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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 been found to be amenable to treatment; cases, which had formerly sorely puzzled the oculist, and were by him but too often deemed incurable.

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.

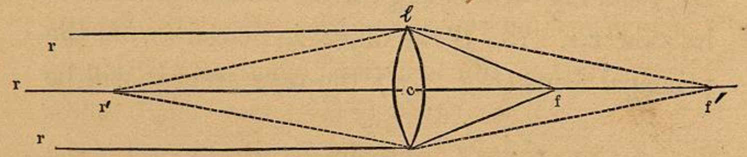
The selection of spectacles is of great importance; and I have no hesitation in saying that the empirical, haphazard plan of selection generally employed by opticians, is but too frequently attended by the worst consequences; and that eyes are often permanently injured which might, by skilful treatment, 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

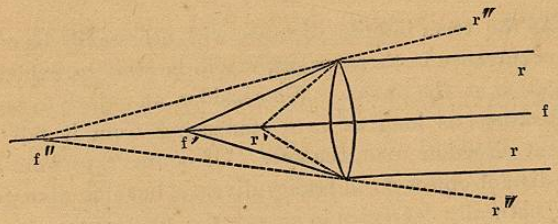
Fig. 1.



* 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

Fig. 2.



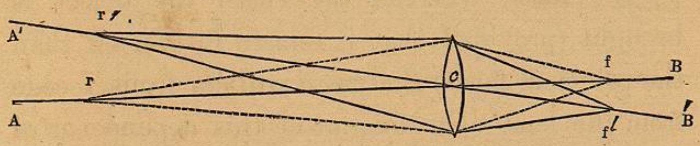
so divergent that the lens will not be able to render them even parallel, and they will, therefore, emerge from it still somewhat divergent. This divergence will of course be less than before they entered the lens, and if the rays ($r''$ $r''$) are prolonged back to

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.

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

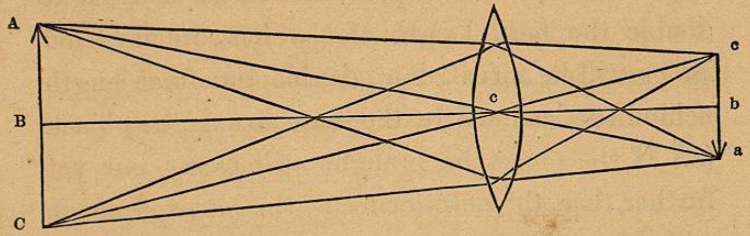
Fig. 3.



behind the lens as *f*. Just as *f* is the conjugate focus of *r*, will *f′* be the conjugate focus of *r′*.

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.

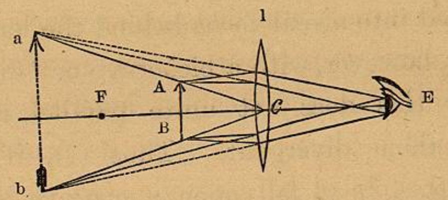
Fig. 4.



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 *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*.

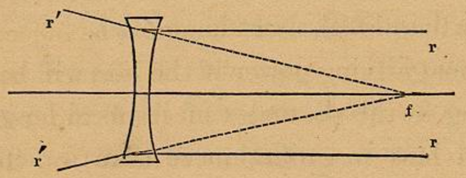
Fig. 5.



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.