyes, the one moves outwards in about the same ratio as the other moves inwards, making an associated movement with this. Still more cautious must we be, if the affected eye

remains stationary at a certain point, without apparently deviating any further outwards.

If both internal recti are much weaker than normal, and if the deviation under the covered hand exceeds 1½‴—2‴, a double operation will be necessary. This, however, should never be done at one sitting. We should first divide the external rectus of the eye most affected, and then, after a few days, when the final result of the operation is apparent, the other eye must be carefully and accurately examined, in order to ascertain to what extent the insufficiency still remains, and to what extent the operation is indicated. It is always safest at the second operation to divide the abductor very carefully and very close to its insertion, and then to test the accommodative movements of the eyes, the amount of convergence at a distance, and the prism required to overcome the homonymous diplopia, and if the convergence at all exceeds our wishes, to insert a conjunctival suture.

As these cases of insufficiency frequently demand great nicety in the performance of the tenotomy, and as it is of the greatest importance that it should be efficiently executed, and all minutiæ carefully attended to, I give the following extract from my work on the Diseases of the Eye, p. 588, to which I would also refer the reader for further information upon the subject of strabismus.

"As the operation is sometimes very painful, the patient should be placed under the influence of chloroform. The eyelids are to be kept apart by the spring speculum, or, if this proves not sufficiently strong, by the broad silver elevators. An assistant should evert the eye with a pair of forceps (I am supposing that the internal rectus of the right eye is to be operated on), taking care to do so in the horizontal direction, without rotating the eyeball on its axis; otherwise, the horizontal position of the internal rectus will be changed. The operator should then seize, with a pair of finely-pointed forceps, a small, but deep fold of the conjunctiva and subconjunctival tissue, close to the edge of the cornea, and about midway between the centre and lower edge of the insertion of the internal rectus. He next snips this fold with the scissors (which should be bent on the flat, and blunt pointed), and burrowing beneath the subconjunctival tissue in a downward and inward direction, makes a funnel-shaped opening beneath the subconjunctival tissue, this being, however, done very carefully, so as not to divide it to too great an extent. If the subconjunctival tissue is thick and strong, it will be better first to take up only a small fold of the conjunctiva, to open this, and then, seizing the subconjunctival tissue, to divide the latter. The squint-hook (which should be bent at a right angle, and have a slightly bulbous point, vide Fig. 22) is then to be passed through the opening to the lower edge of the tendon. Its point being pressed somewhat firmly against the sclerotic, the hook is to be turned on the point and slid upwards beneath the tendon, as close to its insertion as possible, and the whole expanse of the tendon caught up. The operator must be careful not to direct the point of the hook upwards and outwards, otherwise it may perforate the fibres of the tendon, and only a portion of the latter be caught up; the direction of the point should, therefore, be rather upwards and inwards. When the tendon has been secured on the hook, the conjunctiva which covers its upper portion may be gently pushed off with the points of the scissors, so as to expose the tendon, which is then to be carefully snipped through with the scissors as closely as possible to its insertion. When it has been completely cut through, the conjunctiva is to be slightly elevated on the point of the hook, and

a smaller hook passed upwards and downwards to ascertain whether the lateral expansions of the tendon have been divided. Should a few fibres remain, they must be divided, and the surgeon should again ascertain whether any others are still present. He should never omit to satisfy himself upon this point, for sometimes the lateral expansions are considerable, the tendon spreading out like a fan, and although a few fibres only might remain undivided, they would suffice to spoil the effect of the operation.

Fig. 22.

"I have lately adopted a modification of Von Graefe's operation, and perform it more subconjunctivally. I use a pair of straight, blunt-pointed scissors, and, instead of pushing off the conjunctiva from the hook so as to expose the tendon caught up by the latter, I divide the tendon subconjunctivally, quite close to its insertion. In this way, the advantages of Graefe's and of the subconjunctival operation are combined. On account of the smaller size of the hook, and the situation of the incision (which is between the centre and lower edge of the tendon), the subconjunctival tissue is stretched and incised to a much less extent than in the subconjunctival operation. Again, the position and direction of the conjunctival wound are such that a suture can, if necessary, be at once applied;

whereas, in the subconjunctival operation the incision would have to be considerably enlarged upwards, before any effect could be produced by a suture upon the two cut edges of the tendon. But where the degree of strabismus is so considerable that it is certain no suture will be required, the subconjunctival operation may be employed; and also if we have no assistant at hand to roll the eye in the opposite direction.

"If it is found, on the first introduction of the hook, that it slides up to the edge of the cornea without having caught up the tendon, it is certain that we have either not divided the subconjunctival tissue at all, or that the hook has been passed between it and the conjunctiva. If the former is the case, we must open the subconjunctival tissue, and then, on re-introducing the hook, we shall have no difficulty in finding the tendon.

"Mr. Critchett's subconjunctival operation is to be performed as follows:—The patient having been placed under the influence of chloroform, and the eyelids kept apart by the stop-speculum, he seizes a small fold of the conjunctiva and subconjunctival tissue at the lower edge of the insertion of the rectus muscle, and with a pair of blunt-pointed straight scissors, makes a small incision at this point through these structures, or the conjunctiva

and subconjunctival tissue may be divided separately. The lower edge of the tendon, close to its insertion, is now exposed. A blunt hook (Fig. 23) is to be passed through the opening in the subconjunctival tissue beneath the tendon, so as to catch up the latter, and render it tense. The points of the scissors (but slightly opened) are then to be introduced into the aperture, and one point passed along the hook behind the tendon, the other in front of the tendon between it and the conjunctiva, and the tendon is then to be divided close to its insertion by successive snips of the scissors. A small counter-puncture may be made at the upper edge of the tendon to permit of the escape of any effused blood, and thus prevent its diffusion beneath the conjunctiva (Bowman)."

Fig. 23.

The after-treatment is very simple. The eye, after having been well washed and cleansed of any blood coagula, is to be kept constantly moist with cold water dressing during the day of operation, so as to prevent any extensive effusion of blood under the conjunctiva. No button of granulation will form on the stump of the tendon, if the latter has been divided close to its insertion, and if the opening in the conjunctiva has been made near the upper or lower edge of the tendon, so as not to leave the latter exposed.

The effect upon the squint, which follows immediately upon the operation, will not be the permanent one. We may, indeed, distinguish three stages in the effect produced by the operation :—1st. The period immediately following the operation ; 2nd. After three or four days have elapsed ; 3rd. After the interval of a few months,—this being the permanent effect. During the first stage the effect will be considerable, for the eye can now only be moved in the direction of the divided muscle, by the indirect connexion of the latter with the sclerotic by the lateral processes of the capsule of Tenon. As soon as the divided end of the tendon becomes reunited with the sclerotic, which generally occurs within three or four days, the effect will diminish, for the muscle now again exerts a direct influence upon the eyeball. This is the second stage. But we find that a further alteration in the position generally shows itself a few weeks or months after the operation, the effect being then somewhat increased. This is due to the action of the opponent muscle, which, on account of its antagonist having been weakened, can now exert a greater influence upon the position of the eyeball.

I have already stated that if both internal recti are very weak, a tenotomy of the two abductors may be indicated, but this should never be done at one sitting. A few days after the operation upon the one eye, the other should be carefully examined, in order that we may ascertain the degree of insufficiency which still remains, and the extent to which the operation is necessary. The external rectus of this eye should then be very carefully divided, and the accommodative movements of the eyes be tested, as well as the amount of convergence at a distance, and the prism which is required to unite the homonymous double images ; and if the convergence at all exceeds our wishes, a conjunctival suture should be at once inserted. The effect of the suture will vary with its position and with the amount of conjunctiva embraced in it. It will be greatest if it be applied horizontally over the centre of the tendon, so as to unite the middle portion of the edges of the conjunctival wound. The suture diminishes the effect of the operation by re-advancing the tendon, which is closely connected with the subconjunctival tissue ; the divided ends of the tendon will consequently be more closely approximated, and the retraction of the muscle diminished. The suture may remain in for from 24 to 36 hours.

CHAPTER VI.

PRESBYOPIA.

The first symptom of presbyopia is, that small objects (small type, fine needlework, etc.) cannot be seen with such ease, or so clearly as before; but for distant objects vision is perfect. In order to see minute objects more distinctly, the patient has to remove them further from the eye, or even to seek a bright light, so as to diminish the circles of diffusion upon the retina by narrowing the size of the pupil. But as the retinal images of these fine objects are very small, on account of the distance at which they are held, he will soon experience a commensurate difficulty in clearly distinguishing them, the print, for instance, will get indistinct and confused, and the eyes become fatigued and aching.

In simple presbyopia, the far point is at a normal distance from the eye, parallel rays are united upon the retina, and neither concave nor convex glasses (even after the instillation of atropine) at all improve distant vision. The eye is

neither myopic nor hypermetropic. There is in fact no anomaly of refraction, but only a narrowing of the range of accommodation; the near point is removed too far from the eye, and hence the difficulty of accurately distinguishing small objects.

Amblyopia sometimes co-exists with presbyopia, and may even be mistaken for it, as the amblyopic patient likewise cannot see small objects distinctly, and convex glasses also improve his sight by affording him larger retinal images. In a purely presbyopic eye (which is free from amblyopia), we should, by means of the proper convex glass, be able to restore a normal acuteness of vision and a normal range of accommodation. With this glass the patient should be able to read No. 1 of Snellen at a distance of about 8″. If he cannot do this, but only perhaps decipher No. 4 or 6, or if he is obliged to hold the object very near his eye (nearer than is warranted by its size), he is not only far-sighted, but also amblyopic. It may, therefore, be laid down as a practical rule that the nearer we can approximate, by means of convex glasses, the vision and range of accommodation of a presbyopic eye to that of a normal one, the less is the impairment of sight due to amblyopia, and *vice versâ*.

Donders has found that in the normal (emmetropic) eye the near point gradually recedes, even from an early age, further and further from the eye, and that, in consequence of this, vision of very minute objects becomes proportionately more and more difficult. This recession of the near point commences already about the tenth year, and progresses regularly with increasing age. At forty it lies at about 8″ from the eye, at fifty at 11″ or 12″ and so on. In the normal eye no inconvenience or annoyance is experienced from this recession till about the age of forty or forty-five.

This change in the position of the near point is met with in all eyes,—the emmetropic, the hypermetropic and the myopic (if the latter remains healthy).

But the far point also begins in the emmetropic eye to recede somewhat about the age of fifty, so that the eye then becomes slightly hypermetropic (distant vision being improved by convex glasses). At seventy or eighty years of age, the hypermetropia may $= \frac{1}{24}$, *i.e.*, the patient can see distinctly at a distance with a convex glass of 24″ focus. This hypermetropia, which is at first only acquired, may afterwards become absolute; so that the patient is not only unable to accommodate for divergent, but even for parallel rays.

This recession of the near point from the eye,

and the consequent narrowing of the range of accommodation, is chiefly due to a change in those parts within the eye which are passively changed during the act of accommodation, and not so much to an alteration in those which through their activity bring about the accommodation. For, the ciliary muscle, the active agent of accommodation is generally normal, although it may, later in life, undergo senile changes. Whereas the passively changed organ of accommodation, the crystalline lens, gradually becomes more and more firm with advancing years, and in consequence of this increased consolidation, the same amount of muscular action cannot produce the same change in the form of the lens as formerly.

At first, of course, no inconvenience is experienced from this gradual recession of the near point; we do not, in fact, notice it until the distance is so considerable that we cannot easily distinguish small objects. When are we, then, to consider an eye presbyopic? Donders thinks this should be done as soon as the near point has receded further than 8″ from the eye; for as soon as this is the case, patients generally begin to complain that continued work at small objects has become irksome and fatiguing. We, however, sometimes meet with persons with very strong sight, who can read and write for hours without experiencing any inconvenience, even although their near point may be 11″ or 12″ from the eye. But these cases are exceptional. Let us, therefore, with Donders, consider presbyopia to begin when the near point is removed further than 8″ from the eye.

The degree of presbyopia may be easily found if we have decided upon a definite distance as the commencement of presbyopia (Pr.). According to Donders, its degree may be found in the following simple manner. He says "if, that is to say, p^2 (the presbyopic near point), be situated at n Parisian inches from the eye, then assuming the above-mentioned limit, $\text{Pr} = \frac{1}{8} - \frac{1}{n}$. Thus if p^2 lie at 16 inches, $\text{Pr} = \frac{1}{8} - \frac{1}{16} = \frac{1}{16}$; if p_2 lie at 24″ $\text{Pr} = \frac{1}{8} - \frac{1}{24} = \frac{1}{12}$. For this, glasses of about $\frac{1}{8} - \frac{1}{n}$ are required, and in the examples given, glasses of $\frac{1}{16}$ and $\frac{1}{12}$, to bring p_2 to 8″, and so to neutralize the presbyopia."*

The reader will have been struck by the fact, that if we consider an eye presbyopic when the near point is removed further than 8″ from the eye, not only the emmetropic (normal), but even the myopic or hypermetropic eye may suffer from presbyopia. If, for instance, a short-sighted person suffers from a myopia $= \frac{1}{16}$ (his far point lying at 16″ from the eye), and his near point lies at 12″, he is both short and long-sighted. His myopia $= \frac{1}{16}$, his presbyopia $= \frac{1}{24}$. This cannot, of course, occur when the myopia is considerable, *e.g.*, $\frac{1}{6}$ (the far point lying at 6″ from the eye).

In hypermetropia the same thing may happen.

If, with the convex glass, which neutralizes the hypermetropia—which renders the hypermetropic eye capable of uniting parallel and divergent rays upon the retina—the near point lies at 12″ from the eye, the patient is not only hypermetropic, but also presbyopic. He will require two different sets of convex spectacles, one pair which will enable him to see from 12″ to infinity, and another stronger pair which will bring his near point nearer than 12″.

The range of accommodation of a presbyopic eye is easily found by the formula $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$. If such an eye can see from 10″ to an infinite distance, (∞), its near point (p) will lie at 10″, its far point (r) at ∞, its range of accommodation, therefore $= \frac{1}{10} - \frac{1}{\infty} = \frac{1}{10}$. $\frac{1}{A} = \frac{1}{10}$.

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* Donders' "Anomalies of Refraction and Accommodation," p. 212.

There can be no question as to the advisability and necessity of permitting far-sighted persons the use of spectacles. They should be furnished with them as soon as they are in the slightest degree annoyed or inconvenienced by the presbyopia. Some medical men think that presbyopic patients should do without spectacles as long as possible, for fear that they should, even at an early period, get so used to them as soon to find them indispensable.

This is, however, an error, for if such persons are permitted to work without glasses we observe that the presbyopia soon rapidly increases.

It has been already stated how the proper glasses may be readily calculated. If *p* (the near point) lies 16″ from the eye, $Pr = \frac{1}{8} - \frac{1}{16} = \frac{1}{16}$. A convex glass of 16″ focus will bring the near point back again to 8″ from the eye. We must generally, however, give somewhat weaker glasses, because, on account of the greater convergence of the optic axes, the near point will through these glasses (convex 16) be in reality brought nearer than 8″. Late in life, when there is some diminution in the acuteness of vision, the near point may sometimes be brought even to 6″ or 7″, and it may be approximated the more, the greater the range of accommodation.

If no hypermetropia exists, the weakest glasses with which No. 1 of Snellen can be distinctly and easily read at about 12″ distance may generally be given. But I have often found that if the person is much employed in reading and writing, and has always been accustomed to hold his book at a considerable distance, he will be at first much inconvenienced if his near point is brought to 10″ or 12″. We shall, therefore, have to give him glasses which will bring it only to about 16″. With these he will be able to work with ease for a considerable length of time. They may afterwards be gradually changed for rather stronger ones.

In choosing spectacles for far-sighted persons, we must also be particularly guided by the range of their power of accommodation. If this is good, we may give them glasses which bring their near point to 8″; but if it is much diminished, weaker glasses should be chosen, so that it may lie at 10″ to 12″ from the eye.

In conclusion, I would particularly call the reader's attention to the very important fact that a very rapid increase of presbyopia is one of the premonitory symptoms of glaucoma. If a patient therefore tells us that his far-sightedness has rapidly increased within a few months, so that he has had repeatedly to change his spectacles during that time for stronger and stronger ones, our suspicions should be aroused, and we should without fail examine him as to the presence of other premonitory symptoms of glaucoma—*e.g.*, rainbows round a candle, periodical obscurations, &c. Von Graefe thinks that this rapid increase of presbyopia is most likely due to an increase of intraocular pressure and flattening of the cornea. But it is, more probably, owing to the action of this pressure upon the nerves supplying the ciliary muscle, thus causing paralysis of the latter.

CHAPTER VII.

HYPERMETROPIA.

It has been already stated (p. 27) that by the term hypermetropia is meant that peculiar condition of the eye in which its refractive power is too low, or the optic axis too short, so that the focal point of the dioptric system lies behind the retina, and, when the eye is in a state of rest, even parallel rays are not brought to a focus upon the retina, but behind it, and only convergent rays are united upon the latter.

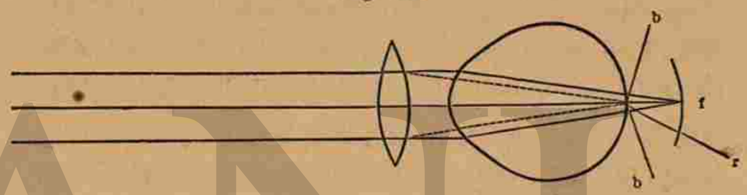
The emmetropic eye unites parallel rays upon the retina without any effort of accommodation, and it also possesses the power of accommodating itself without difficulty for divergent rays, coming from objects 6″ or 8″ from the eye; for a short time it can even unite upon the retina rays which come from 3″ to 4″ distance. The focal point of the dioptric system lies in the emmetropic eye exactly upon the retina, Fig. 10, p. 24.

In the myopic eye, it will be remembered, the state of refraction is too great, or the optic axis too long, so that when the eye is in a state of rest the focus of the dioptric system lies in front of the retina, and parallel rays (emanating from objects at an infinite distance) are brought to a focus before the retina, and only more or less divergent rays are united upon the latter, Fig. 11, p. 27.

Now, in hypermetropia we have just the reverse of this. The refractive power of the eye is so low, or its optic axis so short, that when the eye is in a state of rest, parallel rays are not united upon the retina, but behind it, and only convergent rays are brought to a focus upon the latter. We must, therefore, give to parallel rays emanating from distant objects a convergent direction by means of a convex glass, and the reader will now see how it is that a hypermetropic eye requires convex glasses for seeing distant objects. The patient may require perhaps even a stronger pair for near objects. The consequence of this low refractive power of the eye is, that whereas the normal eye unites parallel rays upon its retina without any accommodative effort, the hypermetropic eye has already, in order to do so, to exert its accommodation more or less considerably, according to the amount of hypermetropia. This exertion increases, of course, in direct ratio with the proximity of the object. If the degree of hypermetropia is moderate, and the power of accommodation good, no particular annoyance is perhaps experienced, even in reading or writing. If, however, the hypermetropia is absolute, the patient will not be able to see well at any point.

Fig. 24 represents a hypermetropic eye, in which, either on account of its being too short in the antero-posterior axis or its possessing too low a power of refraction, parallel rays are not brought to a focus upon the retina (r), but behind it at f; circles of diffusion (b b) are formed upon the retina, and the object consequently appears blurred and indistinct. To remedy this the eye undergoes a change in accommodation, so as to increase its power of refraction sufficiently to unite the parallel rays at r. The less the power of refraction of the hypermetropic eye, the greater must this effort of the accommodation be, and it must increase, of course, proportionately as the object is brought nearer to the eye. By placing a suitable convex

Fig. 24.



lens before the eye, the parallel rays are rendered so convergent that they are united upon the retina (*r*) without any effort of accommodation, and we thus place the hypermetropic in the same condition as the normal eye, upon whose retina parallel rays are brought to a focus without any effort of accommodation.

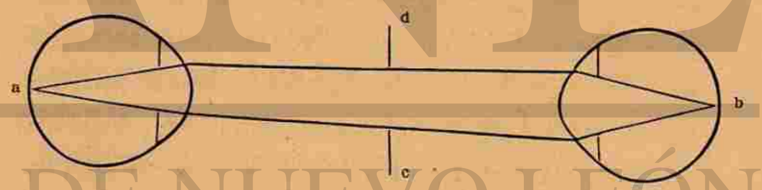
It will be found that this condition generally depends upon a peculiar construction of the eye. The hypermetropic is smaller and flatter than the emmetropic eye, and although all its dimensions are less than in the latter, this is more particularly and markedly the case in the antero-posterior axis. The eye does not appear to properly fill out the palpebral aperture, but a little space may be observed between the outer canthus and the eyeball. Upon directing the eye to be turned very much inwards, it will also be seen that the posterior portion of the eyeball is flatter and more compressed than in the emmetropic eye. Donders considers that the hypermetropic is generally an imperfectly developed eye, that the expansion of the retina is less, and that there is a smaller optic nerve with a less number of fibres. He thinks, moreover, that in hypermetropia there often exists a typical form of face, chiefly dependent upon the shallowness of the orbit, which lends a peculiar

flatness to the physiognomy. The hypermetropic construction of the eyeball is congenital, and often hereditary.

The ophthalmoscope also enables us to diagnose a hypermetropic eye, but in this case just the reverse obtains to what was seen in the myopic eye. (Page 68.)

I. The fundus may also in this case be seen in the erect image at a considerable distance, but we obtain an erect image of it (and not as in myopia a reverse image), for if we regard the optic nerve, or one of the retinal vessels, and move our head to one side, we find that the image *moves in the same direction.* For an explanation of this let us glance at Fig. 25.

Fig. 25.



Let *a* be the hypermetropic eye, *b* the eye of the observer; *a* is adjusted for its far point (convergent rays), and the rays reflected from its background will, consequently, emanate from it in a divergent direction, as if they came from a point behind the retina, and they must, therefore, also fall in a divergent direction upon the eye of the observer. If the latter is myopic (adjusted for divergent rays) the rays will be united upon his retina without the aid of any correcting lens behind the ophthalmoscope. But, if his eye is emmetropic (adjusted when in a state of rest, for parallel rays), he will either have to place a convex lens behind the mirror, or have to accommodate for a nearer point. The strongest convex lens with which the details of the fundus can still be seen in the erect image, affords us a relative estimate of the degree of existing hypermetropia.

The image of the observed eye will be erect, for *c* and *d* retain their relative positions.

II. On going closer, but still examining in the erect image, the field of vision appears much enlarged, and the image removed further from the eye, its size is considerably diminished, whereas the intensity of its light and colour is much increased. If the hypermetropia is high in degree, we can overlook at a glance not only the whole optic entrance, but also a considerable portion of the fundus around it. If our eye is emmetropic, we must, in order to gain a distinct image, either place a strong convex lens behind the mirror, or else we must accommodate for a nearer point.

In the indirect mode of examination the size of the optic disc will appear much larger than in the emmetropic eye, which is due to its image being formed further from the object lens.

The ophthalmoscopic diagnosis of hypermetropia is frequently of much service, especially in young children affected with strabismus, the state of whose refraction we wish to ascertain, but who are too young to read. Again, in spasm of the ciliary muscle dependent upon hypermetropia, the latter may be so completely masked that the patient can only see at a distance with slightly concave glasses, and not at all with convex ones. We hence, perhaps, believe it to be a case of myopia, but on ophthalmoscopic examination we find that the refraction is markedly hypermetropic. In such cases the patient should, however, look at some distant object or into vacant space, so that his accommodation may be quite relaxed. We may notice in such patients how the ophthalmoscopic appearances vary when the accommodation is relaxed, and when it is called into action by their regarding some near object.

We must distinguish various forms of hypermetropia, and in our classification of these we shall follow Donders' system.

We may, in the first place, divide hypermetropia into two primary classes, the original and the acquired.

The latter is met with in old persons in whom the eye has undergone senile changes. When speaking of presbyopia, we saw that the near point begins to recede from the eye at about the tenth year, and that this recession continues uninterruptedly to advanced age. The far point remains stationary till about the age of forty or forty-five, when it gradually recedes from the eye; at the age of fifty-five or sixty, this is distinctly evident in the emmetropic eye, for it has then become hypermetropic, and a convex glass is necessary for distinct vision of distant objects. This, however, varies greatly in different individuals. At seventy or eighty years of age, the hypermetropia often equals $\frac{1}{24}$. This recession of the far point—this diminution of the refractive power of the eye—is evidently due to senile changes in the structure of the lens, which, with advancing years, becomes firmer and more consistent, and its surface somewhat flatter.

Absence of the crystalline lens will also, of course, give rise to very considerable acquired hypermetropia.

Original hypermetropia may be subdivided into manifest (Hm) and latent (Hl).

In order to determine the presence of hypermetropia, we direct the patient to read No. XX at a distance of 20 feet. Let us suppose that he can do so with ease; we then find the strongest convex glass with which he can still see clearly and distinctly, and this gives us the degree of *manifest* hypermetropia. If convex 20 is the strongest glass with which he can read No. XX distinctly (convex 18 making the sight worse), $Hm = \frac{1}{20}$.

Each eye should be tried separately, as the degree of hypermetropia may vary. The patient is next directed to read very small print with this glass, and if we find that he can read No. 1 clearly and distinctly as close as 5″ to 6″ from the eye, we know that his range of accommodation is also good. The position of the near point, and the extent of the range of accommodation, will, of course, vary with the age of the patient.

But although convex 20 may be the strongest glass with which he can see at a distance, the degree of hypermetropia may in reality be very much higher than $\frac{1}{20}$. The fact being, that the patient has been so accustomed to exert his accommodation (even when regarding distant objects), that he cannot relax it all at once, even when there is no occasion for it, the malconstruction of the eye being compensated for by a convex lens. To find the real degree of hypermetropia, we must therefore paralyse his accommodation by a strong solution of atropine (gr. iv ad ℥j). This should be allowed to act for two or three hours. At the end of this time we again examine the patient, and now, perhaps, find that he cannot see No. 20 at all at 20′ without glasses, or even with convex 20. To do so distinctly he, perhaps, requires convex 8; and this difference in the power of the glasses required before and after the paralysis of the ciliary muscle, shows us to what an extent he exerted his accommodation before the application of the atropine. But this great difference only exists in young persons, with a good range of accommodation. The atropine should be only applied to one eye at a time. Its effect goes off in about six or seven days. But as it greatly dims the sight, it should only be applied in those cases in which it is of importance to know precisely the amount of latent hypermetropia. Slight degrees of hypermetropia are often unnoticed till the age of twenty or twenty-five, when symptoms of asthenopia begin to show themselves if the patient is obliged to work for any length of time at near objects. Our suspicion is aroused by these symptoms, and on placing a convex glass before his eyes, we find that he can distinguish distant objects far better than without it. If the glasses be only momentarily held before the eyes, the existence of hypermetropia may escape us, for the patient has been so accustomed to exercise his power of accommodation even for distant objects, that he cannot at once relax it. But if he continues to look through the glasses for a few minutes, he gradually finds that the distant objects become more and more distinct, and clearly defined. In order to make sure to what degree the hypermetropia exists, and to what extent the person is obliged to exercise his accommodation in looking at distant objects, we must paralyse his power of accommodation by the instillation of a strong solution of atropine.

This brings us to Donders' next division of manifest hypermetropia, into the *facultative*, *relative*, and *absolute*.

In *facultative* hypermetropia, the patient is able to see well (with parallel optic axes) at an infinite distance with or without the aid of convex glasses, and his sight is generally sufficiently acute to enable him to read small print and to work at fine objects. We often find that such persons, whilst young, complain of no fatigue during work, but that presbyopia sets in more early than in emmetropia, and then symptoms of asthenopia soon manifest themselves. We must distinguish this form of facultative hypermetropia from that which was formerly distinguished by that name by Donders. We, namely, sometimes meet with emmetropic eyes which not only see perfectly near at hand and at a distance, but which are capable of relaxing their power of accommodation to such an extent, that they can unite convergent rays upon the retina, for they are able to see at a distance with slightly convex glasses.

In *relative* hypermetropia, the eye may also be able to accommodate itself either for parallel or for divergent rays, and see well both at a distance and near at hand; but it can only do so by converging the optic axes for a nearer point than that at which the object is situated; by acquiring, in fact, a periodic convergent squint. This is not of very frequent occurrence in childhood, but is more often met with after the age of puberty and in early manhood. The sight is always more or less affected, and the patient has a difficulty in finding the exact distance at which he can see best.

In *absolute hypermetropia* vision is indistinct both for infinite distance and for near objects; for the patient cannot unite the rays upon the retina even with the strongest effort of accommodation or with the strongest convergence of the optic

axes. The focus of both divergent and parallel rays remains situated behind the retina. It is not often met with in youthful individuals, as they generally possess a sufficiently strong power of accommodation to overcome it. In a superficial examination such a patient might be mistaken for a person suffering from myopia with amblyopia, for he will not be able to see distinctly at a distance without glasses, which may be erroneously attributed to myopia, nor will he be able to read very fine print, and this may be supposed to be due to amblyopia.

It is a curious fact, that when the hypermetropia is considerable, the patient can often read better when the print is only a short distance from the eye than when it is 10″ or 12″ off. Von Graefe thinks this is due partly to the diminution in the size of the pupil which takes place on looking at small objects, for the area of the pupil being smaller, some of the peripheral rays are cut off, and there is consequently a diminution in the circles of diffusion on the retina. He has also shown that on approximating an object to the eye, the circles of diffusion on the retina in a hypermetropic eye increase comparatively less in size than the size of the retinal images. In consequence of this, there is more chance of interspaces between the letters when the print is held at a distance of 5″ or 6″, than at 10″ or 12″. At the latter distance, there would not be so much difference between the size of the retinal images and the circles of diffusion, so that the letters would appear more confused and indistinct. But, besides these reasons, the greater amount of convergence, and consequent increase in the action of the power of accommodation, has most likely some influence in enabling the patient to see better at a distance of 5″ or 6″.

We have already seen that the near point recedes from the eye with advancing years, that at the age of forty-five it is about 9″ or 10″ from the eye, and we followed Donders in considering presbyopia to commence when the near point was removed further than 8″ from the eye. A hypermetropic eye may, therefore, at a certain age become presbyopic; or again, an originally normal eye may become presbyopic at the age of forty-five, and hypermetropic at fifty or sixty, so that we may have presbyopia and hypermetropia co-existing in the same eye. If, with the glasses which neutralise his hypermetropia, a hypermetropic patient cannot read very small print nearer than 12″ to 14″ from the eye, he is also presbyopic. He may, therefore, require a double set of glasses, one pair for distance and a stronger pair for reading.

The range of accommodation of a hypermetropic eye is easily found. We must first change it into a normal eye by furnishing it with that convex glass which will enable it to see distant objects distinctly without almost any exercise of the accommodation; and then, it still wearing this glass, find the nearest point at which it can read No. 1 distinctly and easily. If the patient requires for distant vision convex 20 before the instillation of atropine, and convex 10 after it, we should try his nearest point with a glass between the two—No. 16 for instance, for No. 10 would be too strong. He has been so accustomed to strain his accommodation that he cannot all at once really command his near point with convex 10.

Let us now suppose that with convex 16 his near point (p) lies at 7″; his far point (r) has been found to be at an infinite distance (∞); for he can see distant objects well with convex 16 without much effort, although convex 20 is best. The range of accommodation $\frac{1}{A}$ is to be found by the formula $\frac{1}{A}=\frac{1}{P}-\frac{1}{R}$. Now, $p = 7''$, $r = \infty$, hence $\frac{1}{A}=\frac{1}{7}-\frac{1}{\infty}=\frac{1}{7}$. The range of accommodation $=\frac{1}{7}$.

I must again remark that this plan of finding the range of accommodation is not mathematically exact. It is, however, sufficiently accurate for all practical purposes.

In high degrees of hypermetropia we almost always find that the acuteness of vision is more or less diminished. According to Donders this is partly due to the peculiar structure of the hypermetropic eye. The retinal images are smaller than in the emmetropic eye, because the nodal point is situated closer to the retina, hence the sight is improved by convex glasses, which move the nodal point more forward. The amblyopia may also be due to astigmatism, and to the lesser number of nerve fibres of the optic nerve and retina.

Hypermetropia is very frequently the cause of asthenopia. This affection has received a great variety of names—asthenopia, hebetudo visus, impaired vision, muscular amaurosis, &c. It is distinguished by the following symptoms: The patient cannot continue to regard near objects for any length of time, as in reading, writing, &c., without the eyes becoming fatigued. The print becomes confused and indistinct, the letters run into each other; there is a feeling of tension and pain about the eye and over the eyebrow, which, if the work is persisted in, soon becomes more intense, and

sometimes even assumes the character of headache, (which is often mistaken for nervous headache, or migraine); the eye at the same time perhaps becomes watery, red, and feels hot and uncomfortable. Yet there is nothing in the appearance of the eye to warrant this state of things. It looks perfectly normal, the refracting media are clear, vision is good, the convergence of the optic axes perfect, the mobility of the eye unimpaired. Neither does the ophthalmoscope reveal anything abnormal, except perhaps a slight state of congestion and hyperæmia of the retina and choroid. And yet the eye is perfectly useless for continued work at near objects, for reading, writing, sewing, engraving, &c.; for symptoms of asthenopia soon show themselves, and the work has to be laid aside. Then these symptoms quickly vanish, and the occupation can be resumed until their re-appearance again necessitates an interval of rest, the longer this is, the longer will the person be able to re-continue his employment.

All ophthalmologists know from experience how wearisome such cases mostly prove in the treatment, and how unsatisfactory the result generally is after the whole routine of remedies has been gone through. Purgatives, sedatives, tonics, counter-irritants, alteratives, their name is legion!

But yet how futile do they not almost always prove in curing this affection. But why do they prove futile? Because in the great majority of cases the asthenopia is not dependent upon any overwork of the eyes, or upon general debility, but either upon hypermetropia or upon an insufficiency of the internal recti muscles of the eye.

It was, indeed, a great boon when Donders discovered that most of these cases of asthenopia depended upon hypermetropia, and might, therefore, be permanently cured by the proper use of convex glasses. Since he first called the attention of the Profession to this important fact, I have examined a great number of persons suffering from asthenopia, and have found that in the great majority the latter depended upon hypermetropia.

In these cases of asthenopia dependent upon hypermetropia we sometimes find, with the ophthalmoscope, that the choroid and retina are somewhat congested. And I have known patients in whom this was the case strongly advised to abstain from all work, and particularly to avoid the use of spectacles. If there is much congestion it would be as well to rest the eyes for a short time, to use the eye-douche, &c.; but generally the congestion is but very slight, and is to be removed and prevented by the use of convex glasses. The congestion is, in fact, owing to the overstraining of the accommodative apparatus, and will disappear as soon as the necessity for this over-exertion is removed by the neutralisation of the hypermetropia through convex glasses.

It has been thought that asthenopia might be cured by gradually accustoming the eye to weaker and weaker glasses, so as finally to render their use altogether superfluous. But the reader will now understand how just the contrary proceeding is necessary in hypermetropia. If we wish permanently to cure the patient, we must prevent all undue straining of his accommodation, and this can only be done by the proper use of convex glasses.

I would particularly call the attention of the profession to the important fact that asthenopia is, in the great majority of cases, due to hypermetropia, and that these patients, who under any other course of treatment haunt our out-patient rooms for months and years without relief, may be speedily and permanently cured by the proper treatment of their hypermetropia. Let us but consider the crowd of sempstresses, watchmakers, engravers, &c., who are rendered incapable of following their employment, whose future is starvation, if this fact is not attended to.

It does not, however, follow that all cases of hypermetropia must of necessity be accompanied by symptoms of asthenopia. They may be wanting if the power of accommodation is good, and the degree of hypermetropia but slight. When it is very considerable, asthenopia is never absent. The existence of the hypermetropia may be overlooked if the glasses are only momentarily held before the eyes, as the patient cannot suddenly relax his accommodation sufficiently. We should, therefore, in such cases, always paralyse the power of accommodation by the instillation of a strong solution of atropine, and then ascertain the degree of hypermetropia.

This form of asthenopia, which is dependent upon fatigue of the muscular system of the accommodation, may be termed *accommodative* asthenopia, in contradistinction to the *muscular*, which is due to insufficiency of the internal recti muscles, and to the *retinal* asthenopia.

Another form of accommodative asthenopia, dependent upon debility and want of energy in the muscular apparatus of accommodation, such as is often met with after severe illnesses, diphtheria, &c., will be more fully treated of in the chapter upon Paralysis of Accommodation.

Retinal asthenopia is distinguished by the absence of hypermetropia and insufficiency of the internal recti muscles, and by the presence of symptoms of irritation and hyperæsthesia of the retina. The patients complain that the eyes become painful, red, and watery on an attempt to use them for near work, the acuteness of vision is, however, generally perfect, and the patients are not obliged to desist from work because the letters, &c., become indistinct, but from the pain and irritation in the eye. Such symptoms may also continue long after the work has been laid aside. The feeling of tension above the eyebrows, which is so characteristic of the accommodative form, is absent, but there is often considerable photophobia and chromopsia. In severe cases, all these symptoms are very marked, and are more or less persistent, and the state of irritation and hyperæsthesia may extend from the eye to more distant branches of the fifth nerve. With the ophthalmoscope, we generally find hyperæmia of the optic nerve and retina. The treatment consists chiefly in prescribing tonics, good diet, cold bathing, more particularly in the sea, and great attention to the general health, together with the use of the eye-douche, blue glasses, and complete and prolonged rest of the eyes. Lowering treatment, irritation by continued blisters, &c., often greatly aggravate the affection.

Let us now consider how hypermetropic persons are to be suited with glasses.

Theoretically, it would appear right to neutralize the hypermetropia by a convex lens, and thus to change the eye into an emmetropic one; this lens forming, so to speak, an integral part of the eye. But in practice we find that this does not answer.

In facultative hypermetropia there will be no occasion to prescribe glasses for distance, as the patient can see well without them. Moreover, there is the disadvantage, that after convex spectacles have been worn for some time for distance, the power of seeing distinctly without them is lost, which is of course very inconvenient. For this reason they should never be ordered, except in cases of absolute or relative hypermetropia of a considerable degree. If there are symptoms of asthenopia, glasses should be given for reading, etc., which are somewhat stronger than those which correct the manifest hypermetropia. If these are found too strong and trying to the eye, they must be exchanged for weaker ones, and the strength be gradually increased until the asthenopia has disappeared.

In relative and absolute hypermetropia spectacles should also be worn for distance, as we find that in such instances distant vision is not distinct.

In such cases, I generally commence with the glasses which neutralize the manifest hypermetropia, and in young persons order them to be worn both for near and distant objects. If they prove too strong for distance, a weaker pair must be prescribed, and their strength gradually increased. If they do not relieve the asthenopia, or if presbyopia co-exists, a stronger pair must be given for reading, writing, and sewing.

In using the spectacles for reading, sewing, etc., it is always advisable to interrupt the work for a few minutes at the end of half an hour or an hour. This rests the eye, which is then able to resume the employment with renewed vigour and ease. If the asthenopia does not quite disappear under the use of glasses, we must examine the power of convergence, for together with the hypermetropia there may exist insufficiency of the internal recti muscles, and the asthenopia be partly due to this. If the accommodation has been greatly fatigued by prolonged work at near objects without the aid of glasses, or if there is spasm of the ciliary muscle, the accommodation should be placed in a condition of complete rest, by being paralysed by a strong solution of atropine, and this paralysis should be maintained for several weeks.

Donders has shown that convergent strabismus very frequently depends upon hypermetropia. A person suffering from the latter is always obliged to accommodate more or less, in order to see with distinctness. Even at a distance, he must already accommodate in order to neutralize the hypermetropia, and the nearer the object is approximated, the more will this tension of the accommodation increase. There exists, however, a certain relation between the accommodation and the convergence of the optic axes, for with an increase of the latter there is also an increase in the power of accommodation. This assertion is proved by the fact, that if we place a prism with its base turned outwards before a hypermetropic eye, the latter will squint inwards, in order to avoid diplopia in looking at distant objects; and this convergence will enable the eye to accommodate for parallel rays (distant objects), whereas with parallel optic axes, it before required convergent rays, *i.e.*, the rays from a distant object had to be rendered convergent by means of a convex glass, in order to be brought to a focus upon the retina. Again, if we place a concave glass before a normal eye, we change it into a hypermetropic one; parallel rays are united *behind* the retina, and it either requires an effort of accommodation, or a convex glass to bring them to a focus *on* the retina. If the concave glass is but of slight power, an increased effort of accommodation,—an increase in the convexity of the crystalline lens,—will neutralize the effect of the concave lens and overcome this artificial hypermetropia. But if the concave glass is too strong for this, the eye often overcomes its effect by squinting inwards, and thus increasing its power of accommodation. Now the same thing often occurs in hypermetropia; the eye squints inwards in order to increase its power of accommodation. This has been called periodic squinting. In the beginning, no deviation of the optic axis is observable as long as the person is not looking sharply at anything; but as soon as he looks intently at any object, near or distant, convergent squint shows itself. Sometimes this only occurs when the eye is regarding near objects, the squint disappearing as soon as the eye looks at some distant point. After a time, the squint becomes permanent, particularly in those persons who work at near objects, whether in reading, writing or sewing. We meet with it very frequently in children about the third or fourth year, when they first look attentively at things, or begin to use their eyes for any length of time for near objects. When this tendency to squint first shows itself, it may be corrected by neutralizing the hypermetropia by means of convex glasses; but it will generally require an operation.

Since Donders first pointed out the connexion between hypermetropia and convergent strabismus, I have made a point of examining a great many cases of squint, and have found that hypermetropia was present in the great majority of convergent squints. The degree of hypermetropia is generally not very great, varying from $\frac{1}{40}$ to $\frac{1}{16}$ or $\frac{1}{12}$.

There are, of course, other causes of convergent squint, such as myopia, paralysis of the antagonist muscle, opacities of the dioptric media, &c.; but I reiterate, that of all these causes, hypermetropia is the most frequent.

I have stated that this form of squint often arises in childhood; that in order to correct the hypermetropia by a stronger action of its power of accommodation, the child involuntarily, unwittingly squints inwards when it wants to see any object distinctly. The strabismus soon becomes permanent, the image of the squinting eye is suppressed (in order to avoid diplopia), and its vision is very frequently soon irremediably destroyed, if a timely squint operation be not performed. Yet there is amongst some ophthalmologists a strong opinion that a squint should not be operated upon in childhood. But how erroneous is this advice, how many eyes have not been sacrificed through following it!

If, for instance, a child suffers from hypermetropia, and squints inwards in order to increase its power of accommodation, this strabismus will soon become permanent. To avoid diplopia, the image of the squinting eye is suppressed by the brain; but this negation of the pseudo-image soon leads to deterioration of sight, and the vision of the squinting eye is gradually greatly impaired or even sometimes almost completely destroyed. Hence the necessity of operating on a squint as early as possible, whilst the sight is yet good. I have not the slightest hesitation in saying, that the sight of the squinting eye would thus be saved in the greater number of (if not, indeed, in all) such cases. In some of these cases of amblyopia from disuse, the sight of the amblyopic eye may be greatly improved by exercising it with strong convex lenses.

We must always warn the patient and his friends after the squint operation in eyes suffering from hypermetropia, that if the latter is not treated by the use of convex glasses, the squint may return.

But there may be in hypermetropia an *apparent* squint, the direction of which is not, however, inwards, but outwards. There is an undoubted, well-marked, outward deviation of the optic axes, and yet both eyes are steadily fixed upon the object, neither moving in the slightest degree when the other is closed. The squint is, therefore, not real, but only apparent. Donders has called particular attention to this fact, and furnished us with the explanation. It has been shown by Helmholtz (vide p. 19) that the optic axis and the visual line (an imaginary line drawn from the yellow spot to the object point) do not correspond, but that the latter impinges upon the cornea slightly to the inner side of the centre of the cornea, forming with it an angle of about 5°. It will, therefore, be evident that if the visual lines are parallel, the optic axes must necessarily be slightly divergent, and such is in fact the case in the normal eye, but this divergence is so extremely small, and we are so accustomed to it, that it escapes observation. But, in some cases, the visual line may change its position with regard to the optic axis, and, if this deviation be at all considerable, an apparent squint will arise. In hypermetropic eyes the visual line always cuts the cornea considerably to the inner side of its axis, forming with it, according to Donders, an angle of not less than 7° 55. He has found that the

maximum may even be an angle of 11° 3, instead of one of 5°. If such eyes look at a distant object they will appear to be affected with a divergent squint; for, whilst the optic lines are fixed upon the object, the optic axes will diverge from it. In myopia the reverse obtains, for there the visual line, instead of lying to the inner side of the optic axis, may correspond to the latter, or even lie somewhat to the outer side of it; and in the latter case, there will consequently be an apparent convergent squint, for whilst the visual lines meet in the object point, the optic axes must necessarily cross on this side of it.

CHAPTER VIII.

ASTIGMATISM.

We have seen that the anomalies of refraction resolve themselves into two, viz., myopia and hypermetropia. But the state of refraction may vary in the different meridians of the same eye; thus, it may be emmetropic in the vertical meridian, but myopic or hypermetropic in the horizontal, or *vice versâ*. Or differences in the degree and even in the form of emmetropia may exist in the various meridians. This asymmetry has been termed astigmatism (*α*, privative, and *στιγμα*, a point), which signifies that rays emanating from a point are not re-united at a point. This peculiar defect* was first observed by Thomas Young (1793), who considered it due to some inequality in the structure of the lens, whereas Wharton Jones thought it was situated in the cornea. Donders has shown that it is of frequent occurrence, and

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* For a most interesting historical account of this subject, see Donders' work, p. 539.

that many cases of congenital amblyopia are due to it, and may be cured by suitable cylindrical glasses.

But even in the normal eye the cornea does not refract equally in all its meridians, for the focal distance of the dioptric system is generally shorter in the vertical meridian than in the horizontal. On this account, fine vertical lines can be seen up to a further distance than horizontal lines, but the latter can be seen closer than the vertical lines. For this experiment horizontal and vertical lines may be drawn upon a page, or Von Graefe's wire optometer may be used.

If the stripes or lines are arranged crosswise, we are unable to distinguish both the horizontal and vertical lines with equal clearness and distinctness at one and the same distance; thus, if we can see the vertical line clearly and sharply defined, we must approach the horizontal line nearer to the eye, in order to gain an equally distinct image of it, and *vice versâ*. These facts prove that the vertical meridian has a shorter focal distance than the horizontal, and for this reason horizontal lines are seen distinctly at a shorter distance than vertical ones. For as the rays which are refracted in the vertical meridian are united in a point sooner than those in the horizontal plane, the latter give rise to circles of diffusion upon the retina in the form of small horizontal lines which do not confuse the images of horizontal lines, but interfere with those of vertical lines.

As it is of much consequence in the study of astigmatism that the reader should thoroughly understand these preliminary facts, I give the following extract and explanatory woodcuts from Donders' work. After speaking of the fact that a vertical stripe can be seen further off, and a horizontal stripe at a closer distance, he continues :—"These experiments prove that the points of the refracting meridians are not symmetrically arranged around one axis. The asymmetry is of such a nature that the focal distance is shorter in the vertical meridian than in the horizontal. In order, namely, to see a vertical stripe acutely, the rays, which in a horizontal plane diverge from each point of the line, must be brought to a focus upon the retina; it is not necessary that those diverging in a vertical plane should also previously converge into one point, as the diffusion-images still existing in a vertical direction cover one another on the vertical stripe. On the other hand, in order to see a horizontal stripe acutely, it is necessary only that the rays of light diverging in a vertical plane should unite

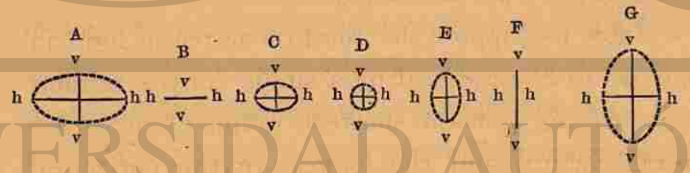
in one point upon the retina. Now horizontal lines are acutely seen, as I have remarked, at a shorter distance than vertical ones, consequently rays situated in a vertical plane, which are refracted in the vertical meridian of the eye, are more speedily brought to a focus than those of equal divergence situated in a horizontal plane; and the vertical meridian, therefore, has a shorter focal distance than the horizontal.

"The correctness of this view appears further from the form of the diffusion-images of a point of light. In accurate accommodation the diffusion-spot is very small, and nearly round, while a nearer point appears extended in breadth, and a more remote one seems to be extended in height. The signification of this phenomenon must be clearly understood, and appears therefore, to demand more particular explanation.

"Let us suppose the total deviation of light in the eye to be produced by a single convex refracting surface, with the shortest radius of curvature in the vertical, and the longest in the horizontal meridian. These two are then the principal meridians. Through a central round opening (Fig. 26, *v v h h*) let a cone of rays, proceeding from a point situated in the prolongation of the axis of vision, fall upon this surface; of this cone let us consider only the rays situated in the vertical plane *v v*, and the rays situated in the horizontal plane *h h*, whereof respectively the points *v v* and *h h* are the most external. After the refraction both approach the visual axis (which perpendicular to the plane of the drawing passes through *a*), *v v* does so, however, more rapidly than *h h*. Before union they therefore lie in the ellipse *A*, as in Fig. 27, and where *v v* meet in one point *B*, *h h* have not yet come to a focus. Thereupon we now find in succession *v v* already intersected, *h h* approached to one another, *C*, *D*, *E*; further, *h h* united in one point, and *v v* after intersection more widely separated, *F*; finally, both intersected, *G*. The focus of *v v* therefore lies most anteriorly, that of *h h* most posteriorly in the axis. The space between these two points where rays

Fig. 26.

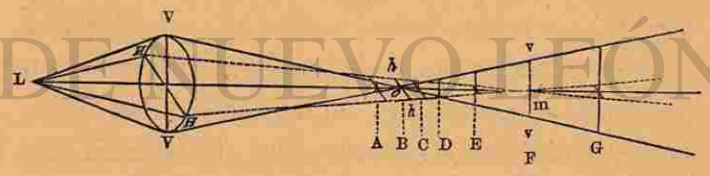
Fig. 27.



of different meridians intersect, may be called the focal interval (*intervalle focale* or Brennstrecke of Sturm). From the above figures it is now evident what successive forms the section of the cone of light will exhibit. In the middle of the focal interval, *D*, it will be nearly round, and anteriorly through oblate ellipses, *C*, with increasing eccentricity, it will pass into a horizontal line *B*; posteriorly through prolate ellipses, *E*, it will come to form a vertical line, *F*, while before the focal interval a larger oblate ellipse, *A*, and behind it a larger prolate ellipse, *G*, will be found."

The position of these figures with regard to the focal interval is shown in Fig. 28. In the cone of light emanating from *L* are depicted the rays which impinge upon the vertical meridian *V V* and upon the horizontal meridian *H H*. The former are united in *o*, the latter in *m*, so that *o m* is the focal interval.

Fig. 28.



In Fig. 28, the letters *A*, *B*, *C*, *D*, *E*, *F*, and *G* correspond to the same letters in Fig. 27. The rays which lie in the plane of the vertical meridian

$V V$ (in Fig. 28), are brought to a focus at o, where the rays which lie in the plane of the horizontal meridian $H H$, are not yet united, but form the horizontal line $h h$ (the *anterior* focal line). The rays $H H$, are united further back at m, where the vertical rays form the vertical line $v v$ (the *posterior* focal line). The distance between these two focal lines forms the focal interval. The anterior focal line $h h$, corresponds to the position of the meridian of the lowest refractive power, whereas the posterior focal line $v v$, to that of the meridian of highest refraction. Generally the astigmatic patient endeavours unconsciously so to regulate his accommodation that the middle portion of the focal interval falls upon the retina; in this way only a small round circle of diffusion D (Fig. 27), is formed, and the object is more distinctly seen than it would be at the anterior or posterior extremity of the focal interval. In case that the anterior extremity of the focal interval (and if this is the focus of the vertical meridian) falls upon the retina, a circular flame appears as a horizontal luminous line. The reverse will of course occur, if the posterior extremity of the focal line (if this corresponds to the focus of the horizontal meridian) falls upon the retina, for then the flame will appear as a vertical luminous line. Hence,

horizontal and vertical stripes will be sharply and distinctly seen when the diffusion-images of all the points of the stripe form respectively horizontal and vertical lines, which cover one another in the stripe; and this will be the case when the beginning and the end of the focal interval correspond respectively to the percipient surface of the retina (Donders).

Although we have hitherto assumed that the principal axes of curvature correspond with the vertical and horizontal meridians, it must be mentioned that they may deviate considerably from these. Also, that instead of the minimum of curvature corresponding with the horizontal meridian, and the maximum with the vertical, the reverse may even obtain, and the maximum curvature coincide with the horizontal meridian.

The aberration which is due to a difference in the focal distance of the two principal meridians, is called *regular* astigmatism, and depends upon the curvature of the cornea. Whereas the aberration which is due to a difference in the refraction in one and the same meridian, is called *irregular* astigmatism, and is generally caused by a peculiarity in the structure of the crystalline lens, and cannot be corrected by cylindrical lenses. It often gives rise to monocular polyopia. The two forms sometimes co-exist. The degree of regular astigmatism met with in normal eyes is generally too slight to cause any impairment of vision; but when it is more considerable, the sight is indistinct. This amblyopia is due to circles of diffusion being formed upon the retina, which cross and overlap each other. The greater the difference in the refraction of the principal meridians, the more considerable will be the circles of diffusion and consequent indistinctness of vision. If the astigmatism is at all high in degree, the acuteness of vision is much impaired, both for near and distant objects. If the eye is myopic or hypermetropic, we find that we cannot with any spherical lens produce a very decided improvement, or raise the acuteness of vision to the normal standard.

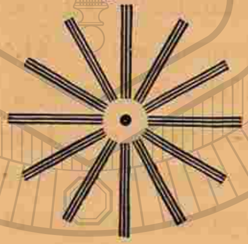
The diagnosis of astigmatism may generally be made without much difficulty; but it is necessary to follow a settled line of examination, otherwise the beginner will fall into great confusion, and waste a large amount of time. Numerous modes of discovering the presence of astigmatism, and of estimating its degree, are in use; but the following are the simplest and most practical:—

In the first place, we must carefully examine the acuteness of vision, and ascertain which number of Snellen's types the patient can see at a distance

of 20′. If the acuteness of vision is below the normal standard (if he cannot read No. xx), we must try whether it can be raised to this by concave or convex spherical lenses. If we fail in doing so, we must suspect the presence of astigmatism, and next proceed to determine the situation of the two principal meridians (*i.e.*, the maximum and minimum of curvature). This may be done by directing the patient to look at a small, distant point of light (varying from two to four millimètres in diameter, and seen through a small opening in a large black screen). The patient should be placed at a distance of from 12 to 16 feet, and directed to look at the luminous point. The latter will not appear round if the eye is astigmatic, but will be elongated in a certain direction according to the fact whether the light is nearer or further off than the point for which the eye is accommodated. Thus, if the maximum of curvature coincides with the vertical meridian, the luminous line will be horizontal if the eye is accommodated for a further point, and vertical if it is adjusted for a nearer point. Weak concave and convex lenses are then placed alternately before the eye (the latter being thus changed into a myopic or hypermetropic one), and the anterior and posterior diffusion line brought alternately upon the retina. The direction of this line will depend of course upon the direction of the principal meridian.

A better test object is, however, formed by a series of straight lines, which cross each other in the centre of a circle. For this purpose I have found Dr. Green's* test objects the best, and use them in preference to any others. He employs three figures, which can be arranged in such a manner as to amplify and check the results obtained. I have, however, found that one of the diagrams (Fig. 29) is sufficient. It consists of a circle, traversed by a set of twelve triple lines, corresponding to the figures on a watch dial; the figures being placed at the extremity of the sets of lines, as in Javal's optometer (Fig. 30). Each line is equal in thickness to the lines employed by Snellen in the construction of No. xx of his test types, and is designed to be distinctly seen at a distance of about 20′. The circle is about 12½″ in diameter.

Fig. 29.



This test circle is to be placed at a distance of 20′, and if the patient can see all the lines distinctly and sharply defined (any existing myopia or hypermetropia being corrected by suitable spherical lenses), he is not astigmatic. But if only the line in one meridian appears clear and sharply defined, whilst the others are indistinct, the presence of astigmatism is proved, and the direction of the distinct line corresponds to the meridian of the highest refraction. If we now wish to discover the degree and nature of the astigmatism, and are only supplied with spherical lenses, we try the weakest concave or the strongest convex lens which, placed in a stenopaic apparatus,* enables the patient to see all the radiating lines with equal distinctness. If a concave lens is required, it is a case of myopic astigmatism, whereas, it is hypermetropic, if a convex lens is required.

If we possess a trial case of cylindrical lenses, the weakest concave or strongest convex cylindrical glass should be found, which renders all the

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* Vide Dr. Green's paper on "The Detection and Measurement of Astigmatism," in the American Journal of Medical Sciences, January, 1867.

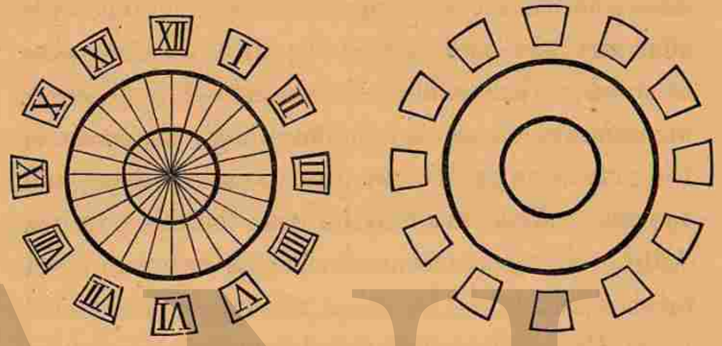
* The stenopaic apparatus employed for this purpose, consists of a small cylinder open at one end, so as to fit closely to the eye, the other end being furnished with a small slit, which can be readily narrowed and widened. The effect of this slit (which should be set to a width of about 1½ or 2 millimètres), is, of course, to admit only rays in a certain direction, excluding all the others. The box of the cylinder should be made to unscrew, in order that spherical lenses may be placed in it.

radiating lines quite distinct and clearly defined. When we have found the lens which corrects the astigmatism, the patient's sight should next be tried with Snellen's test types, in order that we may accurately ascertain the degree of improvement of sight produced by it. In cases of hypermetropia, the effort of accommodation often conceals a considerable portion of the astigmatism, and may thus greatly mislead us as to its actual degree. The examination is therefore much facilitated, if the accommodation is first paralysed by atropine.

In the above modes of examination each eye is to be tried separately.

Javal has devised the following ingenious instrument for the rapid determination and correction of astigmatism.* It is in the form of a stereoscope mounted upon a stand, and is supplied with convex spherical lenses of about 5″ focus. In high degrees of hypermetropia a lens of 3″ should be employed, whereas, in high degrees of myopia we may omit the convex lenses, or substitute concave ones. Two circles are drawn side by side upon a piece of cardboard, just as in a stereoscopic plate, being at such a distance from each other, that the centre of each circle corresponds to the distance between the two eyes. In the one figure (Fig. 30) are drawn a series of radiating lines, and at their extremity are placed the figures I to XII, arranged like the figures on a watch dial. If the visual lines are parallel, the two circles are fused into one image, in the centre of which lie the radiating stripes, and at the circumference the figures. On account of the parallelism of the eyes, the latter are accommodated for their far point. By means of a screw the circles are now removed further and further from the eyes, until all the radiating lines except one becomes indistinct. The direction of this one is easily identified by the figures, and its direction corresponds to the diameter of the highest refraction. Behind the ocular lens of the one eye is

Fig. 30.



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* "Klinische Monatsblätter für Augenheilkunde," 1865, 336. This optometer of Javal's is made by Nachet, 17, Rue St. Séverin, Paris.

arranged upon a pivot, a series of concave cylindrical lenses, so that they can be rapidly rotated in front of the eye, until the lens is found which corrects the astigmatism and indicates its degree. These lenses are arranged in such a manner that they can be used singly or together, thus allowing of most varied combinations. After the degree of astigmatism has been determined, the state of the refraction of the eye must be ascertained, and the same apparatus may be used for this purpose. After the examination of the one eye has been finished, that of the other should be proceeded with, the series of cylindrical lenses being turned over to the other side. The principal objection to this instrument is, that on account of the patient being conscious of the close proximity of the object, he does not relax his accommodation completely, and is hence not in reality accommodated for his far point, and we may, therefore, fall into error as to the degree of his astigmatism. This error is to a great extent avoided if we test him with the radiating lines at a distance, and completely so, if in a case of hypermetropia the accommodation is paralysed.

Donders has distinguished three forms of astigmatism, viz.: I. Simple astigmatism; II. Compound astigmatism; III. Mixed astigmatism.

I. Simple Astigmatism.—The state of refraction of the one principal meridian is emmetropic, whereas that of the other is either myopic or hypermetropic. If we, in such a case, turn the slit of the stenopaic apparatus in the direction of the normal meridian, the acuteness of vision will be perfect, whereas, a certain concave or convex spherical lens will be required if the slit is turned in the direction of the other meridian.

Simple astigmatism is divided into :—1. Simple myopic astigmatism (Am), in which myopia exists in the one principal meridian, and emmetropia in the other. 2. Simple hypermetropic astigmatism (Ah).—In this there is hypermetropia in the one principal meridian, and emmetropia in the other.

II. Compound Astigmatism.—In this form, myopia or hypermetropia exists in both principal meridians, but it varies in degree. If the stenopaic slit be used in such cases, it will be found that a different concave or convex lens will be required in each of the principal meridians, in order to render the acuteness of vision normal.

We must here also distinguish two forms :—1. Compound Myopic Astigmatism (M + Am).—Myopia exists in both principal meridians. 2. Compound Hypermetropic Astigmatism (H + Ah).—Hypermetropia exists in both principal meridians.

III. Mixed Astigmatism.—This is a rare form, in which the one principal meridian is myopic, the other hypermetropic. We must here also distinguish :—1. Mixed astigmatism, with predominant myopia (Amh). 2. Mixed astigmatism, with predominant hypermetropia (Ahm).

Knapp and Schweigger have pointed out that the ophthalmoscope also furnishes us with a valuable and easy diagnostic symptom of regular astigmatism. On examining in the direct method an eye affected with astigmatism, it will be found that the optic disc, instead of being round, appears elongated in one direction, and that the latter corresponds exactly to the meridian of greatest curvature. For as the focal distance is shorter in this meridian than in the other, the image must also be more magnified in this direction. If we now examine the same eye in the inverted image, the optic disc will appear elongated in the opposite direction; thus, if in the erect image the disc appears oval in the vertical direction, in the inverted, it will appear oval in the horizontal direction, and this at once proves the existence of regular astigmatism, and shows also that the vertical meridian is of greater curvature, and, consequently, has a less focal distance, than the horizontal. The comparative examination in the

erect and inverted image therefore furnishes us with a most valuable aid to diagnosis, which will often spare us the necessity of a long and intricate subjective examination.

In examining in the erect image, an eye affected with hypermetropic astigmatism, it will also be found that in order to see with equal distinctness the vessels running in different directions, the state of accommodation of the observer's eye has to undergo a change.

Mr. Bowman "has been sometimes led to the discovery of regular astigmatism of the cornea, and the direction of the chief meridians by using the mirror of the ophthalmoscope much in the same way as for slight degrees of conical cornea. The observation is more easy if the optic disc is in the line of sight and the pupil large. The mirror is to be held at two feet distance, and its inclination rapidly varied, so as to throw the light on the eye at small angles to the perpendicular, and from opposite sides in succession, in successive meridians. The area of the pupil then exhibits a somewhat linear shadow in some meridians rather than in others."*

Astigmatism is generally congenital and often hereditary; it may, however, also be acquired.

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* Donders, p. 490.

The congenital astigmatism is mostly regular and dependent upon asymmetry of the cornea. In the majority of cases it is present in both eyes, although perhaps in varying degree. Donders has found that abnormal astigmatism occurs far more frequently in hypermetropic eyes than others; indeed, he even thinks that out of six hypermetropic eyes one suffers from abnormal astigmatism. The amblyopia which often exists in hypermetropia, and which cannot be remedied by spherical convex lenses, is mostly due to astigmatism. We often find that persons unconsciously correct a certain amount of astigmatism by holding their head on one side, and thus looking slantingly through their spectacles.

Acquired astigmatism is mostly caused by inflammatory changes in the cornea, which lead to consecutive flattening of the cornea, and leave behind them opacities and cicatrices; it may also be caused by irregularity in the apposition of the edges of the incision after the operation of extraction of cataract. We occasionally find that if iridectomy or iridodesis is performed in cases of opacity of the cornea, a considerable degree of amblyopia persists after the operation, although the pupil is now brought opposite to a transparent portion of the cornea. On examination, we then

find that in many of these cases this weakness of sight is due to astigmatism, and that vision is greatly improved by a cylindrical lens. Acquired astigmatism may also be caused by dislocation of the crystalline lens, more particularly if it is obliquely displaced in the area of the pupil.

The best examples of pure, regular astigmatism are furnished by successful cataract operations, for then any irregular astigmatism which may have been caused by the lens, will, of course, have been removed.

The disturbance of vision produced by even a slight degree of astigmatism is often very great and annoying, as the form and shape of minute objects (such as small letters) are so changed, that they cannot be seen with distinctness, but look blurred and confused. This is due to the fact that certain portions of a letter are yet quite distinct, whilst others are faint or unapparent. Thus the vertical lines of the letter H may appear quite dark and clear, whilst the horizontal connecting line is almost invisible. This also gives a peculiar tremulousness and uncertainty to the outline of the object. On account of the co-existence of irregular astigmatism, the patient may also be affected with monocular diplopia or polyopia.

Regular astigmatism may be remedied by the use of cylindrical lenses, which enable us to correct the anomaly of refraction in each of the principal meridians.

A cylindrical lens is the segment of a cylinder, and refracts those rays of light the strongest which strike it in a plane at right angles to the axis of cylindrical curvature; whereas the rays which pass through its axis suffer no deviation at all. In this, therefore, the cylindrical lens differs from the spherical, which refracts the rays in all planes of the segment.

Now, if in a case of simple astigmatism the one principal meridian is normal, so that rays passing through it are united exactly upon the retina, and the other principal meridian is myopic or hypermetropic, and the rays passing through it are brought to a focus before or behind the retina, we should correct this anomaly of refraction by means of a cylindrical lens whose axis corresponds to the normal meridian. The effect of this would be that the rays which pass through its axis would undergo no refraction, whereas those that pass in a plane at right angles to the axis would undergo the necessary refraction, and thus neutralize the anomaly which obtains in this meridian.

A convex cylindrical lens should be placed in such a direction that its axis lies in the plane of the highest refracting meridian, in order that it may give to the rays which undergo the smallest degree of deflection such an increased amount of convergence as if they passed through the meridian of the greatest refraction.

The reverse obtains in the case of concave cylindrical lenses, for here the axis must correspond to the meridian of least refraction, so that the focal length of the meridian of greatest curvature may be increased, and made equal to that of the meridian of least refraction. A glance at Fig. 28, p. 193, will readily explain this.

I will now illustrate the choice of cylindrical lenses by some examples.

I. *Simple Astigmatism.*—The state of refraction of the one principal meridian is emmetropic, whereas that of the other is either myopic or hypermetropic.

1. *Simple Myopic Astigmatism* (Am).—Let us suppose that there is emmetropia in the principal horizontal meridian (the far point lying at an infinite distance, *i.e.*, $r = \infty$), but that in the principal vertical meridian there is myopia $= \frac{1}{8}$, then $\text{Am} = \frac{1}{8} - \frac{1}{\infty} = \frac{1}{8}$.

In order to correct this, a concave cylindrical lens of 8 inches focus will be required, its axis corresponding to the horizontal meridian, so that the rays of light may here pass without undergoing any refraction, and only those which pass at a right angle to the axis (vertically) be refracted, so as to neutralize the myopia which exists in the principal vertical meridian. To be quite accurate the lens should be slightly stronger ($7\frac{1}{2}$ inches focus), for $\frac{1}{2}$ an inch should be deducted from the strength of the concave lens, on account of the distance of the latter from the nodal point. In hypermetropia, on the other hand, this distance of about $\frac{1}{2}$ an inch must be added to the number of the convex lens. In slight degrees of myopia or hypermetropia (below $\frac{1}{15}$ or $\frac{1}{20}$) we may, however, omit this distance in the calculation.

2. *Simple Hypermetropic Astigmatism* (Ah).—In the horizontal meridian let there be hypermetropia $= \frac{1}{10}$, in the vertical emmetropia, then Ah $= \frac{1}{10} - \frac{1}{\infty} = \frac{1}{10}$ and the patient will require a convex cylindrical lens of 10 inches focus with its axis placed vertically.

II. *Compound Astigmatism.*—In this form, it will be remembered, myopia or hypermetropia exists in both the principal meridians, but it varies in degree.

It will be found very much to facilitate the understanding of these cases of compound astigmatism if we consider the eye to be affected with simple myopia or hypermetropia, but that there exists besides a maximum degree of this anomaly of refraction in one of the principal meridians. We have, therefore, a certain degree of myopia or hypermetropia common to the whole eye, besides a certain, special degree in one of the principal meridians.

1. *Compound Myopic Astigmatism* (M + Am).—Myopia exists in both meridians, but to a higher degree in the one than in the other.

In the principal vertical meridian let $M = \frac{1}{15}$.

In the principal horizontal meridian let $M = \frac{1}{30}$; we then have myopia $= \frac{1}{30}$, and $Am = \frac{1}{15} - \frac{1}{30} = \frac{1}{30}$, to be written as $M = \frac{1}{30} + Am\frac{1}{30}$.

In such a case a spherico-cylindrical lens is required, the one surface of which has a spherical, the other a cylindrical curvature, and its action is that of a plano-cylindrical lens combined with a plano-spherical lens, and it may be expressed by the formula for each of the refracting surfaces, united by a sign of combination.

The case which we have supposed would therefore be corrected by $-\frac{1}{30}\,s \bigcirc -\frac{1}{30}\,c.$

For the spherical and cylindrical surface would require to have a negative focal distance of 30″, and the axis of the cylindrical surface would have to be placed horizontally.

2. Compound hypermetropic astigmatism (H + Ah). Hypermetropia exists in both principal meridians, but more in the one than in the other.

In the vertical meridian let H $= \frac{1}{18}$. In the horizontal meridian let H $= \frac{1}{12}$. We have then H $= \frac{1}{18}$ and moreover Ah $= \frac{1}{12} - \frac{1}{18} = \frac{1}{36}$, and we write H $\frac{1}{18}$ + Ah $\frac{1}{36}$. Hence a positive spherico-cylindrical lens will be required, and it will be corrected by $\frac{1}{18}$ s $\asymp \frac{1}{36}$ c. The axis of the cylindrical surface to be placed vertically.

III. Mixed astigmatism. In this form, in which myopia exists in the one principal meridian and hypermetropia in the other, we must make use of bi-cylindrical glasses. These consist of two cylindrical surfaces of curvature, the axes of which are perpendicular to one another; the one surface is concave, the other convex. In consequence of this, the effect of such lenses is to render parallel incident rays divergent in the plane of one axis, and convergent in that of the other. The axis of the concave surface must be placed in the direction of the hypermetropic meridian, and the axis of the convex surface in the direction of the myopic meridian. Their action may be expressed by the formula for each of the two planes, united by a sign of a right angle ⌈.

1. Mixed astigmatism with predominant myopia (Amh).

In the vertical meridian let M $= \frac{1}{10}$. In the horizontal meridian let H $= \frac{1}{20}$. Therefore Amh $=$ M $\frac{1}{10}$ + H $\frac{1}{20} = \frac{1}{6\frac{2}{3}}$, and is corrected by $\frac{1}{20}$ c $\lceil - \frac{1}{10}$ c.

The axis of the convex surface to be placed vertically, that of the concave horizontally.

2. Mixed astigmatism, with predominant hypermetropia (Ahm).

In the vertical meridian let M $= \frac{1}{18}$. In the horizontal meridian let H $= \frac{1}{12}$. Therefore Ahm $=$ H $\frac{1}{12}$ + M $\frac{1}{18} = \frac{1}{7\frac{1}{5}}$, and is corrected by $\frac{1}{12}$ c $\lceil - \frac{1}{18}$ c.

The axis of the convex surface to be placed vertically, that of the concave surface horizontally.

These examples illustrate the method to be adopted in finding glasses to correct the astigmatism and the ametropia. But in many cases it is not advisable completely to neutralize the anomaly of refraction, both on account of the difference in the size of the retinal images which will occur if the lenses are strong, and also on account of the disturbance in the combined action of the ciliary muscle and the internal recti muscles. It is often desirable that the astigmatism should be wholly corrected, but that only a certain portion of the myopia or hypermetropia should be neutralized.

After the operation of extraction of cataract, the sight is often materially improved by cylindrical lenses, even although before the opacity of the lens, the vision had been perfectly normal. Such cases can only be explained on the supposition, that a certain degree of corneal astigmatism had been neutralized (compensated for) by some lenticular astigmatism, so that when the lens is absent, the ill-effects from the corneal astigmatism make themselves felt. This condition must of course be distinguished from the acquired astigmatism due to a faulty cicatrization of the section. In all cases of extraction, in which the sight is not as good as might be expected from the general appearance of the eye, the presence of astigmatism

should be looked for, and the effect of cylindrical lenses tried.

It is of great consequence that the axes of the surfaces of curvature of the cylindrical glasses should be situated in the principal meridians of the eye, for even a very slight deviation will give rise to considerable indistinctness of vision. In order to insure the exact adaptation of the glasses to the eye, the lenses should be set in round frames, which permit of their being readily rotated in any direction. When the proper position of the axis is found, the screw should be tightened, and the lens thus firmly fixed in the desired position. The clumsy and awkward appearance of the circular frames may be greatly diminished by making them of a smaller diameter, or by having the glasses ground down into oval ones, and then reset into oval frames. But this requires great exactitude and nicety.

Irregular astigmatism depends sometimes upon irregularities in the curvature of the cornea, such as occur from thinning of the cornea after corneitis, in conical cornea, and a faulty union of the section in extraction of cataract. Irregularities in the structure of the lens, or displacement of the latter, so that its edge lies partially in the area of the pupil, may also give rise to this form of astigmatism. On account of these irregularities in the cornea or lens, the refraction of luminous rays is much distorted, for not only do the rays in a certain diameter undergo irregular refraction, but even perhaps individual rays in the same diameter. The retina, therefore, receives a very confused and blurred image, and hence there is always a considerable impairment of vision, the object looking crooked and distorted. Not unfrequently there is marked monocular diplopia or polyopia. Whilst this irregular astigmatism cannot be corrected by cylindrical glasses, it is often susceptible of improvement by stenopaic spectacles, which, by excluding a large portion of the irregularly refracted rays, render the image less distorted and confused.

APHAKIA (ABSENCE OF THE CRYSTALLINE LENS).

This condition may be due to an operation for cataract (*e.g.*, extraction, division, or reclination), to absorption of the lens after traumatic cataract, or dislocation of the lens into the vitreous humour, etc. The state of refraction is of course greatly altered by absence of the lens. Thus an emmetropic eye becomes strongly hypermetropic; a hypermetropic eye still more so; whereas a myopic eye will become less short-sighted, or, if the degree of

myopia was very great, it may even become emmetropic. The power of accommodation is completely absent in aphakia. This has been now incontrovertibly proved by Donders' numerous and most exact experiments.

The acuteness of vision, even after the most successful operations for cataract and with the aid of the most suitable glasses, does not usually reach the normal standard. In old persons this is often due to certain senile changes which take place in all eyes, and often deteriorate the sight considerably. Another not unfrequent cause is to be found in the presence of secondary cataract, or even in the wrinkling of the transparent capsule, which may produce considerable distortion and confusion of the retinal image.

Patients who have been operated upon for cataract require very strong convex glasses to neutralize the acquired hypermetropia. The strength of these glasses will vary according to the degree of the hypermetropia, *i.e.*, the length of the optic axis; for the shorter the latter is, the stronger will the lens require to be. Two sets of glasses will be necessary—one for distant objects, and one for reading, sewing, etc. For the former purpose, the number generally ranges from 4 to 5″ focus, for the latter from 2 to 2½″ focus. But as this varies considerably, different numbers must be tried until the best is found, and it must be remembered that in these lenses of high power, a slight difference may exert a very considerable effect upon the sight. In order to remedy the great spherical and chromatic aberration of light which is produced in these lenses from the difference in their thickness at the centre and at the edges, such spectacles are generally set in a broad horn or tortoise-shell frame, which leaves only the more central portion of the glass exposed.

CHAPTER IX.

PARALYSIS, SPASM, AND ATONY OF THE CILIARY MUSCLE.

Considerable diminution, or even complete loss of the power of accommodation is occasionally met with. We have seen that the range of accommodation is often greatly diminished in presbyopia, for the near point may have receded to 16″ or 18″ from the eye, so that the range of accommodation is reduced to $\frac{1}{16}$ or $\frac{1}{18}$, instead of being as in the normal eye, $= \frac{1}{4}$ or $\frac{1}{5}$. The range of accommodation is also frequently considerably diminished in persons who are very short-sighted, and who have worked much at near objects, so that the ciliary muscle has lost some of its elasticity and become somewhat rigid.

Diminution or loss of the power of accommodation, is often due to paralysis, spasm, or atony of the ciliary muscle.

The fact that we frequently meet with loss of accommodative power, together with a general or as this varies considerably, different numbers must be tried until the best is found, and it must be remembered that in these lenses of high power, a slight difference may exert a very considerable effect upon the sight. In order to remedy the great spherical and chromatic aberration of light which is produced in these lenses from the difference in their thickness at the centre and at the edges, such spectacles are generally set in a broad horn or tortoise-shell frame, which leaves only the more central portion of the glass exposed.

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Diminution or loss of the power of accommodation, is often due to paralysis, spasm, or atony of the ciliary muscle.

The fact that we frequently meet with loss of accommodative power, together with a general or partial paralysis of the third nerve, is of great interest, for it tends to prove that the ciliary muscle is most likely supplied by a branch of the third nerve; this view is now generally accepted, and it is thought that the loss of acccommodation is, in such cases, due to a paralysis of the branch supplying the ciliary muscle, therefore to a direct paralysis of the muscle itself.

The fact that loss or diminution of the power of accommodation frequently co-exists with dilatation of the pupil, due to the paralysis of the pupillary branch of the third nerve, is of importance in the consideration of the mechanism of accommodation. As long as ophthalmologists, agreeing with Cramer's theory, considered the iris to play a principal part in the production of the necessary convexity of the lens during adjustment for near objects, it was supposed that the dilatation of the pupil was the cause of the loss of accommodation. It was thought that the anterior surface of the lens was rendered more convex by the pressure of the radial fibres of the iris upon the periphery of the lens. But in order that the iris may exert such pressure, anterior and posterior fixed points are necessary. The contracted sphincter pupillæ (the pupil is, as we have seen, contracted during accommodation for near objects) is the anterior fixed point, the ciliary

muscle, which also contracts, the posterior. Now, when the pupillary branch of the third is paralysed, dilatation of the pupil ensues, the anterior fixed point is lost, the radial fibres can no longer exert a sufficient pressure upon the periphery of the lens, and hence, it was argued, arose the loss of accommodation in such cases.

But that the loss of accommodative power does not depend upon the dilatation of the pupil, and the consequent inefficient action of the iris, is proved by the following facts :—

1. The accommodation may be paralysed without any dilatation of the pupil.

2. The pupil may be dilated, from paralysis of the pupillary branch of the third, without the accommodation being affected.

3. We sometimes find that after the pupil has regained its contractility (after paralysis of the nerve to the constrictor pupillæ), the power of accommodation remains yet for some time impaired.

4. With a weak solution of atropine (1 part to 2,000 parts of water) we may dilate the pupil fully without completely paralysing the muscle of accommodation; a solution of 1 : 9600 produces dilatation in about an hour; in 1½ hour the pupil is perfectly dilated, and the power of accommodation

but very little affected (De Kuyper). In order completely to paralyse the power of accommodation, a very strong solution (1 : 120) is required, and this takes about three hours to act thoroughly.

5. That the iris is not of any particular importance in bringing about the accommodative changes of form in the lens, is thoroughly proved by Von Graefe's interesting case of total absence of the iris, in which the power of accommodation was normal.

We must therefore look upon the ciliary muscle as the principal, if not the sole, factor in producing the necessary changes in the form of the lens during accommodation.

Occasionally the branch to the ciliary muscle is alone paralysed, all the other branches of the third being intact. The isolated paralysis of the branch to the ciliary muscle sometimes co-exists with paralysis of other nerves, particularly of branches of the facial nerve. Paralysis of the ciliary muscle is at times due to cerebral causes ; indeed, mydriasis, with loss of accommodation, is not an unfrequent precursor of cerebral affections. It may also be caused by syphilis, rheumatism, low, debilitating fevers, and diphtheria.

Diminution or loss of accommodation is occasionally met with after severe illnesses, the whole muscular system being greatly debilitated ; it is then sometimes mistaken for amblyopia, or weakness of sight, dependent upon general debility. Paralysis of the accommodation is also often met with after diphtheria ; here, however, it appears to be less due to general constitutional weakness than to some special process, the exact nature of which is yet undetermined.

The symptoms of paralysis of the accommodation are very marked in emmetropic eyes. The patients find that they cannot accurately distinguish near objects, so that they are perfectly unable to read, write, or sew ; but at a distance they can see quite distinctly. The far point has undergone no change of position, but the near point has receded far from the eye. If we test their sight with a convex lens of 6″ focus, we perhaps find that the near point has receded to 5″ or $5\frac{1}{2}$″ from the eye, and that the far point lies at 6″ (the focal distance of the lens), hence that the power of accommodation is almost entirely lost. The position of the near point varies, of course, with the degree of the paralysis, if this be but slight (paresis), the near point may be but little removed from the eye, and the disturbance of vision be but slight.

The sight is far less impaired in short-sighted persons, for if their myopia does not exceed $\frac{1}{12}$ or $\frac{1}{14}$, then they are still able to read at the distance of their far point (12″ or 14″), as only the near point undergoes a change; it coincides, in fact, with the far point in cases of complete paralysis of the accommodation, and the far point lies here sufficiently near to the eye to permit of small objects being seen distinctly. But the case is very different in hypermetropic persons, for their sight suffers both for near and distant vision, as both the near and far point are affected.

When the paralysis is incomplete, the symptoms often resemble those of asthenopia, and the cause of the affection may escape detection, if the range of accommodation and the state of refraction be not accurately examined.

The treatment of these cases of paralysis of the accommodation must depend upon the cause. If the patient has been suffering from diphtheria, or any debilitating disease, tonics must be our chief remedy, and the affection will then generally yield in the course of from two to three months. The same occurs also in the rheumatic form, in which flying blisters to the temples, and the veratrine ointment may be employed with advantage, together with the secale cornutum. In the cases

which are supposed to be due to syphilitic origin, an antisyphilitic treatment should be had recourse to.

In the rheumatic and diphtheritic form I have largely tried the effect of the solution of the Calabar bean, and with good results. I employ it of sufficient strength to cause considerable contraction of the ciliary muscle, and of the constrictor pupillæ, without, however, fatiguing them too much. I then allow the effect to pass off entirely, and after a few days' rest, re-apply the extract, and thus stimulate the muscles periodically.

The action of the Calabar bean, and its peculiar effect upon the pupil were fully investigated in 1862, by Dr. Fraser,* in his valuable graduation thesis for the University of Edinburgh, on the "Characters, Actions, and Therapeutic uses of the Ordeal Bean of Calabar." And in 1863, Dr. Argyle Robertson discovered its effect upon the accommodation.†

On the application of a very little of the strong

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* Further investigations on the physiological action of the Calabar bean are contained in a more recent paper by Dr. Fraser, in the "Transactions of the Royal Society of Edinburgh," vol. 24.

† Shortly after this discovery of Dr. Argyle Robertson, I had the opportunity of carefully studying the effect of the Calabar bean upon a case of paralysis of the ciliary muscle; a full account of which will be found in the "Med. Times and Gazette," May 16, 1863.

solution (1 drop = 4 grains of the bean) to the inside of the lower eyelid, a little irritation and redness is produced, but this passes off very rapidly. Within 5 or 10 minutes, the pupil begins to contract, and at nearly the same time the spasm of the ciliary muscle commences. The contraction of the pupil reaches its maximum degree (about $1'''$ in diameter) in about 30 or 45 minutes. After about 2 or 3 hours it gradually dilates again, but it does not regain its normal size till after the lapse of 2 or 3 days, when it may even become somewhat larger than before. Even during its greatest contraction, the pupil is still under the influence of light.

The spasm of the accommodation commences about the same time as the contraction of the pupil, and both the near and far point become greatly approximated to the eye, which becomes, in fact, strongly myopic. The far point in the emmetropic eye may be brought to $5''$ or $6''$ from the eye, and the near point to $3''$ or $3\frac{1}{2}''$. The effect upon the accommodation passes off much sooner than that upon the pupil, for three or four hours generally suffice to restore the state of refraction and accommodation to its normal condition.

That the spasm of accommodation is due to

the action of the drug upon the muscles of accommodation, and not upon the iris, was incontrovertibly proved by Von Graefe,* who tried its effect upon the afore-mentioned case of complete absence of the iris (p. 42), and found that the action upon the accommodation took place at about the same time, and in exactly the same manner, as in eyes in which the iris was present. The action of the Calabar bean is, therefore, upon the ciliary nerves, and completely independent of its effect upon the iris.

The effect of the Calabar bean, in counteracting the action of atropine, has also been proved by many experiments. The weaker solutions of atropine are easily overcome by a strong solution of Calabar. But the complete paralysis of the accommodation by a strong solution of atropine (4 grains to the ounce) is only temporarily overcome even by a very strong solution of Calabar, 1 drop = 4 grains of the bean; the pupil becomes smaller, and the power of refraction increased, but the action of the atropine re-asserts itself in the course of a few hours. In such cases we must repeat the application of the Calabar when necessary, until the effect of the atropine upon the accommodation has disappeared.†

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* Archiv. ix. 3, 113.

† Instead of the extract, the more elegant preparation of

We find that a considerable amount of asthenopia is sometimes produced by over-exertion of the eyes at near objects. The asthenopia does not, in this case, depend either upon hypermetropia or insufficiency of the internal recti muscles, but simply upon fatigue of the muscle of accommodation, through continued work at near objects; this state being, in fact, analogous to that produced in other muscles by long-continued over work. In order to treat this form of asthenopia effectually, total rest of the eyes is essentially necessary, and a complete abstinence from all accommodative exertions must be enforced. The patient should, therefore, be supplied with convex spectacles of sufficient strength to render rays emanating even from very near objects parallel, *i.e.*, as if they came from distant objects (from the far point); thus there will be no exertion of the accommodation during reading, writing, &c. After these spectacles have been used for some time, Von Graefe advises that the eye should be methodically exercised as to its accommodation, by gradually accustoming it to weaker convex glasses,

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the gelatine discs may be employed. But these do not answer so well when we wish to stimulate the partially paralysed muscle, as we cannot regulate the strength so well as in the solution.

the distance of the object remaining the same. The spectacles should be of a blue tint, in order to diminish the irritation of the retina, which has, in most cases, been produced by the circles of diffusion, caused by the inefficient action of the accommodative apparatus.

We may also rest the accommodation by paralysing it by a strong solution of atropine. In such cases, a pair of dark blue eye-protectors should be worn in bright light, so as to prevent the photophobia dependent upon the great size of the pupil.

Spasm of the ciliary muscle is of rather rare occurrence, and is especially met with in cases of hypermetropia in youthful persons, who have strained their eyes without using convex glasses; this continued tension of the accommodation producing a spasmodic contraction of the ciliary muscle. In such cases, we find that the patient is apparently suffering from myopia, requiring concave glasses for distant objects, and yet on examining his eye with the ophthalmoscope, the refraction is found to be hypermetropic.

These cases of spasm of the ciliary muscle are often mistaken by a superficial observer for myopia, more especially if the state of refraction is not examined with the ophthalmoscope. The patient should be directed either to look vacantly before him or to regard some far distant object in order that his accommodation may be relaxed to the utmost, and the ophthalmoscopic signs of hypermetropia become apparent. If the spasm is at all severe, the patient is unable to distinguish distant objects without the aid of concave glasses, and it is only after the oft-repeated application of a strong solution of atropine (gr. iv to ℥j of water) that the ciliary muscle becomes paralysed and the hypermetropia apparent. The atropine may have to be repeated two or three times daily for several days, or even longer, before this effect is gained. The paralysis should be maintained for some weeks by the instillation of atropine two or three times a week. Afterwards, the proper convex glasses should be prescribed for reading, sewing, etc., and, if necessary, also for distance.

CHAPTER X.

SPECTACLES, ETC.

THE spectacles which are generally used for the purpose of correcting some optical defect in the eye are either spherical or cylindrical lenses, or a combination of both. The properties of such lenses have been already sufficiently explained, (p. 4), and I shall therefore now only add a few remarks as to the different kinds of spectacles and their construction.

From the perusal of the different anomalies of refraction and accommodation, the reader will have been sufficiently impressed with the importance of the proper and scientific selection of spectacles. I have already (p. 3) insisted upon the necessity of the surgeon himself determining the number of the glass which the patient is to wear, and not entrusting this to the optician, to whom, however, written directions should be sent as to the strength of the required lenses, etc. The surgeon should, therefore, possess a box of trial lenses, such as are made by Paetz and Flohr, of Berlin, and which should be directed either to look vacantly before him or to regard some far distant object in order that his accommodation may be relaxed to the utmost, and the ophthalmoscopic signs of hypermetropia become apparent. If the spasm is at all severe, the patient is unable to distinguish distant objects without the aid of concave glasses, and it is only after the oft-repeated application of a strong solution of atropine (gr. iv to ℥j of water) that the ciliary muscle becomes paralysed and the hypermetropia apparent. The atropine may have to be repeated two or three times daily for several days, or even longer, before this effect is gained. The paralysis should be maintained for some weeks by the instillation of atropine two or three times a week. Afterwards, the proper convex glasses should be prescribed for reading, sewing, etc., and, if necessary, also for distance.

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The strength of any given convex lens may be easily ascertained by finding the distance at which the image of a distant object (a candle, the bars of a window frame, etc.), is distinctly formed on a sheet of white paper or the wall. The distance of this distinct image from the lens gives the focal length of the latter. But if we have a set of trial glasses at hand, a more simple and ready mode is to find the concave lens which completely neutralizes the convex one, and this at once gives us the number of the latter.

The complete neutralization of the convex lens by the concave is known by the fact that if the two are placed in close apposition, we can read as well through them as without any glass before the eye. Another test is, that if we regard a vertical line (*e.g.*, the vertical bar of a window) through them, it remains perfectly immovable when the glasses are moved to and fro before the eye. Whereas the line will distinctly move if the two glasses do not neutralize one another, the more so, the greater the difference between them. If the object moves in the contrary direction to that in which the lenses are moved, it proves that the convex lens is the stronger of the two; whereas, if it moves in the same direction, the concave is the stronger. The strength of concave lenses may be tried in the same way.

Care should be taken that the spectacles fit accurately, that the glasses are on the same level, so that one is not higher than the other ; that they are sufficiently close to the eyes, and that the centre of each glass is exactly opposite the centre of the pupil. The last point should be particularly observed in the selection of glasses which fit on to the nose by means of a spring (pince-nez) for we find that on account of their oval shape these are not generally centred. If they do not fit properly, so that their centre corresponds to the centre of the pupil, they act as prisms, and give rise to diplopia or a correcting squint, and the latter may even become permanent if their use is persisted in. Concave glasses should be quite close to the eye, otherwise they will diminish the size and distinctness of the retinal image. As the rays which impinge upon a concave lens are rendered divergent by it, it follows that the further the glass is removed from the eye, the fewer peripheral rays will enter the latter, in consequence of which the retinal image is diminished in size and intensity.* The reverse obtains in the case of convex glasses, for as they render the rays which impinge upon them more convergent, a greater number of peripheral rays will enter, the further (up to a certain point, of course) the convex glass is removed from it, the retinal image becoming at the same time larger and brighter.

Single eye-glasses should not be permitted as a rule, as they often lead to weakness of the other eye from disuse.

Besides the spherical and cylindrical spectacles we must also consider the following kinds :—

The *periscopic* glasses consist of concavo-convex and convexo-concave lenses (so called positive and negative menisci), and consequently have only a very slight spherical aberration. On this account, when the concave surface is turned towards the eye, there is less irregular refraction at the edge of the glass, so that the regularity of the images is much less impaired. In consequence of this, the observer can look more obliquely through them, as was first shown by Wollaston, who on this account

* It has already been stated that concave glasses diminish the retinal image by moving the nodal point further back, and thus diminishing the angle of vision, whereas convex glasses enlarge the retinal image as they move the nodal point forwards, and thus increase the size of the angle of vision. In very high degrees of myopia, I have found Steinheil's solid glass cone very useful for distant objects, as it acts like a Galilean telescope. It consists of a small cone of solid glass, the base of which is convex, and the opposite surface concave, with a smaller radius than the concave. It is about one inch in length, and can be readily carried in the waistcoat pocket. It may be obtained of Messrs. Salom, 137, Regent-street.

termed them periscopic. Their chief disadvantages are that they reflect the light more, and are also more heavy and expensive than spherical lenses.

Spectacle glasses are sometimes required to have a different focus in the upper and lower part (*pantoscopic spectacles*). This is more especially the case if presbyopia co-exists with myopia or hypermetropia. Thus Franklin, who was presbyopic and also slightly myopic, employed glasses, the lower halves of which were convex, to neutralize the presbyopia, and the upper halves concave, to neutralize the myopia. In Paris such glasses are termed *verres à double foyer,* and are constructed by grinding in the upper part of the spectacle-glass, the surface which is turned from the eye, with another radius. Such spectacles must be placed at a proper height before the eyes, so that in looking at near objects the rays only fall upon the eye through the lower part, whereas, those from distant objects must only fall upon the upper part. This form of spectacle is found very useful by miniature painters, lecturers, etc.

Prismatic spectacles are sometimes employed either for the purpose of exercising and thus strengthening certain of the muscles of the eyeball, or to relieve them. The actions of prisms and the uses of prismatic spectacles in the affections of the muscles of the eye, are fully explained in the chapter on muscular asthenopia. The prisms are generally turned with their base inwards (to relieve the internal recti muscles), and may either be used alone or in combination with convex or concave lenses. In the latter case, they are ground in such a manner as to combine the effect of a prism with that of a spherical lens. By turning the base of the prism inwards, the rays will be deflected somewhat to the inner side of the yellow spot, the eye will consequently move slightly outwards, so as to bring the rays again upon the yellow spot; there will consequently be a less convergence of the optic axes, the effect being the same as if the object were placed somewhat further off, but it is seen under the same visual angle, and the divergence of the rays is also the same.

Closely allied to the prismatic glasses, are the decentred lenses of Giraud-Teulon. They are constructed in such a manner, that the eccentric portions of two convex lenses are used instead of the centre, so that they may thus acquire a slightly prismatic action. Thus in convex lenses the centre should lie a little to the inner side of the visual lines, whereas in concave glasses the reverse obtains, and the centre should lie a little to the outer side of the visual lines.

Dr. Scheffler proposes to substitute for the common spherical lenses glasses which are cut out from the periphery of a large lens, and in such a manner as to act as decentred lenses; he calls them "orthoscopic" spectacles. The advantage which he claims for them is, that with them the convergence of the optic axes undergoes an alteration in harmony with the change in the accommodation, which is not the case when the common spherical lenses are used. His work "Die Theorie der Augenfehler und der Brille," in which this subject is fully treated, is being translated into English by Mr. R. B. Carter.

I have already mentioned (p. 113) that eye-protectors are found of much service to guard the eye against very bright light, dust, or cold winds. The best are the medium blue curved eye-protectors. Goggles are only indicated if the patient is exposed to the atmosphere very soon after a severe operation, when the eye is still inflamed and very susceptible to cold, but for all other purposes the curved glasses are to be preferred. Messrs. Salom have lately introduced an excellent modification of the goggle, by adding thin gauze side pieces to the curved blue eye-protectors, which renders them quite as efficient as the goggles, and much lighter, as well as less unsightly and conspicuous.

The sense of dazzling of which many (more especially myopic) patients complain when they are exposed to bright light, is most effectually relieved by blue glasses. I have already stated that it was formerly supposed that the red rays of the solar spectrum were the most trying to the eye, and consequently green glasses (which exclude the red rays) were much in vogue. But it is now a well known fact that it is not the red, but the orange, rays which are irritating to the retina, and as blue excludes the orange rays, this is the proper colour for such spectacles. Moreover, the blue colour, on account of its more eccentric position in the solar spectrum, makes a less impression upon the retina. Smoke-glasses are not so good, as they more or less subdue and diminish the whole volume of light and colour, and thus render the image somewhat indistinct.

It is often very desirable to combine the blue tint with the use of convex or concave spherical lenses; in the weaker glasses this can be very effectually done; but in the higher numbers it is difficult, for the varying thickness of the glass causes a considerable difference in the tint in the centre and at the edges of the lens. In such cases it will be well to adopt Mr. Laurence's suggestion, viz., to join a very thin piece of plain tinted glass with Canada balsam, to the back of a plane concave lens.

Besides the coloured eye-protectors which are used in order to diminish the bright glare of light, or to keep off the cold wind, dust, etc., there are those which are used by workmen in order to protect the eye during their work against injury from pieces of stone, chips of steel, etc. The best are those made of thick plate glass, with wire or gauze sides, for they are sufficiently strong to resist the force of any, excepting a very large projectile. The chief objections to these are their expense and their weight. To obviate these defects, Dr. Cohn* has recommended the use of spectacles made of mica instead of glass. If the mica is of good quality, it is quite as transparent as glass, but lends a faint grey tint to objects, which does not, however, in the least diminish the acuteness of vision, but rather tempers the light. They are made in the shape of the large curved eye-protectors, and should fit quite close to the eye, leaving only the temporal side somewhat open. They are much lighter and cheaper than the glass spectacles, and do not break on falling down.

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* Berliner Klinische Wochenschrift, Feb. 24, 1868.

DIFFERENCES IN THE REFRACTION OF THE TWO EYES.

Differences in the refraction of the two eyes are not of unfrequent occurrence, and generally consist in differences in the degree of the myopia or hypermetropia in the two eyes; or, again, one eye may be emmetropic, the other myopic or hypermetropic; or myopia may exist in one eye, and hypermetropia in the other. Absence of the lens (aphakia) in one eye, gives rise, of course, to a very great difference in the state of refraction of the two eyes. In the majority of cases, the refraction of the two eyes is very nearly alike. Sometimes, however, we find considerable differences in the degree of myopia or hypermetropia. The practical question is, what kind of glasses are we to give to such patients? It might appear proper to furnish each eye with the glass suitable to its own state of refraction, but in practice we find that this does not generally answer, for the patients, as a rule, complain that such spectacles render their vision confused and indistinct, on account of the difference in the size of the two retinal images. It is best, therefore, to furnish both eyes with the glass which suits the least ametropic (hypermetropic or myopic) eye. If it is very desirable that the patient should enjoy the greatest possible acuteness of vision, we may give two different glasses, so as completely to neutralize the difference in the state of refraction, and the patient must try whether he is able to see distinctly and comfortably with them. Sometimes a little practice will enable him to do so, and then their use may be allowed. If this is not the case, we may partially neutralize the difference, and thus diminish the size of the circles of diffusion. Thus if the myopia of the one eye $= \frac{1}{14}$, and of the other $\frac{1}{8}$, we may prescribe concave 15 for the former, and concave 9 or 10 for the latter. It has also been advised that when the sight of the two eyes (which differ considerably in the degree of their myopia) is equally good, the glass which lies midway between the two degrees of myopia should be given for both eyes. If, for instance, the one eye requires concave 4 and the other concave 8, it would be advisable to prescribe concave 6 for both eyes. But such glasses prove unsuitable, as they suit neither eye, being too strong for the one, and too weak for the other.

If there is a difference in the refraction of the two eyes—the one being myopic, the other hypermetropic—it is also often difficult to suit them with glasses which shall neutralize each anomaly. This is owing to the difference in the size of the

retinal images which will be produced, for the convex lens will enlarge, the concave lens diminish the size of the retinal image, and this may prove a source of considerable confusion. In all cases of difference in the refraction of the two eyes, the patients should try the glasses for some little time, so as, if possible, to become accustomed to them, before we decide definitely as to the kind of glasses which we shall prescribe.

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