THE HUMAN EYE AND SOME OF ITS DEFECTS.

By Albert Westland, M.A., M.D.

The sense of sight is generally considered the most valuable of the five senses with which the majority of human beings are endowed at their birth. By means of it more knowledge is acquired than with the aid of any of the other senses, and, generally speaking, more sympathy and active assistance are given to those who suffer from the want of this sense than to those who may be deprived of any of the other four. It is rather curious, then, to discover that the organ of the body which subserves this sense, the eye, is more prone to natural defects which interfere more or less with its perfect action as an instrument, than almost any other part of the human frame. Among the natural defects which occur in infants, and are generally attributed to hereditary transmission, defects in the construction of the eye are among the most common; and, although one cannot attribute these defects, like tendencies to gout and rheumatism, to the sins of one's ancestors, there seems to be little doubt that with the advance of civilisation and the consequent increased application of the eyes to work requiring prolonged strain as well as minute investigation, the defects of refraction especially, in the human eye, have increased very largely.

Fortunately, however, the progress of civilisation has been followed by a vast advance in the knowledge of physical science, and in the application of that knowledge to the relief of those suffering from physical defects, and in no science within recent years has greater advance been made than in optical science, while the application of the knowledge thus obtained to the cure of many of the defects of the eye has been so successful as to place those suffering from them on an almost equal footing with their more fortunate brethren who are gifted with eyes of normal power.

To understand somewhat of the structure of the human eye, and the directions in which divergence from the normal condition is apt to occur, a slight preliminary knowledge of optics is required.

If the reader take an ordinary magnifying glass of fair strength, and, standing before a window, hold the glass at some distance from his eye, he will observe a very small reversed image of any objects outside, the image being apparently situated in the glass itself. If, however, holding the glass in the same position, he place a piece of thin translucent paper, as thin foreign writing paper, between his eye and the glass, and move it backwards and forwards a little, he will find a point between the glass and the eye, where the reversed image appears faintly but distinctly on the paper, thus showing that the image is not situated on the glass, but some little distance behind it. If he has two or three magnifying glasses, and compares one with the other, he will find that the stronger the magnifying glass is, the more near to the glass the paper must be held; while conversely, the weaker the glass, the further the paper must be removed from it in order to obtain a clear image. The distance at which the glass must be held from the paper so as to obtain a clear image, is called its focal length. The image produced by the method described above is necessarily a very faint one, as, in addition to the rays of light coming through the magnifying glass, or lens, as it is scientifically called, the light is falling on the paper from all points round about, producing, of course, a confusion of rays. If, however, instead of simply holding the lens in the finger, it is let into the side of a closed box, so that light can enter only through the lens, and a piece of paper be held at the other side of the box at the proper focal distance from the lens, a very much clearer image will be obtained.

Observing the image in this way, it will be noticed that if objects very near the front of the lens be rendered quite clear in the image—in other words, brought into correct focus—objects further away are rather indistinct, and a little experimental trial will show that the distance between the lens and the paper must vary a little according as the distance of the object in front of the lens varies, so that while objects far away require a shorter focus, objects near require a longer one. It will be found, however, that the difference of focus required is very small indeed compared with the different distances of the objects, and that for all objects more than six feet away from the front of the lens, pratically the same focus is required. This focus, then, for any object more than six feet away from the front of the lens is known as the principal focus of the particular lens in use, and the strength of the lens is technically known by the number of inches of its focus from the glass, *i.e.*, by its focal length.

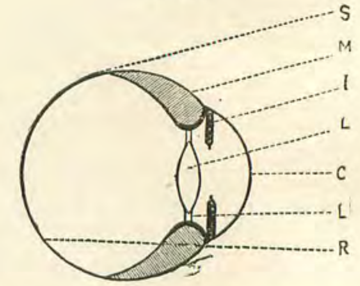
Perhaps it may have struck some of my readers already that the box with the lens in one side and the translucent paper on the other would resemble a little a photographer's camera; and, as a matter of fact, the ordinary camera is constructed exactly on the principle described, the object being there also to obtain an accurate reversed image of some object in front of the lens upon a screen at some little distance behind it. In the case of the camera, instead of a screen made of translucent paper, as in the box suggested, there is one made usually of dimmed or frosted glass, and the image having been properly focussed upon this glass, it is removed, and a sensitive plate to receive the image or negative of the photograph is put exactly in the same place. It has been pointed out before that in order to obtain a clear image the focal distance must vary a little if the same lens is used, according to the distance of the object in front of the lens; and it is obvious that this variation can be effected in two ways, either by moving the lens slightly, keeping the screen fixed, or by moving the screen slightly, while the lens remains stationary. A third method by which a clear image can be obtained while both lens and screen remain fixed is by changing the lens and using one of a slightly different strength whose focal length corresponds exactly with the distance fixed. In the ordinary camera convenience has dictated the movement of the lens as the easiest manner of arranging the focus, and all cameras are provided with a screw, which allows of gradual movement backwards and forwards of the lens. In addition to this movement most cameras are fitted just behind the lens with rings perforated in the centre, by which the amount of light entering can be regulated, and which are known as diaphragms.

The photographer's camera has been described in detail so that from its simple structure the rather more complex arrangements of the human eye may be understood. From an optical point of view, the eye is an instrument exactly similar in structure to the camera. It possesses a lens in front and a screen behind known as the retina; and the main optical condition upon which distinct vision depends is that the lens shall focus exactly upon the retina the image of the objects external to the eye which are regarded at the time.

The human eye is essentially a hollow globe or sphere, the crust of which, to use an expression applied to the sphere of the earth, is opaque everywhere, except on a small portion in front where there is a transparent bulging of the crust, known as the cornea; the opaque part of the crust being termed the sclerotic membrane. The interior of the sphere is filled mostly with a gelatinous fluid; in front, behind the cornea, is the lens, which is a perfectly clear transparent convex lens of considerable hardness, and which is suspended in its position by a ligament which encircles it; and between the back of the cornea and the front of the lens and its ligament is a small space filled with a watery fluid, in which the coloured diaphragm of the eye known as the iris floats, its outer edge being attached all round to the inside of the sclerotic membrane. Behind the iris is the ligament of the lens mentioned previously, which unites with the interior of the sclerotic membrane by means of a circular muscle which is attached at its outside to the interior of the sclerotic, and at its inside to the ligament of the lens. This muscle, which is named the ciliary muscle, is of great importance in focussing the eye, as will be seen later.

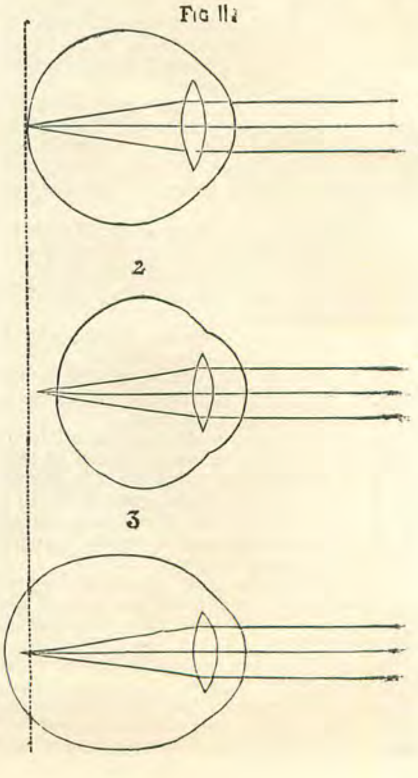
In Fig. 1 the structure of the eye is shown diagrammatically, as if seen cut through the middle from back to front. In front is the transparent cornea (C), behind which lies the lens (L), with the chamber containing the aqueous fluid and the iris (I) between them.

Fig. 1.



The iris is seen projecting like a curtain in front of the lens, cutting off a certain proportion of light, which would otherwise pass through the lens. This iris, or curtain, has the power of contracting or expanding, according to the greater or less amount of light to

Fig II.



which the eye may be exposed at the time. The lens is seen to be attached by its ligament (LI) to the muscle (M) of the eye, which again is united with the external or sclerotic covering (S) of the eye. All round the posterior part of the eye the sclerotic is lined on the inside with the retina (R) or screen upon which the images are projected; and the retina is connected with the brain by a nerve whose function is to convey the physical impression produced on the retina to the more central parts of the brain.

In a perfectly normal eye, such as is represented in outline in Fig. ii. 1, the power of the lens, and its distance from the retina, are such that parallel rays of light—*i.e.*, rays of light coming from any object more than a few feet distant, are brought to a focus exactly upon the surface of the retina. If the focus of the eye were unalterable, then all rays coming from an object nearer than this distance would be focussed at some little distance behind the retina, since it was pointed out that the nearer the object the longer the focal distance from the lens; but the eye, by a most ingenious arrangement, is prepared for this difficulty, and is enabled to focus itself for objects within only a few inches of the lens. While in the camera the focus is adjusted by increasing the distance of the lens from the screen as the object is approached, in the human eye the same result is obtained by an increase of the power of the lens. Although the lens is of fairly dense structure, its shape is capable of being slightly altered by the action of the ciliary muscle; and the purpose of this muscle is, by its construction, so to influence the lens that it possesses greater refractive power, or, in other words, has a shorter focal length.

The continuous contraction of this muscle, however, just as of other muscles, produces a feeling of fatigue; and that sense of fatigue is what exists when the eyes are said to be strained by observing any object held for some little time very close in front of the eyes.

By means of this focussing power, the normal eye has an exceedingly long range of vision, the range extending, practically, from infinity, or at least the distance of the most remote stars, to a distance of three or four inches from the eye, within which, with most people, vision becomes indistinct. Such, however, is not by any means the case with eyes which depart, to any marked extent, from the normal condition, and such departure occurs in two opposite directions, presenting respectively what are popularly known as the longsighted and the shortsighted eye.

The longsighted eye, a diagram of which is represented in (Fig. ii. 2) is characterised by its relative shortness of distance from lens to retina, so that objects at a distance in front of the lens are focussed behind, instead of on the surface of the retina, and consequently are not seen with distinctness. And necessarily the indistinctness becomes greater the nearer the object approaches to the lens, as in doing so it requires a greater focal length.

To a considerable extent this imperfection is remedied by the focussing power of the eye, the ciliary muscle acting on the lens so as to increase the strength, and thus placing the longsighted eye for a time on an equality with the normal eye. But this equality is only partial and only temporary, for in the first place the muscle very soon becomes tired, and relaxes its contraction, thus rendering the image again indistinct; and in the second place the focussing is only possible to a limited extent, so that while the normal eye can see clearly an object three or four inches in front of it, the longsighted eye will not see distinctly anything nearer than from eighteen to twenty-four inches, according to the amount of longsightedness; and even this only for a short time and at the cost of considerable straining and fatigue. Practically, a longsighted eye is at all times in the same condition as a normal eye is when focussed and strained to observe near objects, and the greater the longsightedness the greater the focussing and straining required to see clearly even objects at a considerable distance. The effect of this straining is often to produce continuous and severe headache, and even worse results not unfrequently follow, if the imperfection is not remedied.

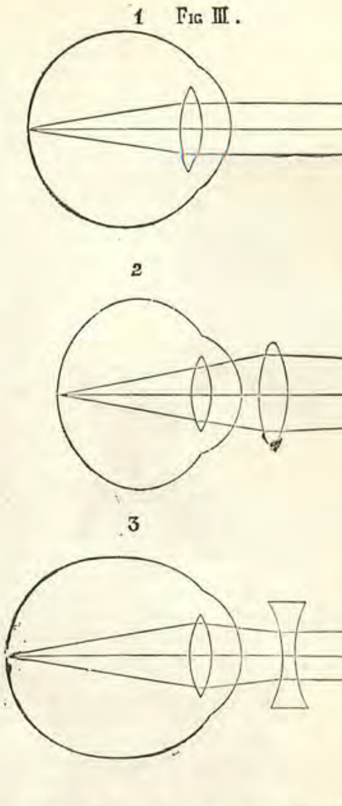
The shortsighted eye (Fig. ii. 3), on the other hand, errs from the normal in the opposite direction. In it the distance of the retina behind the lens is greater than the focal length, and the consequence is that distant objects are brought to a focus in front of the retina, and indistinctness results; and in this case there is no compensation from any focussing power in the eye. While the ciliary muscle by its contraction can increase considerably the strength of the lens, there is no mechanism for decreasing its strength, so that the shortsighted eye is quite helpless as regards distant objects, and a short-sighted person never, without artificial aid, is able to see distinctly any objects more than a few feet, or, it may be, more than a few inches in front of him.

As the objects approach, the focal length gradually increases, until the focus does coincide with the surface of the retina, and then clear vision exists; and as an eye with this character is able to observe objects more closely than a normal eye, often seeing distinctly an object held from half an inch to one inch in front, shortsighted persons are usually gifted with great acuteness of vision for very near objects. While a longsighted eye generally remains much the same throughout life, a shortsighted eye usually tends to become more shortsighted as life advances, and this is especially the case when employments are followed which require close application.

Both these aberrations from the normal type are capable of rectification by the aid of artificial lenses or spectacles. In the longsighted eye, the object to be attained is to shorten the focal length so as to bring the image upon the retina without unduly straining the contractile power of the ciliary muscle, and this is effected, as shown in Fig. iii. 2, by placing in front of the eye a convex lens of the requisite power. The strength of lens required is ascertained by experiment with lenses of known focal length. The action of the muscle, which varies from time to time, would interfere with the exact measurement of the longsightedness if there did not fortunately exist, in the action of the plant belladonna, the power of paralysing it temporarily; but with the muscle completely paralysed for a time one is able to measure exactly the length of convex lens required to bring the focus of distant objects on the retina. Distant objects being thus focussed, as in the normal eye, without any action of the ciliary muscle, near objects with its assistance are seen as clearly with the spectacled longsighted eye as with the unaided normal eye.

A lens of an opposite character is required for the shortsighted eye (Fig. iii. 3), the object in its case being to increase the focal length. This is effected by means of a concave lens, which neutralises a certain amount of the focussing power of the lens of the eye, and thus throws back the focus on the retina. As the ciliary muscle does not interfere with the determination of the amount of shortsightedness, no preliminary paralysis of that muscle is necessary before testing the shortsighted eye, and the concave lens being adjusted of such strength as to permit of distant vision, the muscle accommodates the eye for near vision just as in the case of the normal, or the spectacled longsighted eye. It will thus be seen that the shortsighted eye, if aided by spectacles, has a rather longer range than even the normal eye, for while the near point of the normal eye is at a distance of three or four inches from the eye, the shortsighted eye, by removing its spectacles,

Fig. III.



can bring its near point to an inch or half an inch, while with the spectacles its far point is as distant as that of the normal eye.

The important part which the muscle of the eye plays in adjusting the focus for objects at varying distances has been more than once pointed out; and it has been shown that its utility is dependent upon a condition of the lens allowing of slight alterations in its form. As middle age progresses, the lens loses a considerable amount of this elasticity, and the alteration required for near vision is effected with increasing difficulty, and with less efficiency; so that after from forty to fifty years of age the near point of distinct vision recedes from the eye until often it is impossible to read comfortably at a nearer distance than eighteen inches to two feet. Here also a convex lens becomes useful in aiding the weakened power of the lens of the eye; and its use should always be resorted to when reading or writing becomes irksome at a distance nearer than fourteen to sixteen inches. Spectacles are always conservative in their tendency, and it is an utter mistake to suppose that the eyesight will be in any way weakened by their use, provided only spectacles of a proper character and strength are obtained. The struggle between a wearied muscle and a gradually hardening lens is one that can only end in the defeat of the muscle; and the fight is carried on at the expense of the proprietor of the eye, and paid for in fatigue, headache, and discomfort. Surely, the wiser part is to recognise honestly one of the first symptoms of advancing age, and to take advantage, as early as needful, of the means of alleviation which are afforded by the scientific application of spectacles.