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THREE LECTURES

ON

PRESERVATION OF SIGHT.

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PRESERVATION OF SIGHT.

BY

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"Truly the light is sweet, and a pleasant thing it is for the eyes."—Ecc. xi. 7.

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PREFACE.

THE following Lectures on "Preservation of Sight" were delivered by me in Glasgow in May last. They embody some truths well known to ophthalmic surgeons, but which the public generally is more or less ignorant of; and though the discussion of each section may not be alike interesting to every one, I venture to think that there are few classes who will not find in these Lectures some knowledge, the practical use of which will be of service to themselves or others. Especially to parents and schoolmasters, who have the charge of the education of youth; to the hard-working student; to those who need spectacles, and others that I need not enumerate: I hope these Lectures will be of some service, partly in preventing the germs of diseases of the eyes from supervening, and partly in deferring their period of superannuation.

Of the sources from which the facts contained in these Lectures were gleaned, I have to mention, Donders on the Refraction of the Eye; Scheffler on the Theory of Ocular Defects, translated from the German by Mr Brudenell Carter; Mackenzie's Physiology of Vision; Mackenzie's Practical Treatise on Diseases of the Eye; Giraud-Teulon's article in the French edition of Mackenzie's Practical Treatise on Diseases of the Eye; Brewster's and Lardner's Optics; Soelberg Wells on Long, Short, and Weak Sight; Stellwag von Carion's Treatise on the

Diseases of the Eye, translated from the German by Hackley and Roosa, New-York; Smee on the Eye in Health and Disease; Kölliker's Manual of Histology; Quain's and Wilson's Anatomy; Jones on Failure of Sight from Railway and other Accidents; Herschell's Familiar Lectures on Scientific Subjects; Tyndall's Notes on Light. Lastly, I think it only justice to mention that the practical application of many of the facts contained in these Lectures was acquired by me during an extensive course of observation in the practice of the late Dr Mackenzie, whose private assistant I was for upwards of seven years.

DAVID SMITH.

56 Bath Street,
Glasgow, August, 1871.

CONTENTS.

LECTURE I.

LECTURE II.

LECTURE III.

THREE LECTURES

ON

PRESERVATION OF SIGHT.

LECTURE I.

The Importance of the Eye as an Organ of Vision—The Structures Existing in and Surrounding the Eye which act as its own Protectors—Spectacles as a Cause of Impaired Vision—Defects of the Eye for which Spectacles are required—The Philosophy of Vision in so far as it relates to the Eye—The Indistinctness of the Images of External Objects on the Retina, if they were formed by Radiation alone—The Refraction of the Eye renders the Retinal Images Sharp and Distinct—The Accommodation of the Eye for Distances—Other Consequences of Refraction of the Eye—The Principles of Refraction of Convex Lenses—Biconvex, Plano-Convex, and Periscopic Lenses—Convex Lenses with Two Foci—Decentred Convex Lenses—Orthoscopic Convex Lenses—Presbyopia or Long-Sightedness—Rules for Determining the Focus of the Convex Lenses required in any case of Presbyopia—Directions for Diminishing the Convergence of the Eyes in Presbyopia.

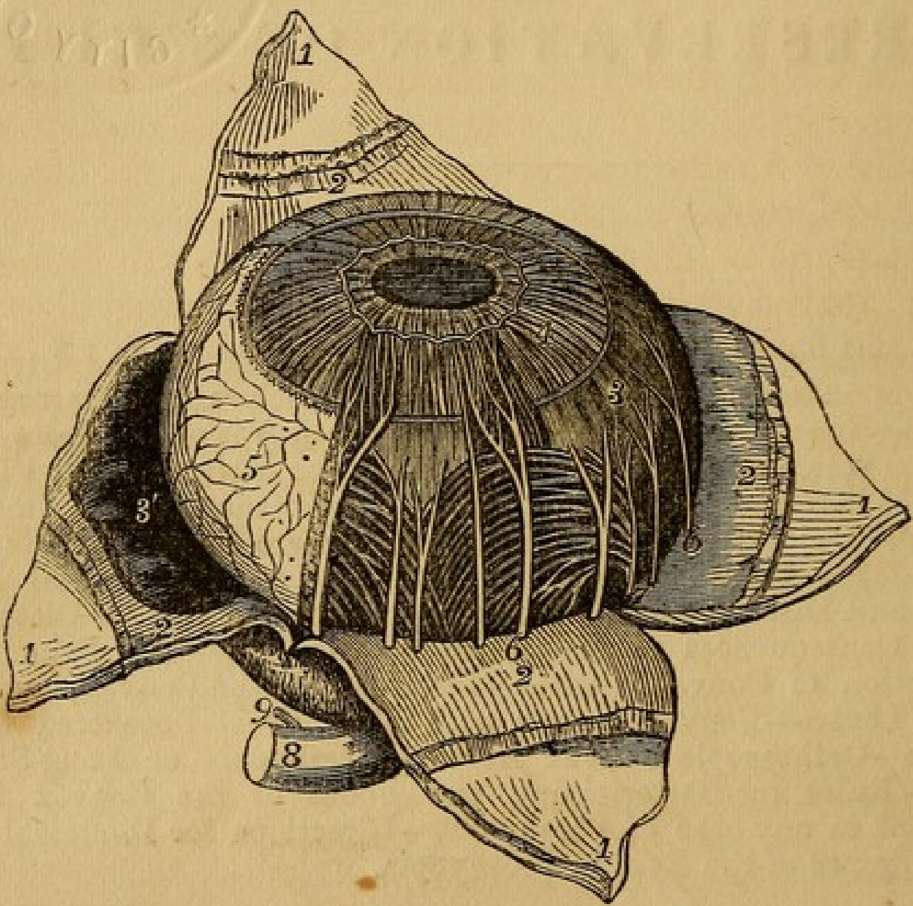
LADIES AND GENTLEMEN,

THE object of the present course of lectures, as is sufficiently indicated by its title, is to put you in possession of such facts regarding the causes of impairment and loss of sight as may tend to their prevention.

The scope of these lectures would certainly be wide if they were carried to their legitimate conclusion. Thus the treatment and consequent cure of most diseases of the eye, in the strictest sense of the term, would, directly or indirectly, be preserving sight; and many of the operations which are performed on the eye might be similarly characterised. My object, however, is not to lay before you the prescribed means of cure of diseases of the eye, but to give you such directions as may, by their adoption, prevent diseases from supervening.

But even this, allow me to state at the outset, it is not possible for me to accomplish. For many diseases of the eye, in the present state of our knowledge, are not preventive. Nay, the majority arise from causes wholly beyond our knowledge. Our subject, then, is further limited to a discussion of the *known* causes of diseases of the eye, and to those which are more or less *in our own power to prevent*—causes,

Fig. 1.

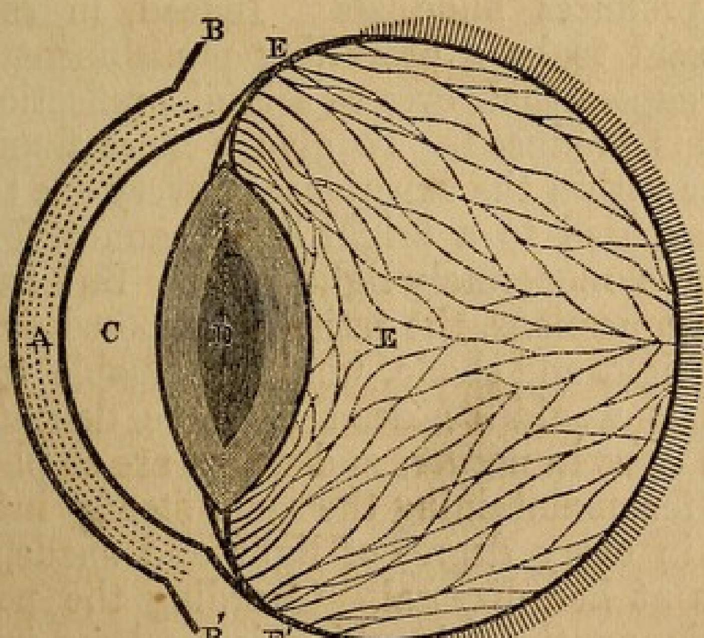


In this preparation of the eye a crucial incision has been made in the cornea, carried back in four directions into the sclerotic coat, and the flaps turned back. (1) The cornea; (2) sclerotic coat; (3) choroid coat; (3') a part of the same turned back exposing the pigment which lines its inner surface, and the retina (5) which lies beneath; (4) the iris, with the pupil in its centre; the few white circular lines in the drawing which surround the pupillary margin of the iris represent the sphincter muscle which contracts the pupil, and the white lines which radiate towards the circumference of the iris represent the muscle which dilates the pupil; the annular white band which surrounds the circumference of the iris is the ciliary muscle; (5) the retina, in which a number of very fine blood-vessels are seen to ramify; it terminates in a saw-like border in front; (6) ciliary nerves; (7) veins of the choroid; one large vein is seen to pass out of the eyeball through an opening in the sclerotic coat. (The structures represented under 6 and 7 are copies of Arnold, as these parts were not so well seen in the preparation from which the drawing was taken). (8) Optic nerve. [Enlarged.]

indeed, which chiefly arise from improper use of the eyes. In a word, we have to consider, in these lectures, what we must do to preserve the eyes in health, and what we must avoid during the use of them.

Of the importance of the eye as an organ of vision, and therefore of our best efforts to preserve it in health, there can be no doubt. Though it is compressed into a sphere less than an inch in diameter, there probably exists no organ in the body, if we except the brain, so comprehensive and accurate in its functions. The eye forms the connecting link between this and other worlds, the distance of which far transcends our imagination. If it were not for IT the records and the literature of former generations would have sunk into oblivion with the memories of the past. To the prince as well as the peasant sight is alike invaluable, and its loss to either is one of the greatest calamities. There is no vocation in which it is not the mainspring of action, nor any position of danger in which it is not the chief monitor of warning. Indeed, so necessary is the eye to our very existence that we are indebted to it, not only for much which renders life pleasant, but we are indebted to it for the means of performing the works of our every-day life.

Fig. 2.



Diagrammatic sketch representing a section of the retina and humours of the eye :—A, the cornea ; B B′, the commencement of the sclerotic coat, which is cut away ; D, the crystalline lens ; E, the vitreous humour ; E′ E′, the parts of the hyaloid membrane from which the beaded structure of the vitreous humour takes its origin ; F, the retina.

Before entering upon the causes of impaired vision, and of the means for warding them off, let us consider some of *the structures existing in and around the eye which act as its own protectors.*

The eye essentially consists of the retina, the percipient membrane of vision (Fig. 1, 5), (Fig 2, F), and of transparent humours (Fig. 2), the cornea (A), aqueous humour (C), crystalline lens (D), and vitreous humour (E). The retina is the canvas on which the images of external objects are formed; the humours perform the functions of convex lenses, and thus give perfection to the images which the retina receives.

Those parts which have been named as the essential constituents of the eye, are bound into a sphere and protected from injury by the sclerotic coat (Fig. 1, 2), and the cornea (Fig. 1, 1), (Fig. 2, A),—the former of which is a thick fibrous membrane, well adapted, from its strength and toughness, to perform these offices. It is continuous with the cornea, the glassy part in front of the globe, in which situation the latter takes upon itself the same limiting and protecting actions as the sclerotic coat, besides its equally important one of a spherical lens.

From momentary excess of light the retina is protected by contrivances of the most perfect kind. Light itself, when too strong, produces blindness. Indeed, in some parts of India it is said to be a prevailing punishment for political offenders, to expose their eyes to a bright reflection of the sun till blindness is produced. To give a more familiar illustration, it will be within the experience of every one that the eyes, after being exposed to a bright light, cannot, for some time, see objects in a moderately light room. But irrespective of such strong impressions, the retina, if exposed even to slight variations of light and shade, would be unable to see minute objects, and it would be dead to those delicate shades of colour which exist in nature, and which are so pleasing to the eye. Now, for maintaining the same steady influx of light into the eye in every degree of light and shade, nature has ample means at her disposal. Guarding the portals of the eye is a membrane, the *iris*, which is rendered impervious to light by being coated behind with black pigment (Fig. 1, 4). Near the centre of this opaque curtain is an aperture, the *pupil*, which serves in the eye the same purpose as does the aperture in the *camera obscura*—viz., by its small size to cut off the circumferential rays of the cones of light. But the size of the pupil is regulated by muscular fibres contained within the iris, some of which contract it to secure the retina from momentary harm when the light is too bright, and others which dilate it when the light is weaker. Moreover, that the iris may perform these duties with the utmost celerity—the transmission of light being instantaneous —*that* membrane floats in a limpid fluid, the aqueous humour (Fig. 2, c), which reduces its weight and resistance to a minimum. The influence of the size of the pupil in regulating the amount of light admitted into the eye may be illustrated by a simple experiment. Dilate the pupil of one eye with a solution of the sulphate of atropia, and, while both eyes are directed to an object, place a prism (page 29), with its angle outwards, before the eye so acted on, for the purpose of producing double vision. The images of the two eyes will stand side by side; but that belonging to the eye in which the pupil is dilated will be brighter than the image as seen with the eye the pupil of which is of normal size. The opposite effect will be produced if the pupil of one eye be abnormally contracted by means of the extract of the Calabar bean.*

But light travels at the rate of 195,000 miles in a moment of time; and as no motor power in our bodies could counteract the effects of a force which travels with such rapidity, the contraction of the pupil, quick though it be, would not be, of itself, a sufficient protection to the retina against excess of light. This apparent deficiency is supplied by a layer of pigment which lines the inner surface of the choroid tunic, and therefore lies in juxtaposition to the outer surface of the retina. This is shown in the preparation which I hand round for your inspection. (Fig. 1, 3′). One of the purposes of this layer of black pigment is, to absorb the superabundant light which is momentarily allowed to enter the eye from the tardy action of the pupil. When excessive brilliancy continues, or when the retina requires repose as during sleep, the pupil contracts to its smallest diameter, and the eyelids come into operation to exclude the light altogether.

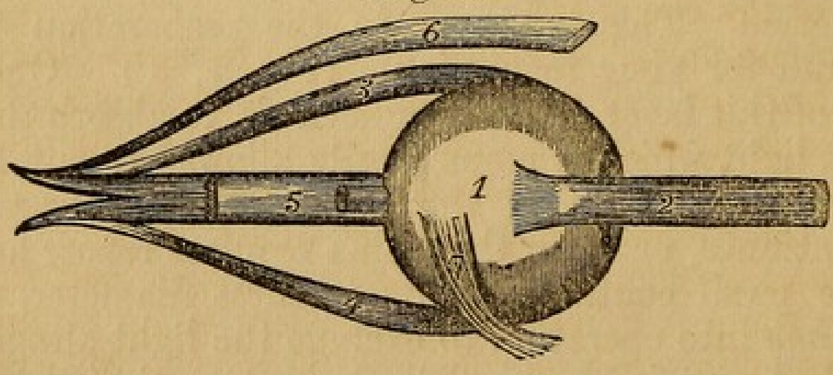
But the retina is of such delicate texture that the slightest movement of it would derange or destroy the fragile elements of which it is composed. Even in the living eye, the faintest pressure on the globe through the eyelids, calls forth its latent sensibility, giving rise to a bright luminous spectrum. Now, the retina is adherent to the surface of the vitreous humour

* These medicines may be procured from any druggist.

(Fig. 2)—a globe of watery fluid limited by a transparent membrane, the slightest wave of which would break up the elements of the retina, and give rise to flashes of light; yet during the varied, sudden, and sometimes forcible evolutions of the body, not a wave of the vitreous fluid is produced, not an element of the retina is disturbed, not a spark of light is emitted. These effects are prevented by a delicate structure within the vitreous itself (Fig. 2, E), which retains the fluid in its meshes in the manner of a sponge, but which is so minute and transparent that scarce a trace of it can be distinguished in the healthy state of parts, under the highest magnifying power.

The crystalline lens also (Fig. 2, D), is a body of such exquisite transparency, symmetry, and smoothness, that nature to protect it, has placed it in the very centre of the eye, beyond the reach of all common influences. But not only this: we shall find that the lens changes its form when the eye looks at near objects, to enable it to perform which, it is surrounded before and behind by fluid (Fig. 2). Now this fluid, which is so necessary to the functions of the lens, is a deadly poison to its very life and existence; for if the fluid by which it is encompassed were getting in contact with it, a few hours would be sufficient to render it as white as milk, and to destroy sight. But from this fluid the lens is protected by a homogeneous capsule, the thickness of which does not exceed $\frac{1}{1500}$th of an inch in diameter, but which is impervious to everything save the nutriment which it draws through its walls.

Fig. 3.



Diagram, shewing the principal muscles of the eyeball of the right side. (1) The eyeball; (2) external rectus muscle severed near its attachments, and turned forward; (3) superior rectus muscle; (4) inferior rectus muscle; (5) internal rectus muscle; (6) levator palpebræ muscle, which raises the upper eyelid, and which is antagonistic in its action to the orbicularis palpebrarum muscle situated in the substance to the eyelids; (7) inferior oblique muscle.

Another source whence the eye would derive injury, but from which it is very perfectly protected, is the wind, which carries before it dust, sand, and other foreign bodies. Now, the surface of the eye is very intolerant of any foreign body lying upon it, the smallest particle of *grit* giving rise to acute pain, and often inflammation. But nature here also is prepared for the emergency. The surface of the eye and inner surface of the eyelids are covered by a thin mucous membrane called the *conjunctiva,* which is endowed with an extreme degree of sensibility; and the nerves which communicate sensation to it are intimately associated with the muscles which move the eye and eyelids (Fig. 3), as also with the lachrymal gland which secretes the tears. Now, by the unity of action which is thus secured between these parts, no sooner does a foreign body touch the eye, than the eyelids attempt to grasp it between their edges, the eyeball rotates upwards, carrying the clear cornea out of the way of harm, and a flood of tears gushes forth to carry the foreign particle into the inner angle of the eye, which having gained, it lies without causing pain or injury, and from which it is ultimately extruded upon the cheek.

The globe of the eye also, is very perfectly protected from mechanical agencies by the eyelids, which instinctively close over it on the approach of danger, and by the edges of the bony orbit, which project considerably, and sustain the force of bodies which may strike the face, or with which the face may come in contact; and if the eyeball do receive a blow, the force of the latter is partly expended on a cushion of fluid fat, which occupies the back part of the orbit, and on which the globe of the eye rests.

It is by no means intended by these remarks that the eye is never hurt or injured by natural phenomena. On the contrary, it is often so hurt and injured. But the probability is, that if the causes of impairment and loss of sight were traced to their fountain-head, they would be found to arise more frequently from imprudences on our own part than from failures on the part of nature. For there is no organ in the body so much abused as the eye, if indeed we except the stomach. Not that it is abused wilfully, but rather from ignorance as to what does and what does not hurt it. Thus, the iris may be a sufficient protection to the eye from light of ordinary brightness, but if we, by our own wilfulness, constantly expose the eye to a too bright light, the iris will ultimately cease to respond to it, and harm to the retina will be the result. Again, *when we will we see.* Nature has ordained a certain number of hours of repose for resting the eyes in common with the body, but there is nothing to prevent us overworking our eyes if we will, a continuance of which must inevitably bring on premature decay of sight. The use of gas-light does not appear to produce any bad effects on the eyes when properly used, and in moderation, but when its brilliancy is excessive, or when it is used during the greater part of the day or night, it brings on disease. Indeed, everything goes to show that nature is infinitely more careful to preserve the eyes from harm than we are ourselves.

We now go on to consider some of the causes of impaired vision which are more or less within our own power to prevent, and the means of obviating them.

1. Spectacles as a Cause of Impaired Vision.

Some of the Injurious Effects of Spectacles.

The fallacies regarding the use of spectacles are very great and very common. Some hold that even when sight is good, the use of glasses preserves it. Glasses in that case go by the name of "*Conservative Spectacles,*" a title which, in the circumstances, they do not merit. Others take credit to themselves for deferring the use of spectacles even after their need is felt. This is as great an error as the last, and is often equally dangerous. Nor are the evil effects much less if, when glasses are required, ones of too short or too long focus are used. For example, if stronger *convex* glasses are used than are required, they will for the time, render the eyes to which they are appended myopic. This necessitates a close approximation of the object, and confirmed myopia may be produced. Or, what is more common, the use of too strong glasses causes rapid degeneration of the accommodating power of the eye. Of the many individuals that I have examined who wore convex glasses for long-sightedness, I have found comparatively few, who had not worn stronger glasses than were necessary. Now, the effect of such a practice on the presbyopic eye is to hold part of the accommodating power of the eye in abeyance—the excessive convexity of the glasses takes the place, for the time being, of part of the accommodating power which should be called into play, and the latter, not being in action, rapidly degenerates from want of use, and is soon for ever lost. There is also some reason to fear that the use of too strong convex glasses operates as one of the factors in producing a very painful disease of the eye called *glaucoma*.

The use of too strong *concave* glasses in cases for which the latter variety of spectacles is required has an opposite effect on the accommodating power, but is attended with results equally dangerous to the eye. By anticipating my remarks on this subject, however, which will fall to be discussed under myopia, I might not be clearly understood.

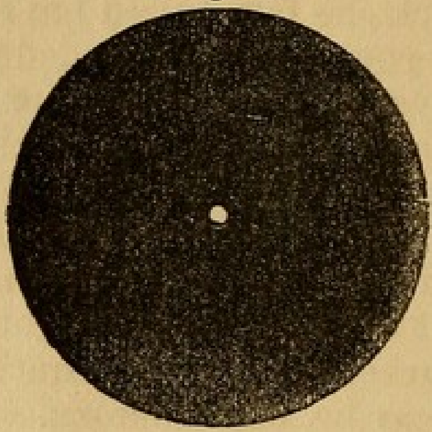
Again, it is not uncommon for spectacles to be used for defects of the eye, to rectify which they are totally unfitted. Thus convex glasses are sometimes sought for impairment of vision wholly unconnected with the refraction of the eye, but which depends, it may be, on amaurosis. In such case, independent of the injury done to the eyes by the use of the glasses, the loss of every day that proper treatment is delayed renders the probabilities of a cure so much the more remote.

Such are a few of the injurious effects of spectacles when injudiciously used, but their number might be largely increased. Used in their proper place, spectacles are inestimable blessings to mankind; abused, and the injury which they inflict is incalculable. My object in this and the following lectures will be to lay before you the scientific principles on which the use of glasses is based; and it will also be my duty to bring before you a variety of spectacles lately introduced, which it is thought will operate in preserving sight. In so doing I shall divest my remarks as much as possible of all technicalities.

A Distinguishing Feature in the Cases for which Spectacles are Needed.

My first duty is to point out to you a ready means of distinguishing between cases in which spectacles are of benefit, and those in which they either do harm, or, at all events, do no good. Spectacles are sought for some impairment of vision. Now, over and above inflammation of the eye, which is readily detected when it exists, dimness of sight may arise from many causes operating within the eye, and which are not readily detected by such means as are commonly at the disposal of the public. Thus cataract, amaurosis, and a host of diseases of the eye, the very names of which would be a burden to your memories, give rise to impairment of vision, in the majority of which spectacles do absolute injury. How may such cases be readily separated from defects of the refraction of the eye, which are remedied by the use of spectacles of some sort? Take a card, or disc of metal, such as this which I show you (Fig 4), with a small aperture pierced in the centre, and place it

Fig. 4.

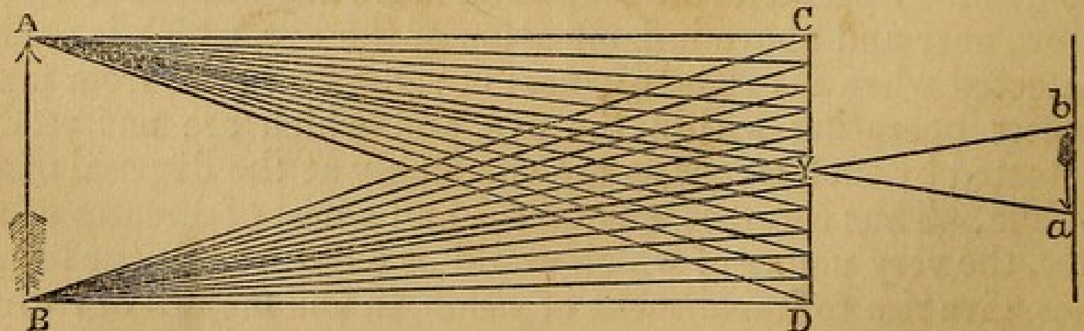


close before one eye, the other being closed. If the dimness of sight which exists arises from such a defect of the humour of the eye that normal refraction can be re-established by the use of spectacles of any kind whatever, vision through the aperture ought to be rendered clearer. On the other hand, if the dimness of sight arises from opacity of the humours, such as exists in cataract, or from diseases of the retina or optic nerve, then vision will generally be rendered dimmer by the use of the diaphragm. This should be done in every case before spectacles are selected; for though, on the one hand, it gives us no indication of the *kind* of spectacles which should be used, on the other it will almost invariably mark out the cases in which spectacles should not be used.

The Philosophy of Vision in so far as it Relates to the Eye.

In order that we may understand the principles combined in the use of spectacles we must consider the manner of the formation of images within the eye. A distinct image can

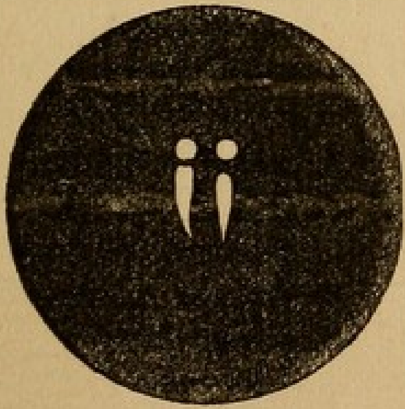
Fig. 5.



only be formed in the eye, by the rays which are given off from points of the object, meeting at accurate points in the image. To illustrate this, let A B (Fig. 5) be an object, and C D an opaque screen placed perpendicular thereto at a certain distance. From A and B respectively a cone of rays proceeds, the base of each of which falls on C D, the same taking place from every intermediate point between A and B. Thus on C D there fall rays which come from every point of the object A B, all of which, however, are mixed up together, and, therefore, no distinct image in that case can be formed. But let a small aperture be made in the screen at Y, and another screen placed beyond and parallel with the first at *b a*, then the central rays of each cone, and those only, will pass through the aperture Y and onwards to *b a*, forming an image of the object A B, in which each point is kept more or less distinct from the other—all the other rays of each cone being intercepted by the screen C D. The rays A Y *a* and B Y *b* are called the *axial rays* of the cones which respectively proceed from A and B.

Now, *the formation of images by this method*, or *radiation*, as it is called, is one of the principles involved in the formation of the pictures of external objects within the eye. The aperture Y represents the pupil, C D the iris, and *b a* the retina. It is from the images so formed that the mind derives much of the information which it possesses respecting objects. I show you here an artificial eye formed on these principles, having a small aperture in front, and a segment of ground glass behind, representing respectively the pupil and the retina. If this instrument be held facing an object, an image of that object will be formed on the disc of glass. (Fig. 6.) On examining this image the distinctive colours of the object may be discovered in it. By its variations of size, the mind is enabled to

Fig. 6.



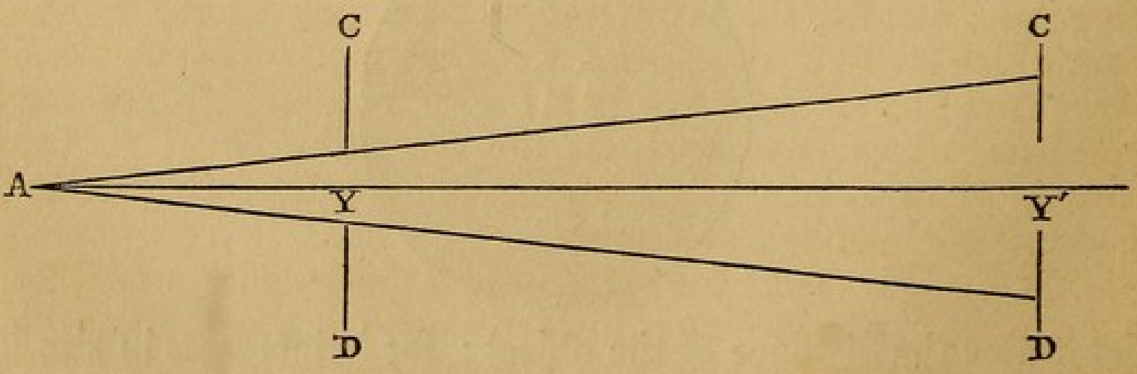
determine the distance of the object; for it increases in size in proportion to the nearness, and diminishes in proportion to the remoteness of the object. You will also observe that the image moves with the lateral movements of the object.

But the position of this image, with respect to the object, is inverted—the upper part of the image corresponds to the lower part of the object, the right side of the image to the left side of the object, and *vice versâ*. This follows as a natural consequence of the direction of the rays which are admitted into the eye; for, from their direction, they must cross each other in some part of their course. (Fig. 5.) For the same reason, the movements of the object are also inverted. This inversion of the position and movements of the retinal image, as compared with those of the object, are corrected by the mind in a manner which we cannot tell.

Such are the images formed by radiation, but if this were the sole means whereby images were formed in the eye they would be very indistinct and confused; for the large size of the pupil, which is from the $\frac{1}{8}$th to $\frac{1}{4}$th of an inch in diameter, would admit a cone of rays of its own diameter from each point of the object, and thus the neighbouring points of the object would in the image be so large and diffused as to overlap. In order to rectify this confusion the rays of light proceeding from points of the object must be brought to accurate points in the image, which is accomplished by refraction through spherical surfaces, presently to be described.

Before we proceed to discuss the principles of refraction, there is one quality of *the rays of light* which we must briefly consider—namely, *their divergence with distance, and, consequently, the exclusion from the eye of a given number of rays as the distance between the object and the eye is each time increased.* The rays of light which enter the eye from all near objects are more or less divergent; but the rays which *the eye receives* from any object become less and less divergent as the distance of the latter is increased. Let A (Fig. 7) be

Fig. 7.

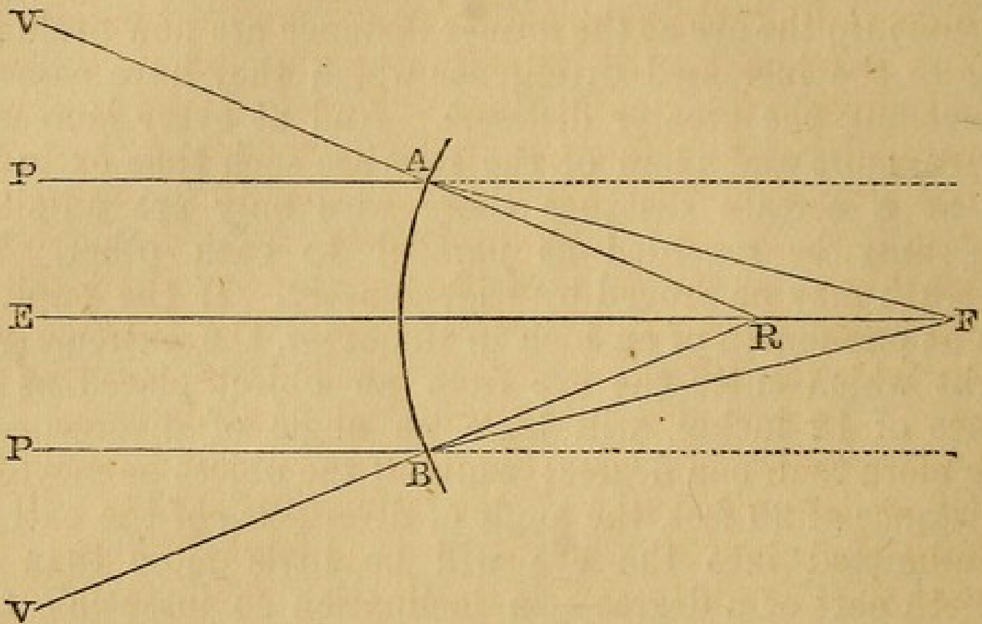


the point of an object placed near the eye, C D the iris, Y the pupil. Of the congeries of rays given off from the point A, the greater number are so divergent as to fall wide of the pupil, those rays only being admitted into the eye by the latter which have the least degree of divergence. If the object be removed to a greater distance, A Y′, some of the extreme rays admitted into the eye at the former distance are now excluded, owing to the increased divergence which they have assumed in travelling the greater distance. And at every increasing distance, more and more of the rays are each time excluded, until at a certain distance those rays only are admitted which may be regarded as parallel to each other. The same truth may be proved by trigonometry. If the pupil be taken at one-fourth of an inch in diameter, the extreme rays of light which enter the eye from an object placed at the distance of 12 inches, will have an angle of divergence of rather more than one degree; while, if the object be moved to the distance of 20 feet, the angle of divergence of the extreme rays admitted into the eye will be little more than the twentieth part of a degree—an inclination so insensible that the eye cannot detect it. Therefore, the rays of light which *enter the eye* from objects at the distance of 20 feet and more may be regarded as parallel to each other, while the rays which *enter the eye* from objects placed nearer than this are divergent, their divergence increasing nearly in the same ratio as the distance of the object from which they proceed diminishes. But we must proceed with the discussion of the principles of refraction in so far as they relate to the eye.

When rays of light pass obliquely from one medium to another, each differing from the other in density, they are bent out of their original course, or are refracted. The course of the refracted rays depends on the obliquity or form of the refracting surface: within a certain limit the rays may be bent in any required direction, and to any required degree, by giving the refracting surface a particular form. It is possible, therefore, to give the refracting surface such a form that the rays which strike it, proceeding from any particular point of an object, will be brought to a point after refraction, a *necessary condition*, as we have seen, for the formation of an accurate image. This is nearly accomplished by a refracting surface, which is the segment of a sphere.

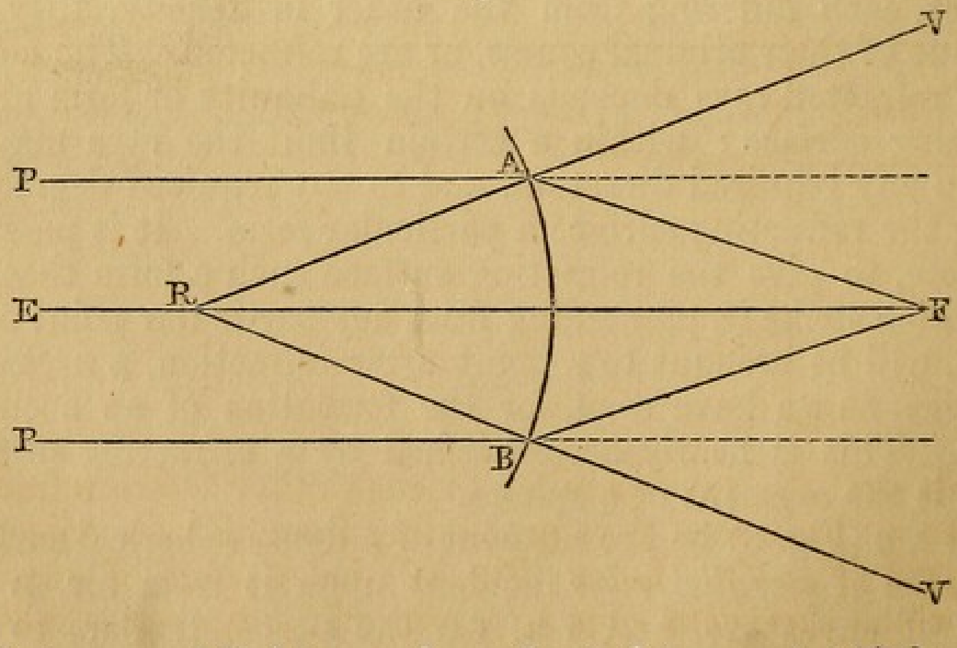
Let A B (Fig. 8) be the segment of a dense spherical surface, P P a cone of *parallel rays* incident upon it from air, R the centre of curvature, and V R, V R the perpendiculars to the refracting surface at the points of refraction. Now, the rays pass from a rarer into a denser medium, and when this is the case, in obedience to the general law of refraction, they are bent from the perpendiculars to the refracting surface V R, V R.

Fig. 8.



Therefore P A is bent as P F. But a cursory glance at the diagram will show that the rays which strike the surface A B at equal distances from the axis E F, will be bent towards each other in the same degree, and, therefore, will meet at the same point on the axis F. What is true of the rays which strike the surface at equal distances on each side of the axis, is nearly true of all the rays which strike the surface between A and B.

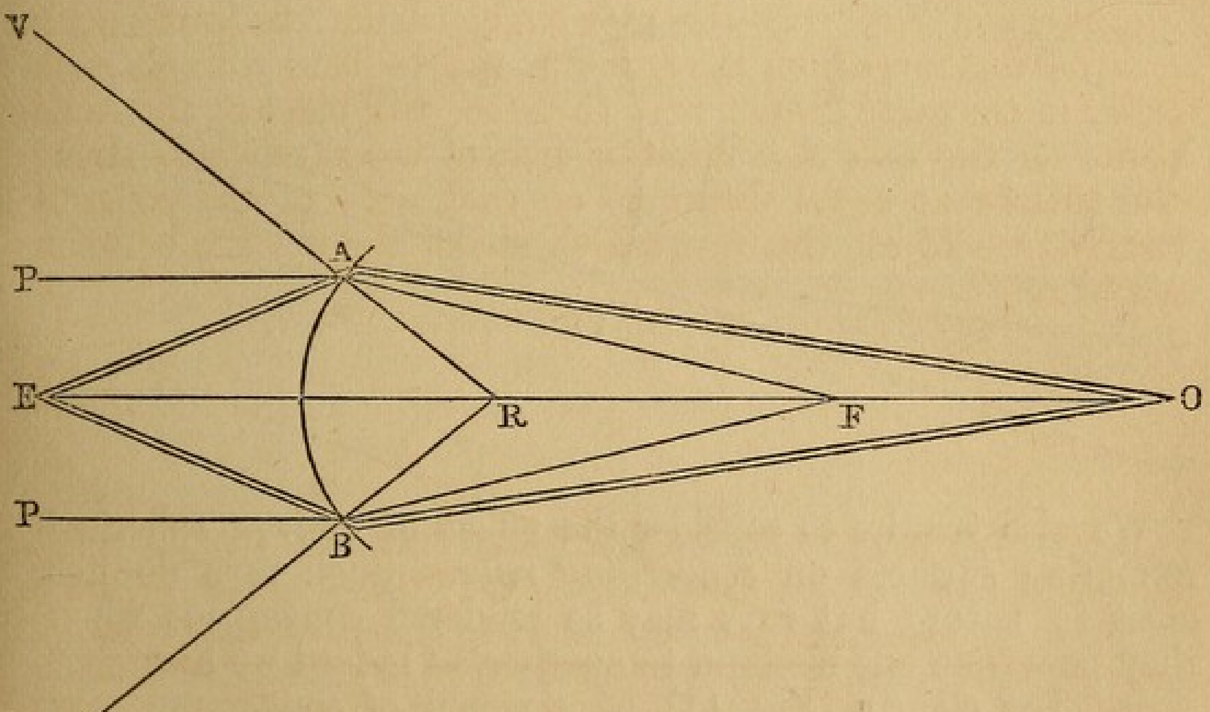
Fig. 9.



But rays of light are also refracted to a point if they pass from a dense spherical surface into a rarer medium. Let A B

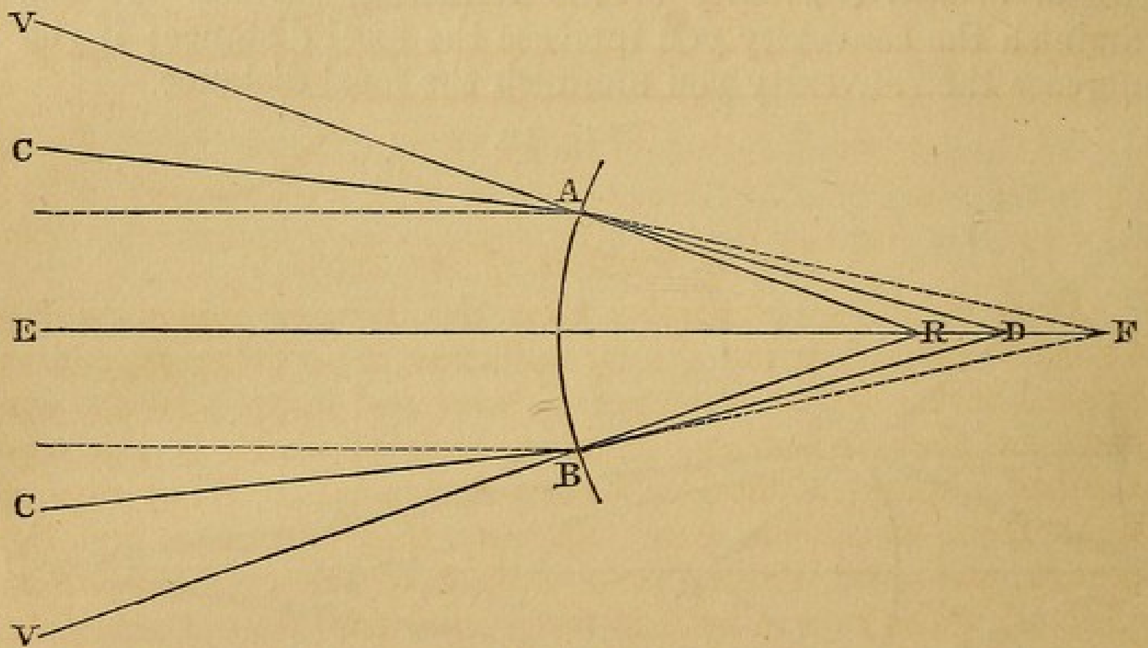
(Fig. 9) represent this surface, P P a cone of parallel rays passing from a denser into a rarer medium. It is another general law of refraction that the rays in such case are bent from the perpendiculars to the refracting surface. But you will observe that the perpendiculars V R and V R radiate from a point anterior to the refracting surface, and, continued beyond, diverge from each other. Therefore, the rays which are parallel before refraction, in being bent from the perpendiculars after refraction, must, in this case also, converge to a point on the axis E F. In both of these cases F is the focus of *refracted rays,* as the point of the object from which the rays come is called the focus of *incident rays.* The distance of the point F from the refracting surface is called the *principal focal distance.* In reference to the principal focal distance, I wish particularly to explain, that it is diminished or increased by the greater or less convexity of the refracting surface. If you diminish the convexity you increase the focal distance; if you increase the convexity you diminish the focal distance.

Fig. 10.



Such are the rays parallel to each other before refraction. But, as we have seen, rays proceeding from all near objects are divergent (Fig. 7). Let E (Fig. 10) be a point of an object from which *divergent rays* are given off; A B a dense spherical surface. As such rays meet the perpendiculars to the refracting surface at a greater angle than parallel rays, so the same rays after refraction, in their relation to the same perpendiculars, must also have angles proportionately greater, and therefore the focus of such rays must be correspondingly more remote than parallel rays. V A E will be the angle of such rays as compared with V A P, the angle for parallel rays; O A R the angle of such rays after refraction as compared with F A R the angle of parallel rays after refraction; O the focus of such rays as compared with F, the focus of parallel rays. The refracting surface being the same, the focus of divergent rays, O, recedes from it as the point E approaches it; on the other hand, the focus O approaches the refracting surface as the point E recedes from it, until the object is so distant that the rays proceeding from it are parallel, in which case the focus corresponds with the principal focus F.

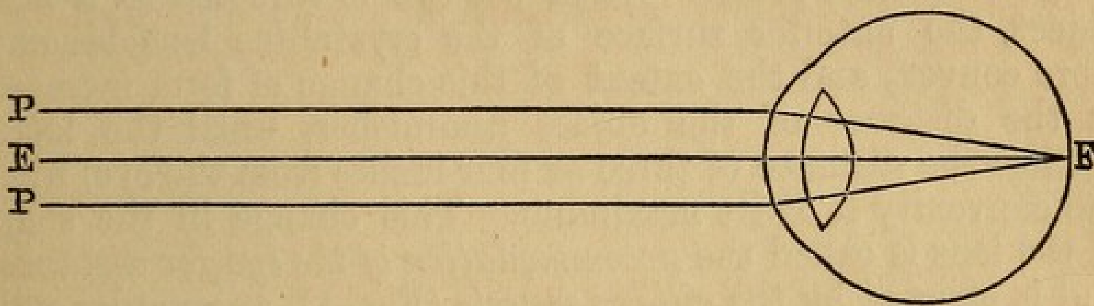
Fig. 11.



We also require to consider the effect of convex spherical refracting surfaces on *converging rays*. Such rays do not exist in nature, but rays may be rendered convergent when they pass from one medium to another, as indeed we have just seen. Let C A, C B (Fig. 11), be a pencil of converging rays incident upon the spherical refracting surface A B; V R, V R, perpendiculars to the refracting surface at the points of refraction. It will be observed that the converging rays meet the perpendiculars to the refracting surface at a less angle than parallel rays, which are represented in the diagram by interrupted lines; and as both must bear the same ratio to the perpendiculars after refraction that they did before it, the focus of the former must be *nearer* the refracting surface than the latter. D, therefore, is the focus of the converging rays in the present case, as compared with F, the focus of parallel rays.

And now to sum up these remarks. From what has been explained it will be observed, that the distance of the focus of refracted rays is influenced by two conditions—it may be *increased* either by diminishing the convexity of the refracting surface (page 19), or, the convexity remaining the same, the object is brought nearer to it; the focal distance may be *diminished*, either by increasing the convexity of the refracting surface, or, the convexity remaining the same, the object is removed to a greater distance from it.

Fig. 12.



The Refraction of the Eye.

It is on these principles that the diffused images which would be formed in the eye by radiation, if no other expedient existed within it, are rendered distinct and sharp. In the eye there are three refracting surfaces, each of which is the segment of a sphere, almost mathematically exact. When rays of light from an object enter the eye they encounter first the cornea, and next the anterior surface of the crystalline lens (Fig. 2). The rays in both of these cases pass from a rarer into a denser medium, and are refracted as in Fig. 8. Next in order the rays are refracted by the posterior surface of the crystalline lens (Fig. 2); but the rays in this case pass from a denser into a rarer medium, and, therefore, they are refracted as in Fig. 9. The combined effect of these refracting surfaces is to bring pencils of parallel rays to foci on the retina (Fig. 12). The retina, therefore, is placed at the principal focal distance of the lenses of the eye.

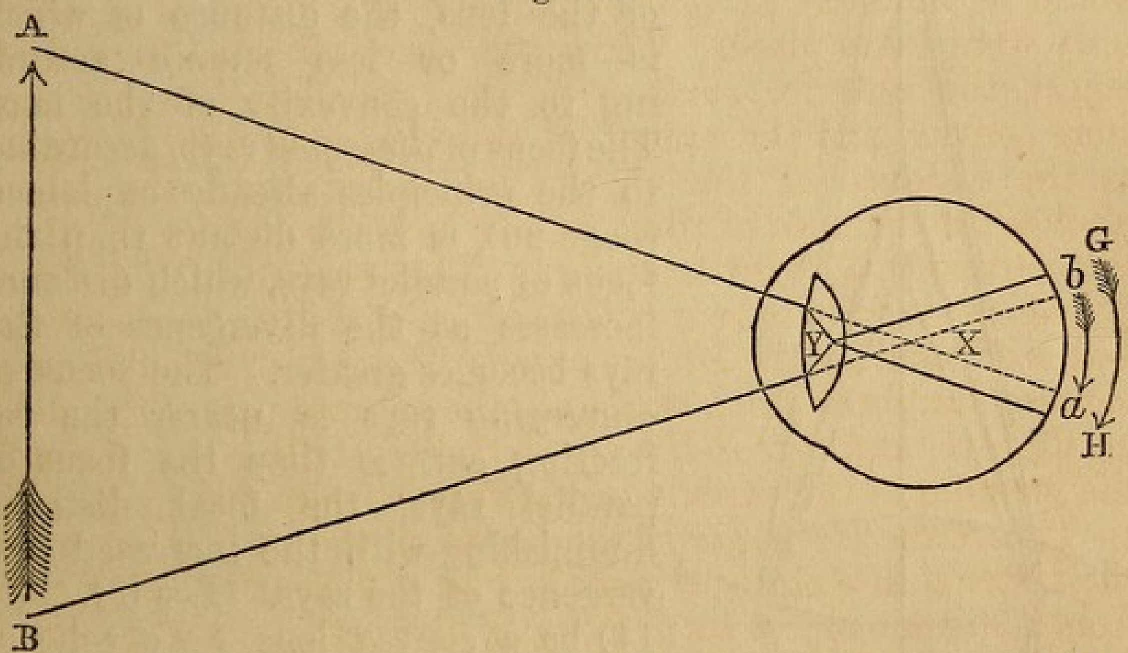
The Accommodation of the Eye for Distances.

But we found that the focal distance becomes greater with the approach of the object (page 20); and, therefore, it would follow, if no other mechanism existed within the eye, that the focus of divergent rays would be behind the retina, in which case the eye would only be capable of seeing distant objects distinctly, and all near objects would be dim. Now, as we see near as well as distant objects distinctly at our pleasure, by what means is this accomplished? I explained (page 19) not only that the focal distance increases with the nearness of the object, but also that it is diminished by the refracting surface becoming more convex. When the eye fixes an object, therefore, if, with its approach, one or other of the refracting surfaces named were becoming more convex, the increased focal distance which would be produced by the approach of the object might just be counterbalanced by the increased convexity of the surface, in which case the focal distance of divergent rays would be the same as that of parallel rays. And this is exactly what takes place. When the eye is directed to a near object, the anterior surface of the crystalline lens becomes more convex, and the extent of this change of form increases as the distance of the object diminishes, until the latter reaches the distance of three or four inches from the eye, when the convexity is at its maximum. This change in the shape of the lens is called the *accommodation of the eye for distances*, and is effected by the *ciliary muscle* (Fig. 1), an annular strip of muscular fibres which surrounds the anterior part of the globe of the eye, and *acts indirectly* on the crystalline lens through the medium of the capsule in which it is contained (page 10).

The refractive power of the lenses of the eye, then, when the latter is in a state of rest, is just sufficient to bring rays from a distant object to a focus on the retina; and to bring to a focus on the retina rays from near objects—objects within 20 feet—the eye calls its accommodating power into operation, and that in a direct ratio as the distance of the object diminishes. For the sake of simplicity, the former is called the *static* refraction of the eye, the latter its *dynamic* refraction. Such is the refraction possessed by what may be termed the Model Eye.

But the refraction of the eye has two other important effects. If the images of external objects were formed in the eye by radiation alone, the axial rays of each cone would intersect in the vitreous humour (Fig. 2, E), and, therefore, besides the images being indistinct, they would be of smaller size to the size of the objects—a condition which would considerably limit our vision. The reason of this I must try to explain. The angle formed by the image on the retina, calculated from the point of intersection of the axial rays, determines the size of the image itself—both increase and decrease together. Let X (Fig. 13) be the point of intersection of the axial rays if the image were formed in the eye by radiation alone; b X a would be the angle which the image would subtend at the centre of the eye, and b a its size. But in the eye the axial rays are refracted by the cornea and crystalline, so that they intersect at a point (Y) in the crystalline, in which case G Y H is the angle of the image, and G H its size, as compared with b a, the size of the image if it were formed by radiation alone. Therefore the refraction of the eye shifts forwards the point of intersection of the axial rays of each cone, and by so doing magnifies the image.

Fig. 13.



The imaginary point Y is called the *optical centre* of the eye, and its knowledge is of importance in another respect. It is the centre of motion of the eyeball on its axis, and, therefore, it does not alter its position with the movements of the eye; and since the axial rays intersect at the same point, the movements of the eye produce no movement of the image. If it were otherwise, objects would appear to change their position, and dance about, with every movement of the eye.

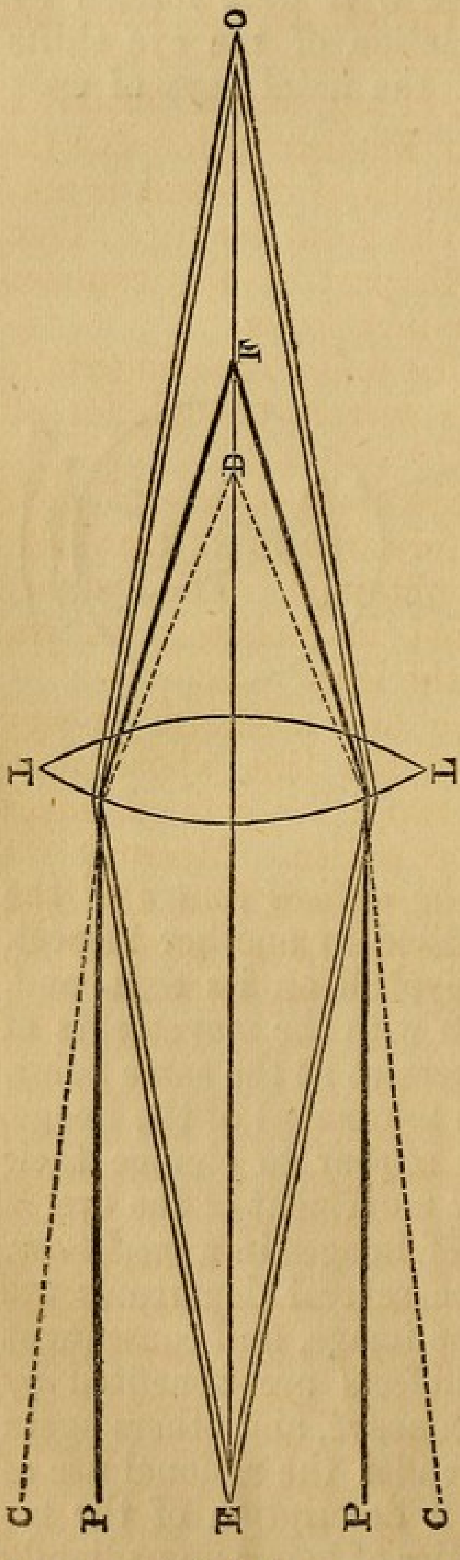
Such is the manner of formation of images in a *model eye*. But from an eye of this perfect type several departures are common, causing indistinctness of the image, and consequent dimness of sight. Some of these defects are benefited by ordinary convex, others by ordinary concave, and others again by cylindrical glasses. In order to render the rational use of glasses more intelligible I will give a description of the refracting qualities of each of the varieties of lenses immediately before the defect of the eye for which it is used. First of all, then,

Convex Glasses.

What are the characteristics of convex glasses?

Felt between the finger and thumb their surfaces are raised like the outside of a watch glass.

Fig. 14.



Held in the beams of the sun the rays are collected to a focus. The principles of this I have already explained. (Figs. 8 and 9, page 18).

The point where *parallel* rays meet is called the principal focus of the lens, the distance of which is more or less remote according to the convexity of the lens. The focus of *divergent* rays, according to the principles already explained (page 20), is more distant than the focus of parallel rays, which distance increases as the divergence of the rays becomes greater. The focus of *converging* rays is nearer the refracting surface than the focus of parallel rays, the focal distance diminishing with the increased convergence of the rays. Let L L (Fig. 14) be a convex lens, P P a cone of parallel rays, F is the focus of such rays. Let E be the point of a near object from which divergent rays are given off, O is the focus of such rays as compared with F, the focus of parallel rays. As the object is removed to a greater distance than E, the point O approaches the lens till the incident rays become parallel, when O merges into F, the principal focus of the lens. Let C C be a cone of converging rays, the focus of such rays is D as compared with F, the focus of parallel rays.

Here I must explain that it is a law in optics that, if rays pass from a point in one medium to a second point in another medium, they will retrace their steps by the same course if they pass in an opposite direction. If, therefore, an object be placed at F (Fig. 14), the rays which are given off from it will be refracted as P P; if the object be placed at O the rays given off from it will be refracted to E. If the object be placed at D the refracted rays will take the courses of L C and L C. In this way, if the object be placed at intermediate distances between O and D, they will be refracted in varying degrees of obliquity between convergence as L E L E, and divergence as L C L C.

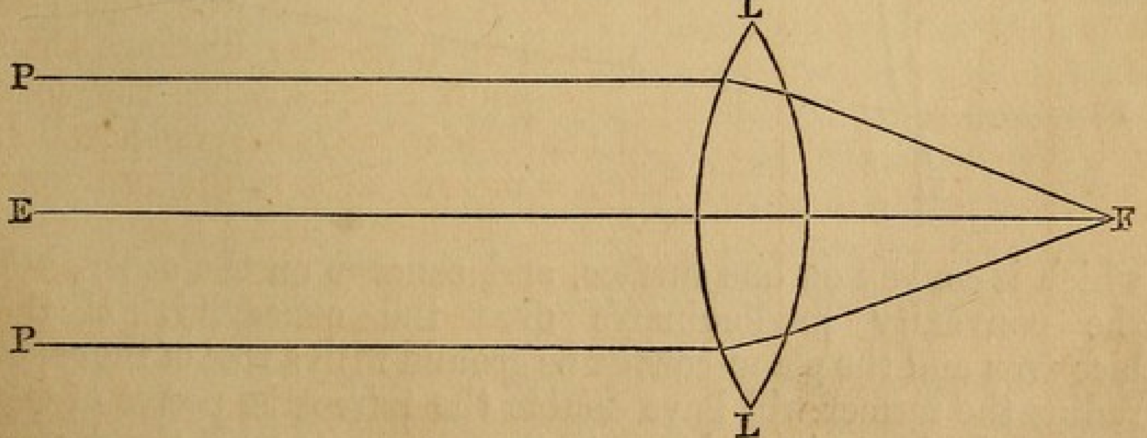
In computing the refracting power of any convex lens, it is referred to one common standard—an English inch. As the power of a lens is inversely as the length of its focus, it may be expressed by 1 : F, F representing the focal length. Thus 1 : 10 or $\frac{1}{10}$ signifies a lens the $\frac{1}{10}$th part of the common standard, or the $\frac{1}{10}$th of a lens of one-inch focus.

The focus of a convex lens may be found experimentally by a very simple means, and which is correct enough for all ordinary purposes.

(*a.*) Hold the lens in the direct rays of the sun, and move a sheet of white paper backwards and forwards on its distal side until an accurate image of the sun is obtained. The distance between the paper and lens measured in inches, gives the principal focal distance, or power, of the lens.

(*b.*) Place a candle or other flame and a screen at any distance from each other, and move the lens, whose focal distance is to be found, between the two, till a defined image of the flame is produced upon the screen. Measure the distance of the flame and the screen respectively from the lens, multiply the two distances, and divide their product by their sum. The quotient is the required focal distance.

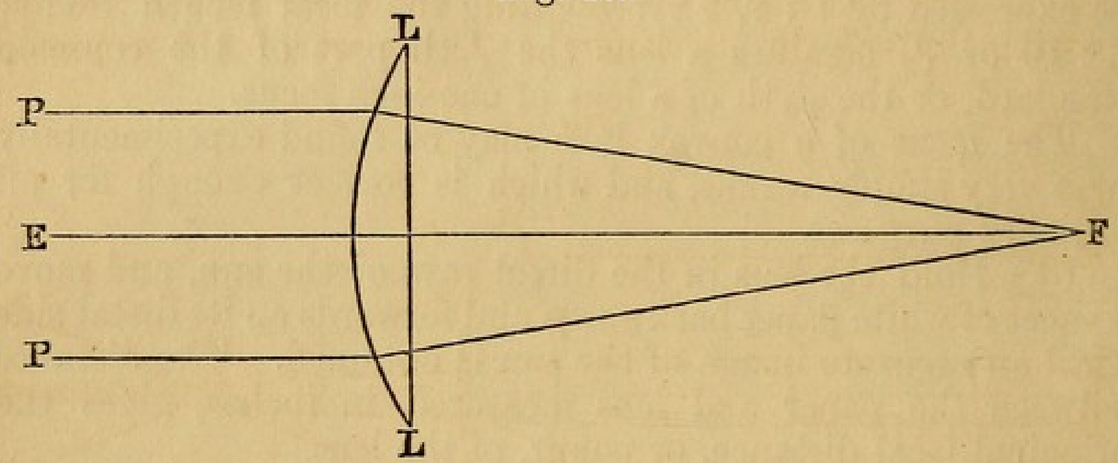
Fig. 15.



(*c.*) If the experimenter is in possession of a case of convex lenses whose focal lengths are accurately known, the focal length of any other lens may be readily determined by the following method. Draw two parallel lines on a sheet of white paper. Hold the lens to be tested between the paper and the eye, but nearer the latter than the former, and so as to see the parallel lines through it. That test lens which, held at the same distance, magnifies the lines and space between in the same degree is a lens of the same power as that whose focal distance was to be found.

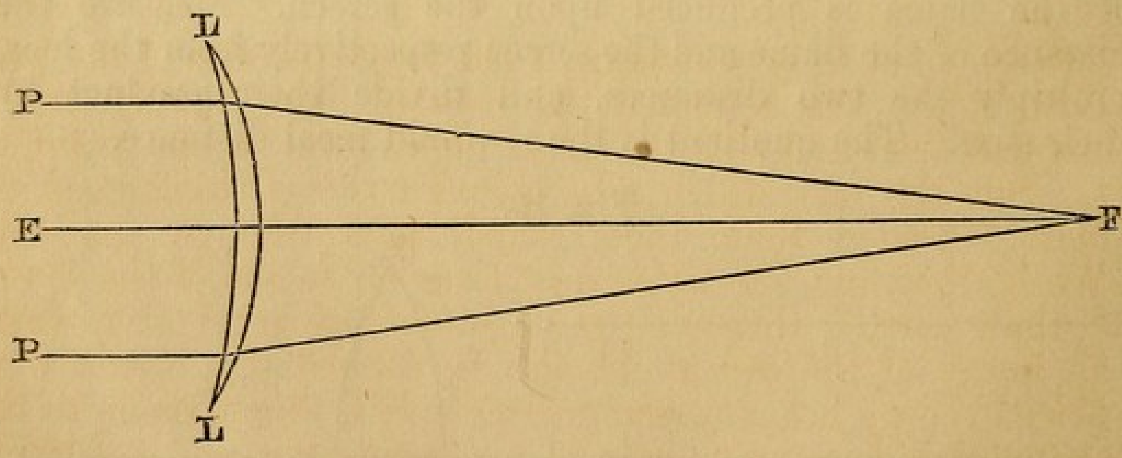
There are three kinds of ordinary convex lenses. (1) The biconvex (Fig. 15), which is convex on both surfaces. (2) The plano-convex (Fig. 16), which is plane on one side, and convex

Fig. 16.



on the other. (3) The meniscus or convexo-concave (Fig. 17),

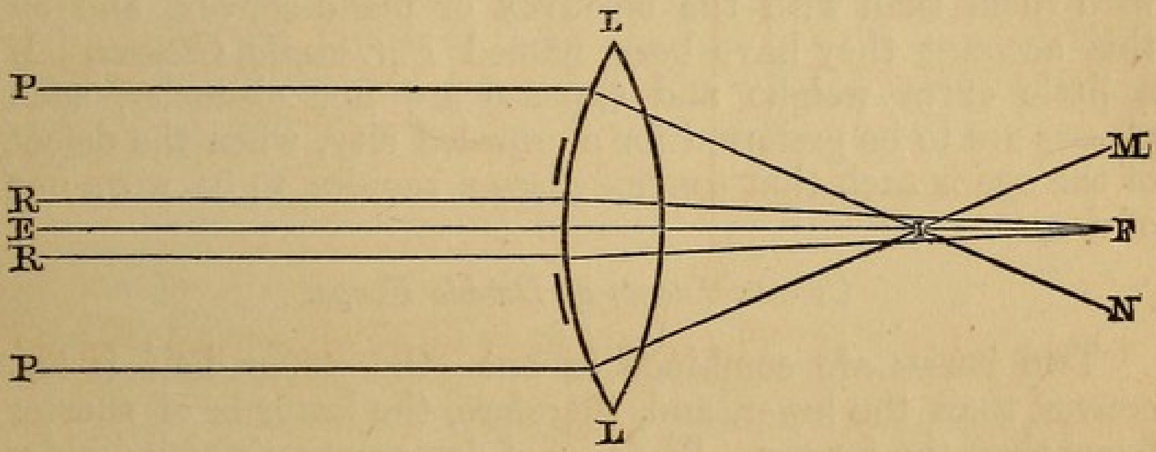
Fig. 17.



which is convex on one surface, and concave on the other, but the convexity predominates over the concavity. If the biconvex and the plano-convex be ground with a tool of the same radius the former will have double the refracting power of the latter. The meniscus lens will vary in power with the degree of its concavity.

Each of these lenses does not produce an equally clear and defined image. In order to simplify the exposition of refraction by spherical surfaces it was stated, that the rays of light proceeding from the point of an object, are nearly brought to an accurate point in the image. This, however, is sometimes far from correct. To illustrate this, take a biconvex lens partially covered by a circular strip of black paper, so as to leave a clear space at the circumference and the axis. Hold the lens so covered in the direct rays of the sun, and a screen at the focal distance of the lens. An image of the sun will be formed upon the screen, but it will be rendered indistinct by a halo of light which surrounds and covers it. Let us see how this is explained. Let L L (Fig. 18) be the section of a convex lens covered in the manner stated, P P rays of the sun passing through the circumference of the lens, R R rays passing

Fig. 18.



through the lens near its axis, F the focal distance of the lens. Now, if the lens refracted the rays of light equally at the circumference and axis the latter would meet in one point at F. But the rays which pass through the circumference are more refracted than those which pass through the axis. While, therefore, the latter rays form an image of the sun at F, those passing through the circumference meet at I, where an image of the sun would also be formed if a screen were placed there; but not being intercepted, they pass on to the screen at F, forming a circle of aberration M N, and rendering F indistinct. The distance I F is called the *longitudinal spherical aberration* of the lens, and M N the *lateral spherical aberration* of the lens.

Now, a plano-convex lens, turned with its plane surface towards parallel rays, has a spherical aberration of $4\frac{1}{2}$ times its thickness; turned with its convex surface towards parallel rays, it has a spherical aberration of only $1\frac{1}{2}$ times its thickness. The biconvex lens, having both surfaces of equal radii, has a spherical aberration of $1\frac{56}{100}$ths of its thickness. So far, therefore, as spherical aberration is concerned, it is almost a matter of indifference whether the plano-convex or the biconvex lens be used as spectacle glasses, provided that in using the former the plane surface be turned towards the eye.

When the object is placed obliquely to an ordinary biconvex or plano-convex lens, a distortion of the image occurs. In these circumstances the image of a star, for example, projected on a sheet of white paper by one of these lenses, would be drawn out like the tail of a comet. Now, the meniscus lens, turned with its concave side to the eye, produces a less distorted image when the object is placed obliquely to its axis, than either the biconvex or the plano-convex. Consequently when such lenses are used for spectacles, side vision is clearer with them than with the biconvex or plano-convex, and on this account they have been named *Periscopic Glasses.* If a little extra weight and expense are not obstacles, such glasses are to be preferred for a crowded city, when the defect of the eye is such that convex glasses require to be worn out of doors.

Convex Lenses of Double Focus.

Two lenses are combined in one—the upper half is less convex than the lower, and, therefore, the latter is of shorter focus than the former. The line of demarcation which divides the two segments is semicircular, and, therefore, it encroaches somewhat on both. On this account vision through neither is perfect. A better form of lens of double focus is that in which the upper and the lower segments are halves of two lenses of different foci placed in apposition by their plane edges. Spectacles having lenses of double focus are useful in those cases of defects of sight in which one pair of spectacles require to be frequently changed for another pair, such as in directing the eyes from a near to a distant object, or *vice versâ.*

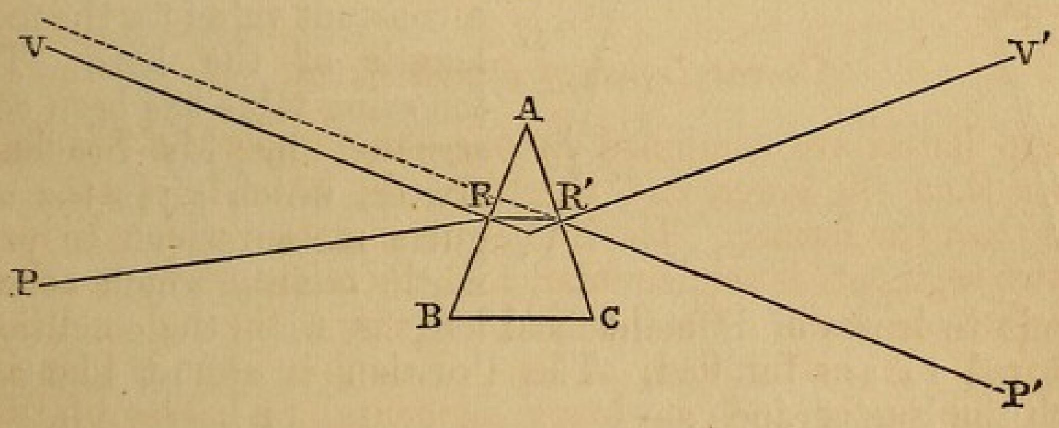
Decentred Convex Lenses.

These lenses consist simply in their being so cut that the axis of each, in place of being in the centre of the spectacle ring, is placed more outwardly or inwardly to suit the necessities of the case. The latter position of the axis is the most frequent.

Orthoscopic Spectacles.

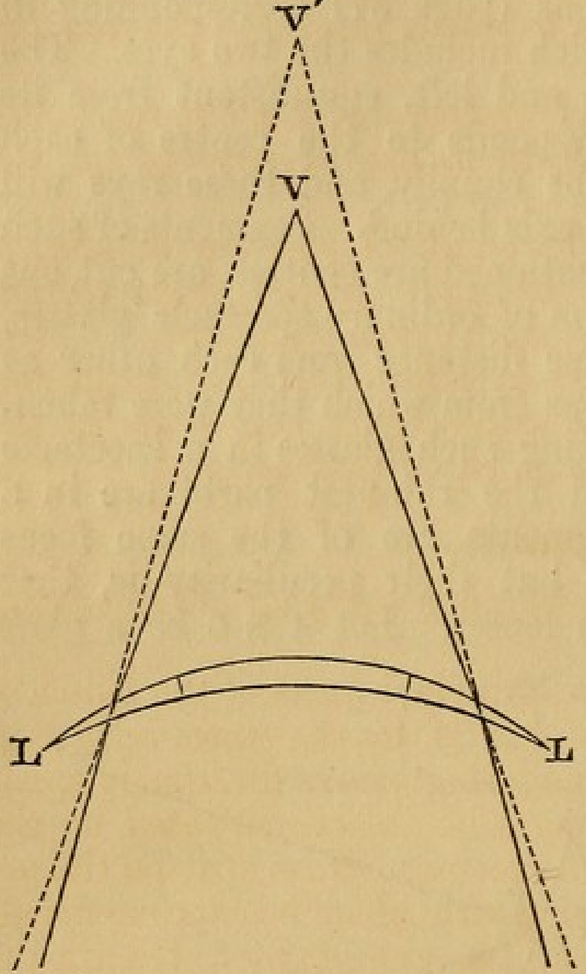
The spectacles which go under this name consist of a *pair* of lenses cut out of the circumference of one larger lens. To understand the formation of the convex variety of orthoscopic spectacles, take a reading lens (page 37) corresponding in diameter to a straight line which includes the two eyes. The two points in the lens, right and left, equidistant from its axis, which respectively corresponds to the centre of each pupil, will refract rays of light equally, and these rays will meet at a certain point on the axis behind. Segments of such a lens, of which the points mentioned are centres, are cut out of its sides of the size and form of ordinary spectacle glasses, and set in a frame at the same distance from each other as that which they held in the lens from which they were taken. Care must be taken in mounting such glasses in a spectacle frame, that the thickest and the thinnest parts are in a *horizontal* plane. These segments are of the same focus as that of the original lens; but their peculiarity is, that they act as prisms as well as lenses. Let A B C be a glass

Fig. 19.



prism, V R the perpendicular at the point of refraction of the first surface, and R′ V′ the same at the second; P R a pencil of parallel rays incident upon the surface A B. As the rays P R pass from a rare into a dense medium, they are bent towards the perpendicular V R as R R′. In proceeding onwards through the second surface the rays pass from a dense into a rare medium, and they are, therefore, bent from the perpendicular R′ V′ as R′ P′. It will be observed that at both surfaces the rays are bent from the apex A towards the base B C of the prism, and therefore if an eye were placed at R′ the apparent direction of the incident ray R P would be the dotted line which is the projection of the ray R′ P′. Now, the segments of convex orthoscopic lenses act as prisms, and refract the pencils of rays which pass through them towards their base or thickest part, so that if continued backwards they would *meet* at the focal distance of the lens, in place of being continued backward in a plane parallel with the incident rays, as is the case with ordinary convex lenses. In consequence of this, an object seen through such lenses has its apparent position changed. Thus, an object placed at V (Fig. 20) appears through a pair of such lenses as if at V′. If the large lens, whatever its focus, from which the segments are cut, be always of the same diameter, and if they be cut in every case at the same distance from the axis, the prismatic effect of the segments will always have a constant value for the focal length of the lens. The following table has been constructed by Mr Brudenell Carter, which gives the angular measurement or prismatic quality which corresponds to lenses of different focal lengths, when the conditions referred to are fulfilled. The Prussian is almost identical with the English inch :—

Fig. 20.



Number of each lens in the Series.	Focal Length in Centimetres.	Focal Length in Paris Inches.	Focal Length in Prussian Inches.	Angular Measurement of the Prism that forms with it an orthoscopic combination.
1	240	88·66	91·75	1° 29′ 10″
2	120	44·33	45·88	2 58 23
3	80	29·55	30·58	4 27 37
4	60	22·16	22·94	5 56 54
5	48	17·73	18·35	7 26 14
6	40	14·78	15·29	8 55 39

The variety of lens from which orthoscopic spectacles are formed is generally the periscopic. In place of being segments of one large lens, a pair of orthoscopic lenses may be made by grinding them separately, the external surface being ground convex, and the surface next the eye of the form of a prism; but the same prismatic effect to the focal length of the lens requires to be maintained. In certain special cases, however, the strength of the prism may be made to exceed the proportion of the focal length.

One objection to the use of orthoscopic convex spectacles is, that objects seen through them appear concave on the surface.

We are now in a position to speak of the use of convex glasses for removing defects of sight arising from certain departures of the eye from the model type (page 22).

Probably the most common case for which convex-glasses are required is that defect of sight which comes on as the result of advanced years, and named on that account

Presbyopia.

This defect essentially consists in a decrease of the accommodating power of the eye.

It has been stated that the principal focus of the lenses of a model eye is on the retina—that is, by the static refraction of the eye alone, the accommodating power for the moment being in abeyance, perfect images of objects situated on the horizon, are produced upon the retina. Now, if it be the accommodating power of the eye which alone becomes deficient with age, the *principal focus* of the eye ought to remain the same, and distant objects ought to be seen distinctly by a presbyopic eye. Such is exactly the case—at all events up to the 65th or 70th year. Distant objects are seen distinctly, as a general rule, by a presbyopic eye, and hence this defect of the eye is also named long-sightedness.

At 60 or 70 years, however, the aqueous and vitreous humours diminish in quantity, so that the eye is no longer a model eye even in form, its antero-posterior axis being somewhat shortened. The focus of parallel rays in such cases lies slightly behind the retina, in consequence of which distant objects then are also dim. But this may partly be accounted for by the sensibility of the retina being somewhat impaired, which it usually is at that time of life. Long-sightedness, then, having been ascertained to consist chiefly in loss of the accommodating power of the eye, whether is the seat of that loss in the ciliary muscle, which is the active agent, or in the crystalline lens, which is the passive agent, of the accommodation. Undoubtedly the latter is its most frequent seat. The outer layers of the crystalline lens in the earliest years of life are nearly quite fluid, but with the growth of the body these become firmer and more solid, which changes go on without intermission till old age, when the lens is hard throughout. It is this hardness of the lens in presbyopia which prevents it changing its form for near vision, and thus the potential cause of long-sightedness has already begun in childhood, though it does not interfere with near vision till the 45th or 50th year.

Now, in order to form an idea of the extent of loss which the accommodating power of the eye has sustained in any particular case, we must know the extent of it in the normal eye, and have an easy method of measuring it. A young active person, then, with good eyes, can see objects distinctly at any distance between the horizon and 3½ or 4 inches. At the latter distance, the entire accommodating power is called into operation. If in such a case the action of the ciliary muscle were restrained (which can be readily accomplished for the time by dropping into the eye a solution of the sulphate of atropia), the power of a convex lens, which, placed before the eye, enables it to see an object distinctly at 4 inches distance, will represent the change of shape which the crystalline undergoes when the eye brings into operation the full extent of its accommodating power. This obviously will be a lens of 4 inches focus; for the object in that case is placed at the principal focal distance of the lens, and, as we have seen, the rays emerge from the posterior surface of the latter in a parallel condition (page 24), the same condition as the rays which enter the eye from an object on the horizon, no accommodating power is required to bring them to a focus. Therefore, a four-inch convex lens is the measure of the accommodating power of an eye of a perfect type in a young person.

But a child or a youth can see nearer than is necessary, for vision never requires to be exercised at the distance of 4 inches from the eye. In this, I remark in passing, we discover one of those wonderful provisions which everywhere exist in our bodies, to qualify us for a definite period of existence; for, as we have seen, the cause of presbyopia has already begun in childhood, and if we were born with the nearest point of distinct vision at the ordinary reading distance, say 12 inches from the eye, by the time we were 16 or 20 years of age the density of the lens would be so great as to necessitate the use of glasses at that time of life. But nature has it so, that this change may go on for 40 or 50 years without interfering with the near point of distinct vision.

The accommodating power of the presbyopic eye may also be computed by a convex lens; for, as the power of a convex lens is inversely as its focal length (page 25), so the degree of recession of the near point of distinct vision in presbyopia is inversely as the accommodating power of the eye. Thus, if the nearest point of distinct vision is at 8 inches, the existing accommodating power will be represented by a convex lens of 8 inches focus; and the amount that the former has fallen below the normal standard (in a young person) will correspond to the increased focal length of the lens over that of 4 inches.

The first manifestation of presbyopia may only consist in the object, such as the small type of a Bible, being held at a greater distance than that at which habit has for a long time fixed it. By-and-by the book requires to be held at 16 inches from the eye; and as small type at that distance forms an image on the retina too small and faint to be distinctly recognized, larger type is sought for. Soon, however, the distance still increasing, large type is not seen distinctly unless in a bright light, and then convex glasses must be used.

But what proof is there that this failure of vision which I have referred to arises from presbyopia? (*a.*) In presbyopia distant objects are distinct, and near objects are dim. (*b.*) The vision of near small objects is rendered clearer through a small aperture (page 14). (*c.*) In adjusting the focus of a hand telescope or opera glass to the vision of a presbyopic eye, the tube requires to be more drawn out than for a model eye of a young person. (*d.*) Age forms an indication of the existence of presbyopia, for it manifests itself in all eyes at a certain age, with the exception of some cases of myopia, which will be afterwards referred to. It may be supposed to exist at 50 years of age. (*e.*) The most conclusive proof of the existence of presbyopia lies in the benefit derived from convex glasses of the proper focus, such glasses rendering near objects distinct, and distant objects dim.

To show you practically the necessity for the use of convex glasses in presbyopia, I have here an artificial eye adapted to the presbyopic condition. On turning the instrument facing two lighted candles placed close together, inverted images of the two flames are observed on the plate of ground glass behind, which represents the retina; but you will observe that a certain amount of confusion exists between them owing to the adjoining edges of the two shading off into each other. I now place a convex lens before the artificial eye, and the two images are rendered sharp and distinct, and the former fusion which existed between the neighbouring edges no longer exists (Fig. 6).

The Selection of Convex Glasses for Presbyopia.

From what has been said, spectacles in presbyopia are intended to fill up the gap produced by the loss of accommodating power which the eye in question has sustained by age, or, in other words, to make vision easy at 12 or 14 inches from the eye. But convex glasses will require to be used long before the absolute nearest point of distinct vision, which we have seen is in youth only at 4 inches, has receded to either of these distances. In fact, they will be required as soon as the near point has receded to 8 inches, which may be regarded as the starting point of presbyopia; for the whole accommodating power in any case is only called into existence by a great effort, the surplus being used only on extra occasions. In all cases of presbyopia, then, the near point of distinct vision must be brought up to 8 inches in order that vision may be maintained easily and continuously at 14 inches.

In finding the focus of the required lens, it follows that we must ascertain the loss of accommodating power which the eye has sustained, for the former is intended to replace the latter. This is accomplished by finding the amount of accommodating power which still exists; the difference between which and that which ought to exist gives the amount of loss. We already know the amount which ought to exist. We have seen that in order to read comfortably at 14 inches the absolute nearest point must not be farther from the eye than 8 inches, which is represented by a convex lens of 8 inches focus. How do we ascertain the amount of accommodating power which still exists in any given case of presbyopia? We find the *nearest* distance at which small type can be read. In making this examination we ordinarily employ a scale of test types constructed by Snellen,* the letters and figures of which vary in size from the smallest type of letter to that of 3½ inches square. Above each division of the series is placed a number, which represents the distance in feet which the text corresponding thereto, ought to be seen distinctly by a healthy model eye. No. 1 should be seen at one foot, 10 at ten feet, 20 at twenty feet, and so on, and each of the series placed at

* H. Snellen, M.D., Utrecht. Test-types for the determination of the acuteness of vision. 1868.

its own respective distance forms an image on the retina the size of which is the $\frac{1}{12}$th part of a degree. If in any case an eye cannot see the type in every division at its own particular distance, in such an eye some defect exists. In a presbyopic person we ascertain the smallest type which can be clearly made out, and then the *nearest* distance at which it can be read. Supposing this to be 16 inches, the amount of accommodating power which such an one possesses is equal to a convex lens of 16 inches focus; for if the accommodating power of which the eye is possessed were replaced by such a lens he would not be able to see nearer than 16 inches. Again, if the nearest point of distinct vision be at 20 inches, the existing accommodation is equal to a convex lens of 20 inches focus, and so on, the nearest distance of distinct vision in inches being represented by a convex lens of the same number of inches focus. But we found that the nearest point of distinct vision must be brought up to 8 inches from the eye, which, as we have said, is equal to a convex lens of 8 inches focus. Therefore, the difference between a convex lens of 8 inches focus and the strength of the convex lens which represents the existing accommodating power in any particular case, gives at the same time the loss of accommodation which the eye has sustained and the focus of the convex glass required to make up the deficiency.

Let me illustrate this by one or two examples. A person, 61 years of age, has his nearest point of distinct vision at 17 inches. Such an one possesses accommodating power equal to a convex lens of 17 inches focus. But his near point must be brought up to 8 inches in order that he may read persistently and with comfort at 12 or 14 inches. Therefore, a convex lens equal to the difference between one of 17 inches focus and one of 8 inches focus, placed before such an one's eye, will make up the deficit: $\frac{1}{8} — \frac{1}{11} = \frac{1}{15\frac{1}{9}}$, or convex glasses of 15 inches focus. If the nearest point of distinct vision is 24 inches, then a convex lens of 12 inches focus will be required; for $\frac{1}{8} — \frac{1}{24} = \frac{1}{12}$.

It is advisable to compare the results so obtained with the following table, which is one modified from Donders; for a slight inaccuracy in the measurement of the near point of distinct vision, will sometimes make a material difference in the focus of the glass which should be worn. Moreover, there are few presbyopes who can easily summon into use, without previous practice, all the accommodating power which they possess. In column B is given the focus of the required lens at the age against which the numbers are placed, so as to bring the near point up to 8 inches. (C) The distance which is preferred for reading with such glasses. (D) The range of accommodation through which vision is acute with such glasses:—

A Age.	B Focus of the required lenses.	C The distance preferred for reading with such glasses.	D The space within which the eyes can accommodate with such glasses.
48	60 inches.	14 inches.	Between 60 inches and 10 inches
50	40 "	14 "	" 40 " " 12 "
55	30 "	14 "	" 30 " " 12 "
58	22 "	13 "	" 22 " " 12 "
60	18 "	13 "	" 18 " " 12 "
62	14 "	13 "	" 14 " " 12 "
65	13 "	12 "	" 13 " " 11 "
70	10 "	10 "	No accommodation.
75	9 "	9 "	" "
78	8 "	8 "	" "
80	7 "	7 "	" "

If the results obtained by the examination for the near point of distinct vision give a much stronger lens than is indicated by the age of the person in this table, then there is either an error in the measurement or calculations, or the case is one of hypermetropia, to which is added longsightedness, a defect which will be treated of in the next lecture.

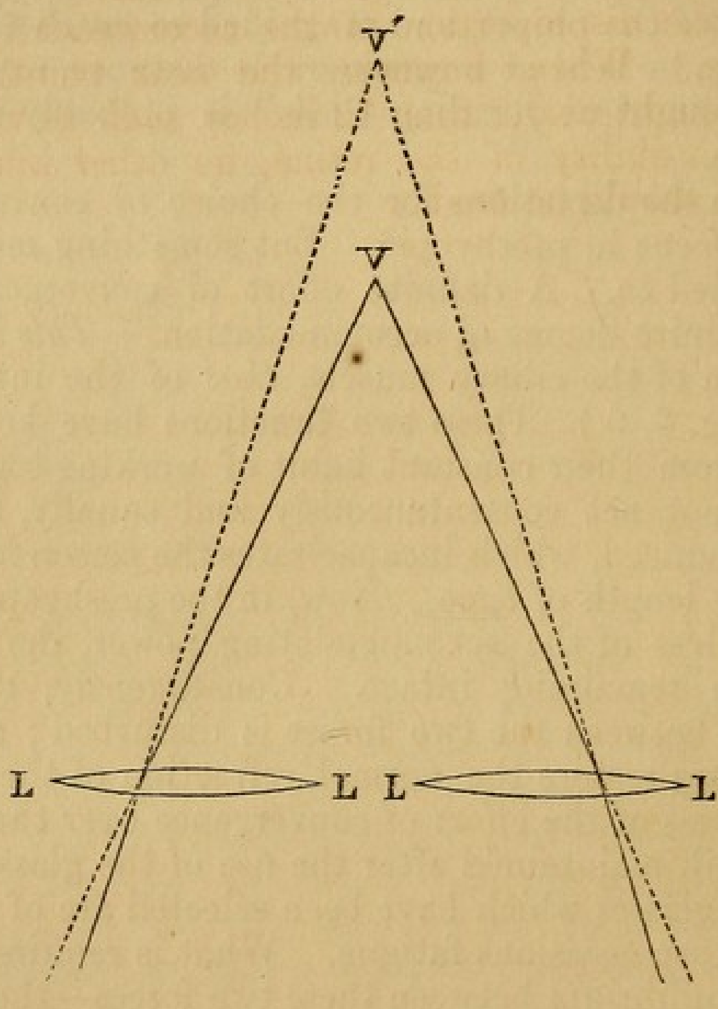
But after the eyes have been properly suited with spectacles, the latter will not always continue suitable; for presbyopia, notwithstanding, goes on increasing, and a time will come when ones of shorter focus must be substituted for them. Even then, however, the weaker pair may be used for writing and other work during the day, and the stronger pair reserved for use in artificial light.

What I have said as to the choice of spectacles in presbyopia refers to persons under 70 years of age, in whom the sensibility of the retina is unimpaired, the glass in such case being intended to bring the ordinary distance of distinct vision up to 12 or 14 inches from the eye. But as age advances, the sensibility of the retina becomes impaired, so that at 70 years and upwards an image on the retina of the $\frac{1}{12}$th part of a degree in size is not distinctly seen. The size of the retinal image is increased simply by bringing the object nearer; but the rays which enter the eye from it in that case being more divergent, a stronger lens is required to bring them to a focus on the retina. At the ages referred to, then, the near point of distinct vision will often require to be brought to 10, 8, or 7 inches from the eye. Or the "Reading Glass" may be used in place of spectacles, which is simply a glass lens, 4 or 5 inches in diameter, and of 8 or 10 inches focus, set in a convenient frame and handle. In using it, it is held nearer the object than its principal focal distance, which produces an erect image of the object, and magnified so much that the eye can afford to be held at a considerable distance, say 16 inches. The "Bycylindrical Reading Glass" is probably the best for this purpose.

Such are the directions for the choice of convex lenses of the proper focus in presbyopia. But something more requires to be attended to. A definite effort of convergence accompanies a definite degree of accommodation. *This* is the effect of the action of the ciliary muscle, *that* of the internal recti-muscles (Fig. 3, 5.) These two functions have become so inseparable from their constant habit of working together, that if both do not act consentaneously and equally, a feeling of strain is produced, which incapacitates the person for using the eyes for any length of time. Now, in the presbyopic eye there is simply a loss of the accommodating power, the function of convergence remaining intact. Consequently, the healthy equilibrium between the two forces is disturbed; and though convex glasses restore the normal refraction of the presbyopic eye, the excess of the effort of convergence over the accommodation, is still maintained after the use of the glasses. Hence though the glasses which have been selected are of the proper focus, their use occasions fatigue. What is required is to restore the equilibrium between these two forces—the accommodation and the convergence. As it is impossible to heighten the action of the accommodation, it is necessary to lower or diminish the action of the convergence, which may be effected by several means.

(1.) The ordinary convex glasses which have been selected, may be placed closer together in the spectacle frame, so that the outer half of each lens is opposite to the corresponding pupil. The effect of this displacement will be at once understood by moving a convex glass before the eye—the object appears to move in the opposite direction. Therefore, by displacing the glasses inwardly, the object under observation appears as if displaced by each glass outwardly—to the right and to the left—to see which, each eye involuntarily turns in the direction of its own image, thus diminishing the action of the internal recti-muscles. For example, while the object is placed at v, Fig. 21, the axes of the eyes are directed through the lenses to v′. By this means, the convergence of the eyes will be reduced in the same degree as the bridge of the spectacle frame is shortened.

Fig. 21.



When convex glasses begin to be worn during the first stages of presbyopia, this arrangement of the lenses is generally sufficient to prevent fatigue of the eyes, when it comes on as the result of excess of convergence over accommodation.

(2.) In place of displacement of the lenses inwardly, decentered lenses may be employed to produce the same effect (page 28). When used for this purpose the axes of the glasses must be internal (as regards the mesial line of the face) to the centres of the spectacle rings. These lenses may be used in the same cases as those for which the bridge of the spectacles is shortened.

(3.) Orthoscopic spectacles (page 29). When the use of convex lenses in presbyopia has been deferred till the latter is so great that lenses of comparatively short focus require to be used, such as those of 22, 18, or 15 inches focus, the orthoscopic spectacles should be preferred to all others, as they diminish the convergence of the eyes in the same degree as they supersede or replace the accommodating power ; but in cases of presbyopia, in which the use of convex glasses has been begun early, and frequently changed, they will not be so necessary, as by this means the eyes become gradually accustomed to the disproportion of the accommodation and the convergence. When, however, the near point of distinct vision is brought nearer than 12 inches, such as when there is impaired sensibility of the retina, no other kind than the orthoscopic should be used.

LECTURE II.

Second Departure of the Eye from the Model Type requiring the Use of Convex Glasses, named Hypermetropia—It is divided into Three Degrees—How this Defect of the Eye may be Recognised—The Selection of Convex Glasses for it, (*a*) for Young Persons, to enable them to read—Should Glasses be worn for the Vision of Distant Objects ?—The Prevention of Convergent Squint, which comes on as one of the Results of Hypermetropia—(*b*) Convex Glasses for Adult Hypermetropes—The Mounting of Convex Glasses—The Principles of Refraction of Concave Lenses—Myopia—Characteristics of the Vision of Myopes —The Selection of Concave Glasses for Young Myopic Individuals when the Accommodating Power of the Eye is normal — The Selection of Concave Glasses for Adult Myopes—Complications of Myopia—The Principles of Refraction of Cylindrical Lenses—Astigmatism—The Distinctive Characters of Astigmatism—The Adaptation of Cylindrical Glasses to Astigmatic Eyes.

HYPERMETROPIA.

WE proceed to the consideration of the second departure of the eye from the model type requiring the use of convex glasses. It is called Hypermetropia. The hypermetropic eye is a smaller eye than the model one, being shorter in all its axes, but more particularly in its antero-posterior axis. This seems to arise from want of development. In this defect the principal focus of the lenses of the eye lies beyond the retina, from which is derived the name that it goes under—hypermetropia—a compound word signifying that the rays meet in a focus beyond the measure of the eye. Rays that are convergent are those only which the humours of the eye can bring to a focus on the retina. Such rays, however, do not exist in nature; parallel and divergent rays, in order that they may meet at points on the retina, require to be rendered convergent *by a convex lens before they enter the eye.*

The vision of a hypermetropic eye may be imitated by placing a concave lens before a model eye.

In the healthy model eye, as we have already explained, no accommodating power is called into exercise in looking at distant objects, but that it is reserved for the vision of near objects. In the hypermetropic eye, however, the accommodating power requires to be used even for the vision of distant objects, and, consequently, to a greater degree still for near objects, if, indeed, the latter can be seen at all.

This defect of the eye was formerly considered incurable, and it is not many years since those affected with it, were condemned to a life either of misery or idleness, such is the pain which the hypermetropic person often experiences, in attempting to see near objects.

Three degrees of hypermetropia are recognised :—

First Degree.—When the antero-posterior axis of the eye is so short that parallel rays, and consequently divergent rays, are not brought to a focus on the retina, even when the accommodating power is called into full exercise. Such an one has distinct vision at no distance. This variety when it exists is certain to show itself in youth, but it is very uncommon.

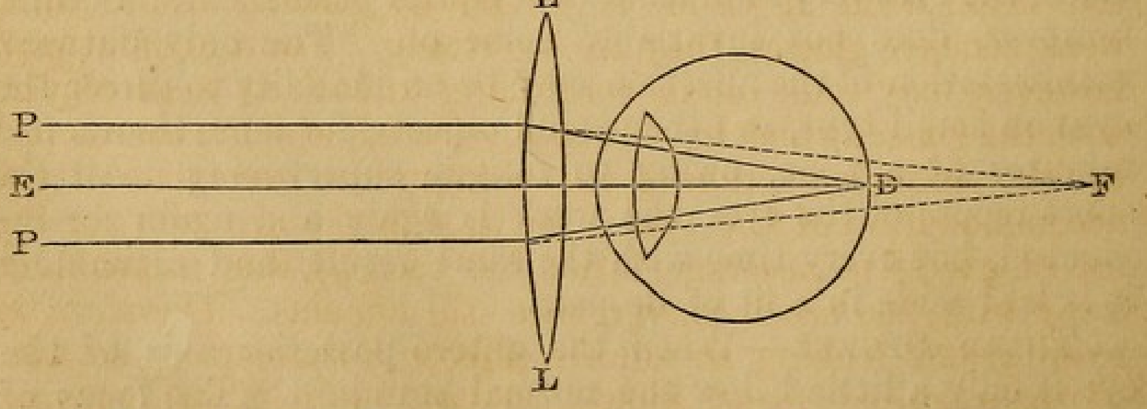
Second Degree.—When the antero-posterior axis of the eye is somewhat longer than the last, so that by a moderate exercise of the accommodating power, parallel rays, and by a strong effort, divergent rays, are brought to a focus on its retina. This is generally first detected in youth, when the eyes begin to be much engaged on near objects. There is one peculiarity that I must stop to point out connected with the vision of such persons. The efforts of accommodation in every one are intimately associated with the convergence of the eyes; the muscles which converge the eyes on near objects, called the internal recti muscles—(Fig. 3, 5)—and the ciliary muscle, which accommodates the eye to near distances, being governed by one and the same pair of nerves—the third pair. Not only, therefore, do the convergence and the accommodation act in unison, but each reacts more or less on the other. Now, in the strong efforts which the hypermetropic person makes to see near objects, he converges to a nearer point than the object, which calls into existence a corresponding greater amount of accommodating power—in fact a squint of one eye is produced. The squint so caused may subside when the eyes cease to be directed to the near object, but the habitual use of the eyes very soon makes the squint permanent. Squint, however, does not invariably come on. The only outward manifestation of the affection may be an inability to direct the eyes on small type, or other small objects, for more than a few minutes at a time, owing to fatigue supervening. After a short repose of the eyes the work is again and again recommenced, but every time with the same result, and ultimately it is laid aside in a fit of despair.

Third Degree.—When the antero-posterior axis of the eye is only a little below the normal standard. The focus of parallel rays is in this case also behind the retina, but at so short a distance, that a slight use of the accommodating power enables the eye to see distant objects distinctly, and, by a still greater effort, near objects up to 8 or 6 inches. This anomaly may pass unnoticed till the 30th or 40th year of life, when the loss of the accommodating power which comes on with advancing years, begins to tell on the ordinary near point of distinct vision—14 inches—which probably at that age will be 16 or 18 inches from the eye. This is the most common variety of hypermetropia, and is observed most frequently at the middle period of life.

How is Hypermetropia Recognised?

(*a*) On a hypermetropic person looking through a small aperture in an opaque disc (Fig. 4), the vision of near objects is perfect. (*b*) He has pain on attempting to see near objects with the naked eye, and such vision can only be maintained for a short time without rest. There may also be a squint on attempting to see near objects. Distant objects are generally seen distinctly, but also with an effort. (*c*) His nearest point of distinct vision is generally not less than 6 inches from the eye, and may be 8 or 10 even though he be young. (*d*) On suiting the opera-glass or hand telescope to his sight, he finds that he requires to draw out the tube further than his companions or friends of the same age. (*e*) If his accommodating power be subdued by the use of a solution of the sulphate of atropia, neither near nor distant objects are seen distinctly. (*f*) Convex glasses enable him to see distant objects distinctly, as well as near ones, a condition which exists in no other defect of the eye. (*g*) The surgeon possesses another means of detecting hypermetropia, viz., by the use of the ophthalmoscope.

Fig. 22.



The Selection of Convex Glasses for Hypermetropia.

Regarding the necessity for the use of convex glasses in hypermetropia, I show you here an artificial eye adapted to the hypermetropic condition. You will observe the same indistinctness of the images on the plate of frosted glass which represents the retina, as we found in the presbyopic eye (page 33). Fig. 22 also shows this. Parallel rays of light, P P, would meet at F behind the retina, and to bring them to a focus at D requires the interposition of the convex lens L L.

(*a*) *The selection of glasses for young individuals affected with this defect of the eye.*

The strongest convex lens which enables the hypermetropic eye to see letters, one inch square, across a street about fifty feet wide, are the glasses usually most suitable. The figures which form the numbers of streets are often about the proper size, and may be used as a test in the examination. If the scale of Snellen be taken as the test, no lower numbers than "20" should be used. The glasses so selected do not neutralize the entire hypermetropia, but they should bring the absolute nearest point of distinct vision to within an inch or two of what it is in the model eye. Thus, in the model eye of a young person, the absolute nearest point of distinct vision is four or five inches, according to the age; in a hypermetropic person of the same age the absolute nearest point will generally require to be brought up to six or seven inches. Such glasses ought to enable the eye, to which they are applied, to see small type at the distance of 14 inches. But if they cause the person to bring the object nearer than 14 inches, it is an indication that they are too strong, and weaker ones must be substituted for them. To save time and trouble in trying on a number of glasses of different foci, if by advancing a pair slightly, as good or better vision is obtained, the glasses are too weak, while if vision is clearer by placing before them weak concave glasses, they are too strong. Feelings of fatigue, however, may come on in continuing to look at near objects with the glasses which have been so selected, which is occasioned by the excessive action of the convergence over that of the accommodation of the eyes; for though the necessity for the use of excessive accommodation has been by this means done away with, too much convergence still remains. Therefore, in reading and looking at minute objects, orthoscopic spectacles of the required focus should be used, which will prevent the feeling of fatigue from supervening.

If the vision of distant objects is good without glasses, and there is no pain or fatigue of the eyes in looking at them, convex glasses for distant vision are not required; but if the hypermetropia is so great that distant objects are indistinct, or if there is pain or fatigue attending such use of the eyes, then weaker glasses than those used for near objects are indicated. In such cases glasses of double focus may be worn (page 28), the upper halves, which are used when the eyes look at a distance, being of longer focus than the lower halves, which are used for reading and writing. In place of glasses of double focus the usual biconvex orthoscopic glasses may be used for near objects, and periscopic glasses for out-of-door use—the concave side being always turned towards the eye.

If an internal squint is threatening, such as is indicated by the occurrence of an intermittent squint, the lenses of the proper focus which correct the manifest hypermetropia (already pointed out, page 43) may remove the squint before it becomes permanent. To assist this, the axes of the lenses may be placed internal to the axes of the eyes, so that the outer half of each lens is in relation to the corresponding pupil. The effect of this displacement has been already explained. Or decentred convex glasses may be used to produce the same effect, in which case the axis of each glass is placed *within* the centre of the spectacle ring.

If these means are not sufficient to prevent the squint from coming on, or if it has already become established, prismatic convex glasses should be had recourse to, of the necessary convexity and angle, and turned with their convex surfaces to the object. But for the accomplishment of this end it is necessary that binocular vision should exist, and, therefore, that the squint should have taken place recently, for there is a tendency for the image of a squinting eye to be neglected.

If after giving the prismatic glasses a fair trial the internal squint still continues, section of the internal recti muscles should be performed. But after the operation convex glasses of the proper focus must be worn, to prevent the squint returning. It has been the neglect of this precaution hitherto, which has brought the operation for internal squint into discredit. But if the patient is a child which is too young to be operated on, the sound eye should be tied up, and the squinting eye alone used for two or three hours each day, so as to preserve the sight of that eye till the child is old enough to undergo the operation.

(*b*) *Glasses for older individuals.*

As has been said already, presbyopia comes on in hypermetropic eyes; indeed, in such it manifests itself unusually early. In a hypermetropic eye the nearest point of distinct vision at 30 or 35 may be at 16 inches, which in the model eye does not reach the same point till about the 55th year. In selecting spectacles for such a case, the same rules are to be followed as those given for presbyopia in the model eye. The only peculiarity is, that the nearest point of distinct vision is much farther off than is indicated by the age, and therefore correspondingly stronger glasses require to be selected. Two pairs of glasses will usually be required in such cases, one pair for reading and doing other minute work, and a pair with weaker glasses for going about with, or glasses of double focus may be used.

The Mounting of Convex Glasses.

When convex glasses are used for walking out of doors, their axes may be parallel, and their surfaces vertical on the face. But when they are used for near objects, such as they most frequently are, each glass should be placed oblique on the face, from without inwards, and from above downwards, so that a line representing the axis of each glass will meet at an object placed downwards and forwards, when the head is slightly inclined. Clear vision is thus obtained without bending the head much over the object.

The "Folder" or "Clip" Spectacles are not to be recommended in all cases, as the distance between the spectacle glasses when fitted on the face, depends on the breadth of the nose. As this is almost invariably too short, the convergence of the eyes in looking at near objects is less required; and, as a certain amount of convergence is necessary to react on the accommodating power of the eye, stronger glasses are sooner required as a compensation, especially by presbyopic individuals.

Glasses used only for near objects are sometimes truncated on their upper edge, so that if a distant object requires to be looked at, or if the eyes require a few minutes' rest, this may be conveniently done by looking *over* the glasses without removing them from the face.

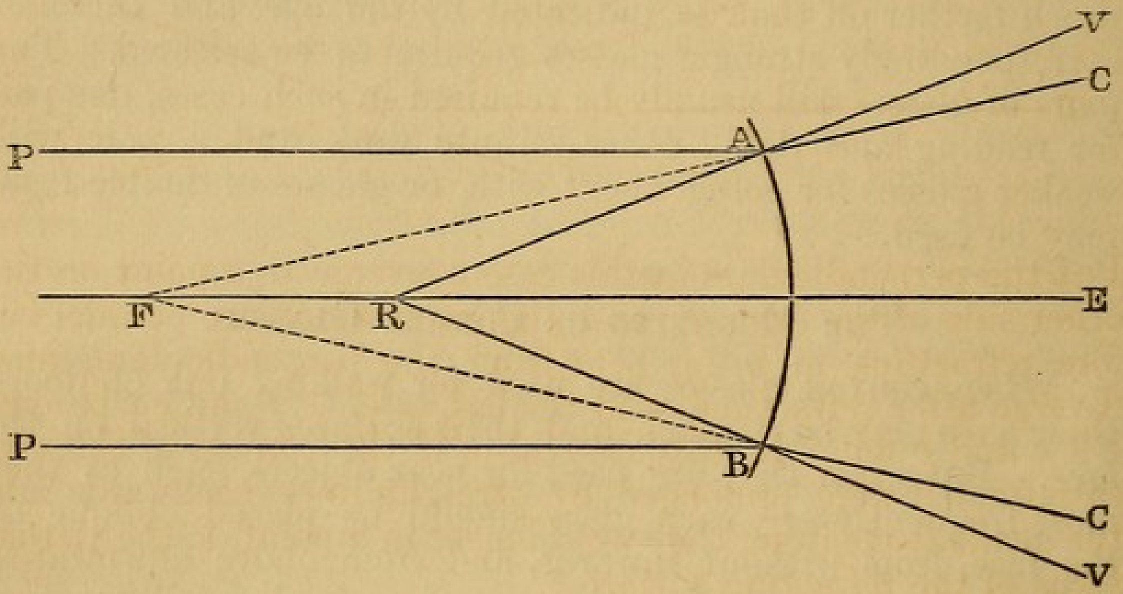
We come now to the consideration of that departure of the eye from the model type which requires the use of concave glasses. But, following our preconcerted arrangement we must briefly consider first some of the characters of

Concave Glasses.

(*a.*) Felt between the finger and thumb, they are depressed in the centre like the inner surface of a watch glass. (*b.*) Held in the beams of the sun, the rays are scattered. The principles of refraction on which this depends are as follows:—

When parallel rays of light enter a concave dense medium from air, they diverge from each other beyond the surface.

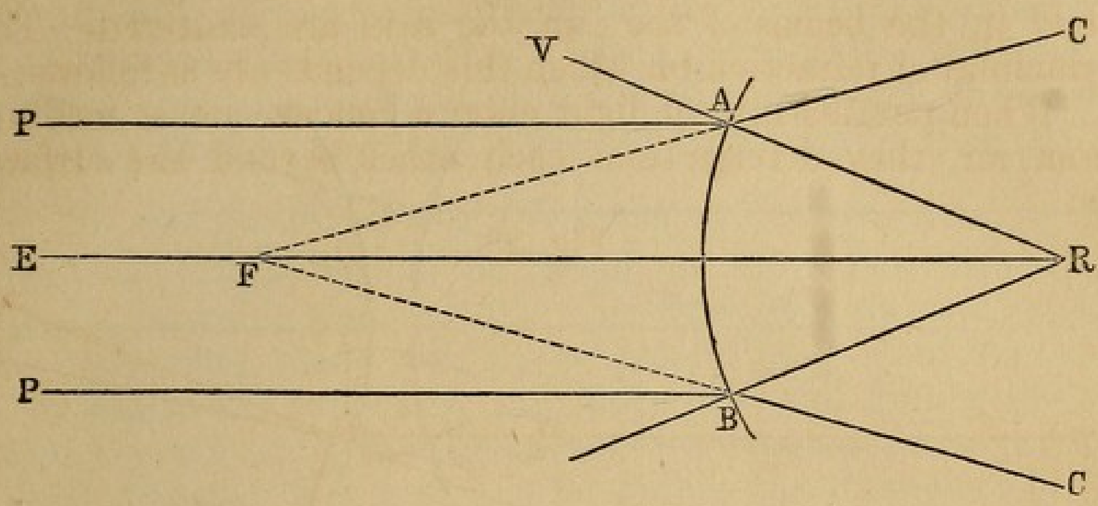
Fig. 23.



Let A B, Fig. 23, represent a concave surface of glass; P P a pencil of parallel rays incident upon the surface at A B from air, V R V R, the perpendiculars to the surface at the points of refraction. The rays, therefore, pass from a rare into a dense medium, and according to the general law already enunciated, they are bent towards the perpendiculars to the refracting surface. But the perpendiculars radiate from a point, R, anterior to the surface, consequently the rays which are parallel before refraction, in being bent towards the perpendiculars, must likewise diverge after refraction. P A and P B therefore become P A C and P B C. If lines representing these rays be continued backwards they would meet in a point, F, in the incident medium. This point is called the principal focus of such a surface, but inasmuch as it is not the rays which meet, but the prolongations of them, the focus is an imaginary one, and on that account is also called a *virtual focus.*

Rays also diverge from each other if they pass from a dense concave into a rare medium. Let A B, Fig. 24, be such a surface of glass. Following the general law formerly stated, the rays P P, in passing from the dense into the rare medium, are bent from the perpendiculars to the refracting surface.

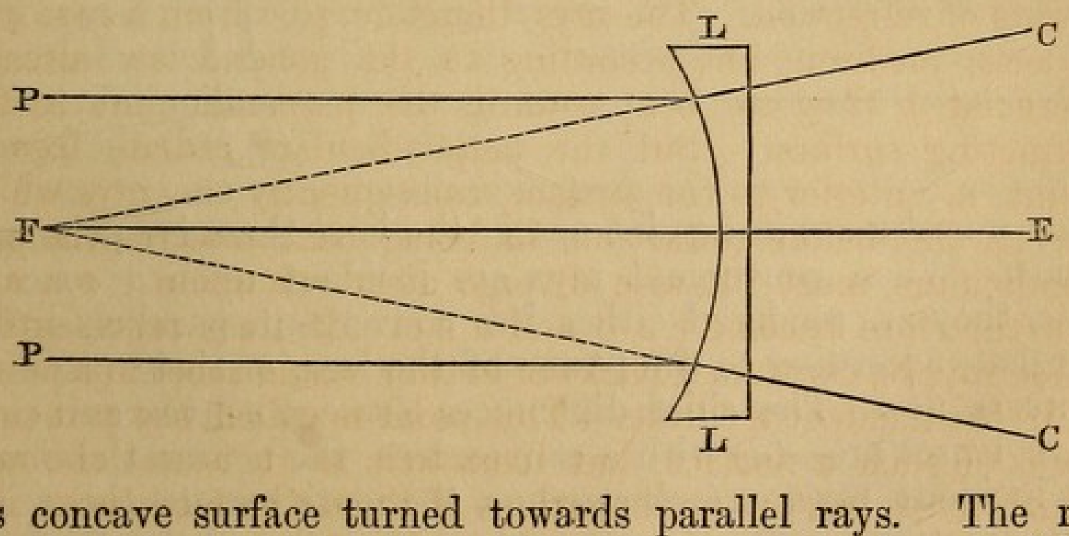
Fig. 24.



But the perpendiculars in this case converge to a point on the other side of the surface, and the rays, which are parallel before refraction, in being bent from the perpendiculars, must diverge after refraction, as in the last case. P A and P B become P A C and P B C. In this case also, if the courses of the rays so refracted were prolonged by straight lines backwards into the incident medium, they would meet in a point, F, the virtual focus of the refracting surface.

These are the principles of refraction of concave lenses. Fig. 25 represents the refraction of a plano-concave lens, with

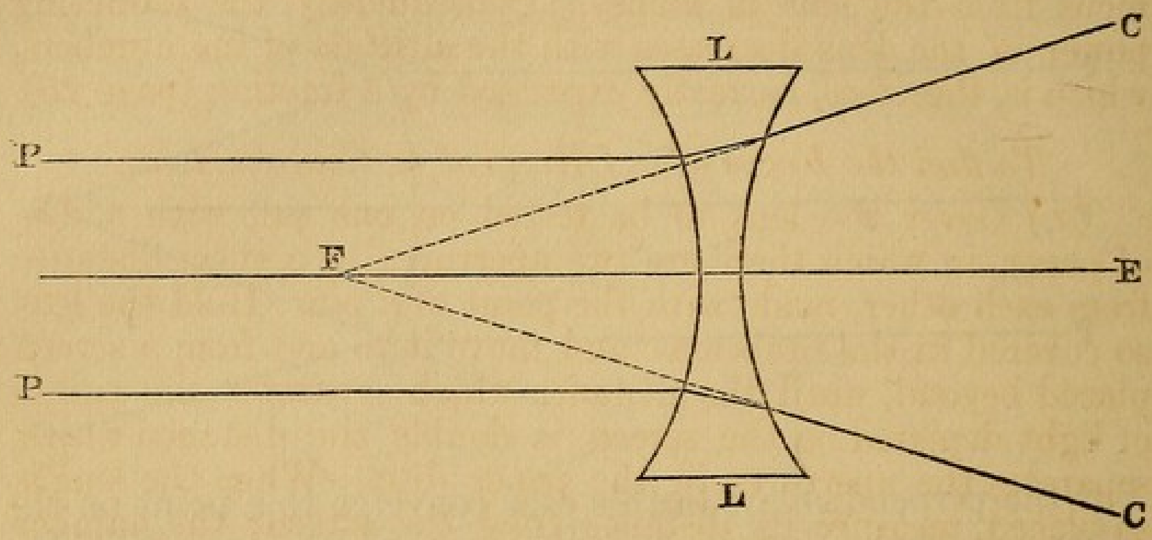
Fig. 25.



its concave surface turned towards parallel rays. The refraction of a biconcave lens (Fig. 26), combines the principles of Fig. 23 and Fig. 24, the refracting power of which is double that of the plano-concave lens of an equal radius of curvature.

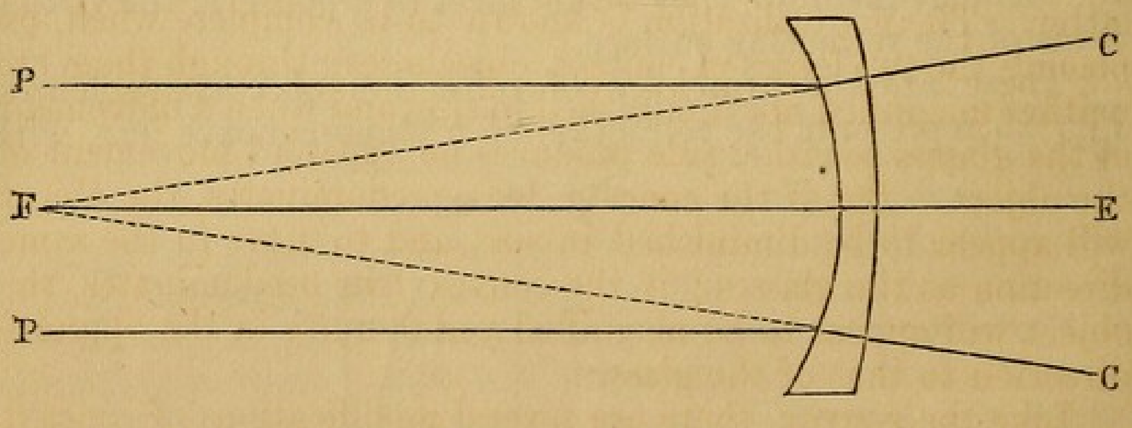
The concavo-convex lens (Fig. 27), combines in the one lens the refraction of a convex and concave lens, but the concavity predominates over the convexity. It is also, therefore, a divergent lens, but its divergent power is minus its convexity.

Fig. 26.



When divergent rays pass through a concave lens, they are rendered still more divergent, so that if prolonged backwards

Fig. 27.



they would meet in a point nearer the lens than its principal focus. When convergent rays are incident upon a concave lens, they are rendered either less convergent, parallel, or divergent, according to the power of the lens, or their previous convergence. The chief differences between convex and concave lenses are—(*a*) with a convex lens, the nearer the focus of incident rays, *cœteris paribus*, the more remote the focus of refraction : with a concave lens, the nearer the focus of incident rays the nearer the focus of refraction ; (*b*) with a convex lens, the rays *converge* to a real point beyond the lens: with a concave lens, the rays diverge beyond the lens, and the focus, which is imaginary, is on the side of the incident rays.

As with convex lenses, one concave lens is distinguished from another by the distance in inches of its principal focus—*one inch* being taken as the standard. Thus the numbers 2, 4, 8, 16, &c., represent respectively the distance of the principal focus from the lens in inches. Consequently, the refracting power of the lens decreases with the altitude of the numbers, which is, therefore, correctly expressed by a fraction (page 25).

To find the Focus of a Divergent or Concave Lens.

(*a.*) Cover the lens to be tested on one side with a disc of paper, in which there are two apertures, at a short distance from each other, made with the point of a pin. Hold the lens so covered in the sunbeams, and move it to and from a screen placed beyond, until the distance which separates the points of light depicted on the screen, is double the distance which separates the apertures in the paper disc. When the lens is so placed, measure its distance from the screen; the number of inches gives the principal focal distance of the lens.

(*b.*) If the experimenter is in possession of a set of convex test glasses of known power, the focal length of that convex glass which just neutralizes the refractive power of the concave glass whose focus is wanted, is also the focal length of the latter. The neutralization is known to be complete when, on placing the two lenses in contact, objects seen through them are neither magnified nor diminished in size, and when a movement of the glasses to either side produces no apparent movement of the object. But if the concave lens predominates, the object will appear to be diminished in size, and to move in the same direction as the glasses ; if the convex lens predominates, the object will appear to be magnified and to move in the opposite direction to that of the glasses.

Like the convex, there are several modifications of concave lenses, some of which are used for spectacles.

Decentred Concave Lenses.

The biconcave, the plano-concave, and the concavo-convex or periscopic, lenses, may be *decentred.* The axis of the lens may be placed either inwardly or outwardly to the centre of the spectacle ring, to suit the purposes for which the glasses are to be used.

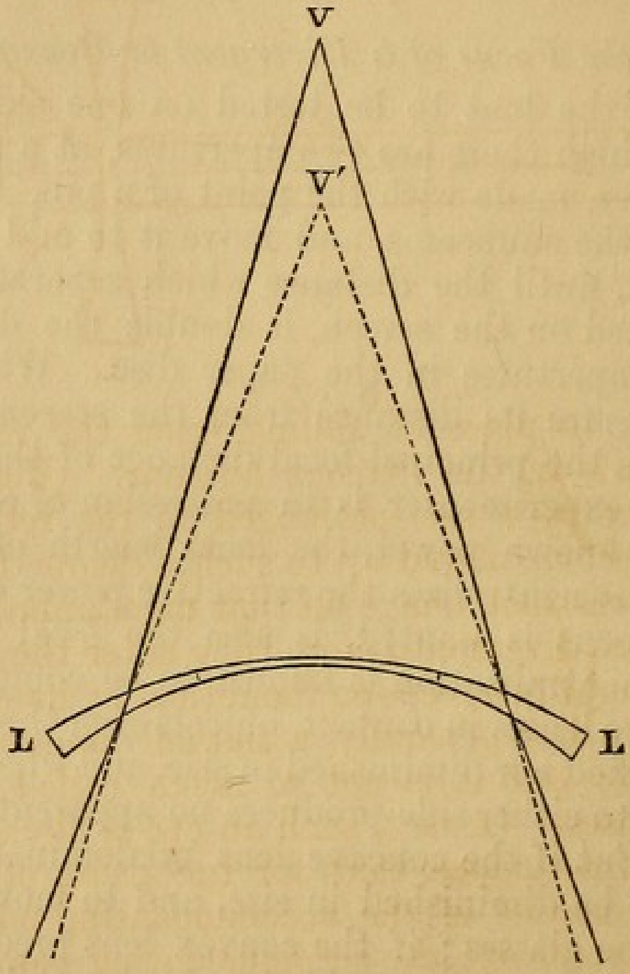
Prismatic Concave Lenses.

The one surface is ground as a concave lens, and the other is ground as a prism, the degree of either being more or less, as may be required.

Orthoscopic Concave Lenses.

The orthoscopic concave lenses are formed from one large lens in the manner described for orthoscopic convex lenses

Fig. 28.



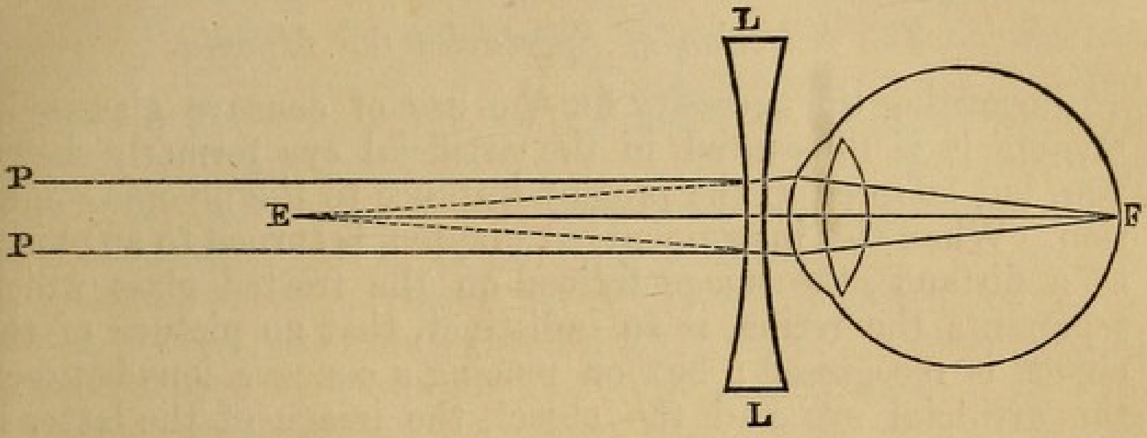
(page 29). The centres of the segments require to be placed at the same distance from each other in the spectacle frame, that they held in the original lens. Lenses so formed are prismatic as well as concave. The base of each segment being towards the corresponding temple, it deflects the rays of light which pass through it outwards, and, therefore, the apparent position of the object is displaced inwards. An object placed at V (Fig. 28) is seen as if at V′. One objection to the use of such lenses as spectacle glasses is, that objects seen through them appear as if they were convex on the surface.

We now proceed to consider the defect of sight which is benefited by the use of concave glasses—viz.,

Myopia.

The myopic eye is usually larger than the model eye, its antero-posterior diameter especially being lengthened. (Fig. 29.) The consequence of this condition is, that the focus of

Fig. 29.



parallel rays, in place of falling upon the retina as in the model eye, falls in the vitreous humour. (Fig. 2, E.) From this point the rays are prolonged to the retina, but in so doing they become mixed up to such a degree that they cease to portray a distinct image on that membrane. Rays, therefore, which are divergent before they enter the eye, and those only, are brought to a focus on the retina, by its static refraction. A myopic eye has generally a normal amount of accommodating power; but it is not so much called into operation as in other cases. In fact, such an eye is already possessed of too much refraction, so that, for the vision of objects which requires the exercise of the accommodating power in a model eye, in the myopic one the accommodating power is relaxed to the utmost. But the accommodation is peculiar in this, that its *region* is different from that of the model eye. In the latter, it is exercised on objects at any distance between the horizon and four inches, whereas in the myopic eye, it is exercised on objects within a much more limited space, which is less according as the degree of myopia is greater. The accommodation and the convergence of the eyes are associated in their actions in this limited space. The knowledge of this is of importance, as when the region of vision is lengthened by concave glasses, the want of the association of the two powers is for some time felt.

Characteristics of Myopia. There is usually no difficulty in recognising this defect of the eye.

(*a*) Near objects, and not distant ones, are seen distinctly.
(*b*) Distant vision is improved by looking through a small

aperture in a diaphragm. (*c*) In adjusting the focus of an opera glass or hand telescope to such an eye, the tube does not require to be drawn out to the same extent as for healthy model eyes, and for very myopic eyes it will not require to be drawn out at all. (*d*) Concave glasses render distant objects distinct.

The Selection of Spectacles for Myopia.

Regarding the necessity for the use of concave glasses in myopia it is illustrated in the artificial eye formerly shewn you, but adapted in the present instance to the myopic condition. When this instrument, so adapted, is turned to an object at a distance, the image formed on the frosted glass which represents the retina, is so indistinct, that no picture of the object is recognised; but on placing a concave lens between the artificial eye and the object, the image of the latter is rendered sharp and distinct.

(*a*) *The Selection of Concave Glasses for young myopic individuals when the accommodating power is normal.*

What is required by a myopic eye is a reduction of its refraction, so that it will be able to see distant objects distinctly, the rays from which are, practically speaking, parallel. The myopic eye possesses too much refraction, and, as a consequence, it is only capable of bringing divergent rays to a focus on its retina. Parallel rays, therefore, must be rendered divergent before they enter the eye, which is accomplished by means of a concave lens. In order to find the focus of the concave glass necessary for this purpose, we require to ascertain first the excess of refraction possessed by the myopic eye in question. The model eye possesses such an amount of static refraction, that it is enabled thereby to see a distant object distinctly, but if you add a convex lens thereto, distant objects will not be seen at all: you render such an eye myopic, and the remote point of distinct vision will be at the principal focal distance of said lens. For, the rays which are given off from an object placed at the focal distance of the lens, in such case, in being refracted by the latter, will be parallel to each other after refraction (Fig. 14), and, therefore, they will be in the same condition as those which the naked eye receives from a distant object. If the said convex lens be one of 24 inches focus, the most distant point of distinct vision will be at 24 inches. If it be a convex lens of 6 inches focus, the most distant point of distinct vision will be at 6 inches. The former would represent a myopia of $\frac{1}{24}$, the latter a myopia of $\frac{1}{6}$. You may try this for yourselves. Now, in this way the excess of refraction of the myopic eye may be computed —the most distant point of distinct vision, measured in inches, represents a convex lens of the same number of inches focus, which the myopic eye possesses in excess of refraction over that of the model eye. Suppose the most distant point of distinct vision to be 18 inches, such an eye possesses refraction in excess of that of the model eye equal to a convex lens of 18 inches focus, and to enable it to see a distant object distinctly *that* excess of refraction must be neutralized. How is this accomplished? If you place a convex and concave lens together, each of the same focus, the one will neutralize the other. *Then*, the excess of refraction in the case supposed will be neutralized by a concave lens of 18 inches focus. Therefore an eye of this degree of myopia, armed with such a concave glass, will see a distant object distinctly, for the rays which come from the distant object will be made by the glass to diverge in that degree before they enter the eye, as if they emanated from its farthest point of distinct vision—viz., 18 inches. This is shown in Fig. 29, in which E is the most distant point of distinct vision, and P P parallel rays of light. The latter are made to diverge by the concave lens L L, as if they emanated from E. If the farthest point of distinct vision be at eight inches, a concave lens of eight inches focus will be required in that case to neutralize the excess of refraction; and in the same way for every case, the distance of the remote point of distinct vision, measured in inches, gives not only the degree of myopia, but the focus of the concave lens required, to reduce the refraction to that of the model eye.

How is the Farthest Point of Distinct Vision Ascertained?

It is done by simply finding the greatest distance from the eye at which small type can be read. In place of types, Græfe's Optometer may be used, which is a metallic frame crossed by several fine vertical wires at short distances. When the instrument is removed to a greater distance than that of distinct vision the wires become doubled or indistinct. The greatest distance at which the wires are seen single, gives the remote point of distinct vision in any case of myopia.

In making this examination an error is apt to arise, especially in high degrees of myopia; for the eyes, in converging on the near object, call into existence a certain amount of their accommodating power, and if this measurement be relied upon, concave glasses of too short focus will be given, which will neutralize, not only the excess of the refraction which the eye possesses, but part of its normal static refraction as well. The results so obtained, therefore, should only be taken as an approximation of the strength of the glasses required. To check the result, (*a*) try the remote point of distinct vision with each eye singly. (*b*) Advance the concave glasses which have been selected somewhat from the face. If as good or better vision is thereby obtained, it is an indication that they are too strong, and that others must be substituted for them, of so much longer focus as the distance between the glasses and the face is increased; (*c*) or weak concave or convex lenses may be placed alternately in contact with the glasses already on the face. If better or as good vision of distant objects is obtained by adding weak concave lenses, those which have been selected are too weak. If, on the contrary, better vision of distant objects is obtained by adding weak convex lenses, the spectacles which have been selected are too strong. In all cases the *weakest concave glasses* with which distant objects are seen distinctly should be preferred, as it is in the wearing of too strong glasses that injury to the eyes most frequently arises.

The glasses which have been so chosen are intended for distant vision; but if the person is young, and the remote point of distinct vision with the naked eye is nearer than 10 inches, such glasses may also be worn in reading and writing. When, however, the myopia is great, such as when the remote point of distinct vision is at six inches from the eye, it is often advisable to have two pairs of glasses—a stronger pair for remote objects, and a weaker pair for objects at a moderate distance, such as for reading at the distance of 14 inches. For finding the focus of the weaker glass, we shall suppose, in our present illustration, that the most distant point of distinct vision is at 6 inches. To enable such an one to read at 14 inches, the refraction must be reduced from its present excess, which is equal to a convex lens of 6 inches focus, to one of 14 inches focus, the difference between which is nearly represented by a convex lens of 11 inches focus, for $\frac{1}{6}-\frac{1}{14}=\frac{1}{10\frac{1}{2}}$. To neutralize this difference a concave lens of 11 inches focus is required. Or, if the objects on which such an one chiefly exercises his eyes are situated at about the distance of 24 inches, for example, in reading music, concave glasses of 8 inches focus will be required to remove his far point to the distance of 24 inches, for $\frac{1}{6}-\frac{1}{24}=\frac{1}{8}$.

(b) *The Selection of Concave Glasses for Adults.*

A definite degree of convergence accompanies, and to a certain extent incites, the accommodation of the eye. If concave glasses have been dispensed with till adult age, the eyes will have been accustomed to bring the accommodating power into action with a considerable degree of convergence, owing to the nearness which, in such cases, the object is brought to the eye; and if in these circumstances the entire myopia is neutralized at first by concave glasses, the removal of the remote point of distinct vision to a great distance, will do away with the necessity of convergence, from which it will follow either that less accommodation will be at the disposal of the individual, or that the glasses will give rise to a feeling of pain or fatigue, from the disturbance of the anomalous harmony which has for a long time existed between the accommodation and the convergence. Remote vision with such glasses will be good, but the vision of objects within the distance of a few feet will be attended with difficulty or pain. Therefore, when the use of concave glasses has been deferred till adult life, it is advisable to begin with the orthoscopic concave lenses, the bases of which are turned outwards. This has the effect of maintaining the same proportionate effort of accommodation and convergence which existed before the use of the glasses was commenced. The employment of these glasses, however, presupposes an otherwise healthy condition of the eyes, and that the exercise of the previous convergence was not attended with injury.

Another method, which may be beneficially followed in the same class of cases, is to begin with concave glasses considerably short of neutralization of the myopia, which may be worn constantly, and when a very remote object requires to be looked at, a pair of "folders," with weak concave lenses, held in the hand, may for the moment be superadded. The manner of finding the focus of these "folder" concave lenses is very simple. A myopic person who has his remote point of distinct vision, we shall suppose, at 8 inches, wears concave glasses of 12 inches focus, which enable him to see objects at the distance of 24 inches from the eye. To enable him to see a very remote object, his entire myopia must be neutralized, which is done by adding concave lenses of 24 inches focus to the ones he already possesses, for $\frac{1}{12} + \frac{1}{24} = \frac{1}{8}$. When the eyes have become accustomed to bring their accommodating power into action by these weaker concaves, they may be set aside for stronger ones, in which case the "folders" will not be required.

The myopic eye is subject to loss of accommodating power through age as well as all other eyes. This, as I have already said, influences the near point of distinct vision, and that alone: the distant point remains the same. And thus, as the accommodating power becomes less and less with age, the near point recedes more and more from the eye, till it merges into the distant point, and then the person sees at the latter distance, and no other. A young myopic person requiring 18 inch concave glasses to see a distant object, has his near point, we shall say, at 3 inches. But at 55 years of age such an one's near point will probably have receded to 10 inches. At that age he will not be able to see nearer, but his far point will still be at 18 inches. One so situated is myopic and presbyopic at the same time; to see to read, he requires 48 inch convex glasses, and to see a distant object, 18 inch concave glasses. But if the distant point of distinct vision is at 10 or 12 inches, convex glasses will never be required; for though the entire accommodating power were becoming lost, the near point could not be beyond 12 inches, which is within the ordinary reading distance. If the latter individual, however, has worn concave glasses since youth, both for near as well as distant objects, which has completely neutralized his myopia, he will require at 45 or 50 years of age to substitute for them weaker concave glasses for reading, &c., for his accommodating power at that age, will not be sufficient to bring the point of distinct vision from a distance to 12 inches from the eye.

(*c*) If there is diminution of the sensibility of the retina, such as often exists in elderly adults with high degrees of myopia, completely neutralizing concave glasses should not be worn, for the retinal images would thereby be reduced to so small a size, that minute objects could not be seen at the ordinary distance of 12 or 14 inches. Or, if the objects are seen, the person instinctively brings them very near the eyes, which increases the size of the retinal images, and enables the objects to be seen even at the expense of their sharpness; but this causes an injurious pressure on the eyeball from the convergence of the eyes (page 80). In such cases, to prevent the necessity for bringing the object too near the eyes, a reading glass (page 37) may be employed along with weak concave spectacles, so as to constitute a kind of opera-glass.

(*d*) With the largeness of the eyeball of the myopic eye, there is a want of relative increase in the strength of the internal recti muscles. Moreover, since this increase is chiefly due to an enlargement of the posterior pole of the eye, the points of insertion of the ocular muscles remain the same, which detracts still more from their relative strength. Therefore, rotation of the eyeball in any direction is more difficult than in the model eye, but especially the inward movement, which is required to a greater degree than that of any other direction. Owing to this difficulty of converging the eyes on near objects, which may also be accompanied with pain, the person is apt to use one eye to the exclusion of the other. This he accomplishes by holding near objects to one side of the face, so that one eye only can participate in vision. The disused eye soon becomes weakened both in vision and power of convergence, binocular vision soon ceases to be accomplished, after which the eyeball rotates outwards, producing an external squint.

If such weakness of the internal recti muscles exists, the use of concave glasses for the vision of near objects, will do away with the necessity for so much convergence, and in all probability prevent the pain referred to from coming on. But if, notwithstanding the use of concave glasses of the proper focus, there is pain in looking at near objects, it is advisable to place the axes of the glasses farther apart than the axes of the eyes, so that the inner half of each glass may be opposite the pupil of the corresponding eye. By this means, the object, as seen through each glass, will appear to be displaced outwards, to see which, each eye involuntarily turns in the same direction. This takes the action off the internal recti muscles, allows binocular vision to be performed with ease, and by keeping up the action of both eyes, may prevent divergent squint. In place of lengthening the bridge of the spectacle frame, the decentred lenses may be employed—that is, each glass is so cut that its axis is placed to the outside of the centre of the spectacle ring; or prisms may be combined with the requisite concave glasses, the bases of the former being turned inwards. If these means fail to prevent the feeling of tension or pain in looking at near objects, or if divergent squint has occurred, and there is sufficient mobility of the eyes both outwards and inwards, the external rectus muscle of one or both eyes may be cut.

The attempt to *cure* a divergent squint, complicated with myopia, by prisms, is in all cases hazardous to the eye, and should never be thought of.

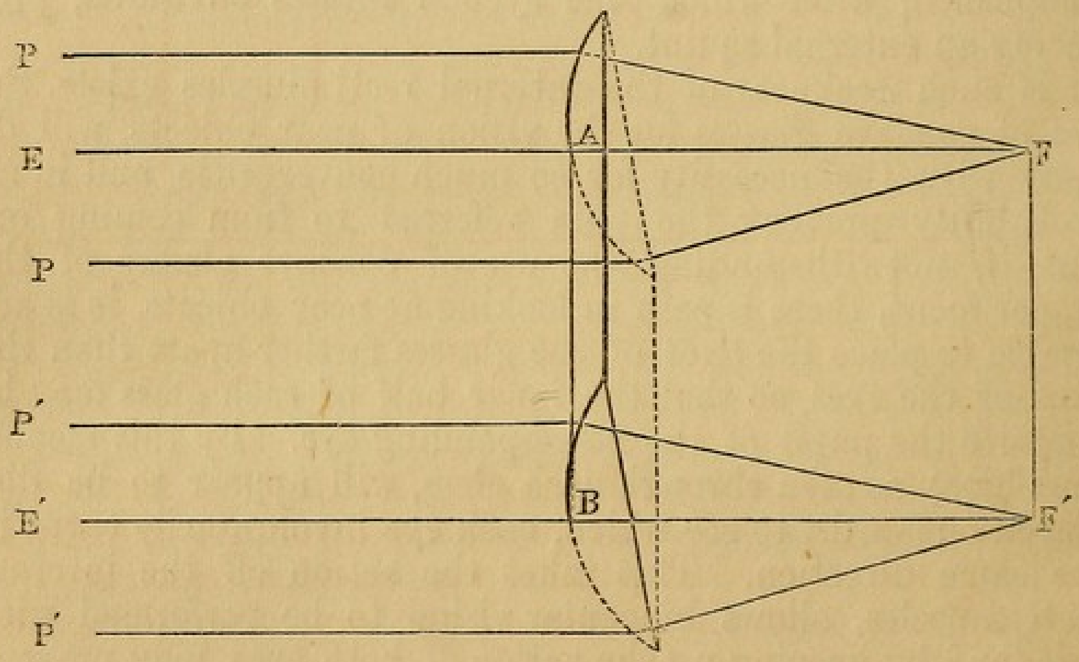
(*e*) If the myopia is very progressive, the use of glasses should, for the time, be suspended, and the convergence of the eyes on near objects avoided. The probability is that, in such case, a low inflammatory action is going on in the eye, for which medical supervision is required.

4. Conditions of the eye requiring the use of

Cylindrical Glasses.

Characteristics of Cylindrical Lenses.—Like ordinary spherical spectacle lenses they are convex and concave. To give you some idea of the curvature of cylindrical lenses, if a round glass rod be longitudinally divided into two segments (Fig. 30),

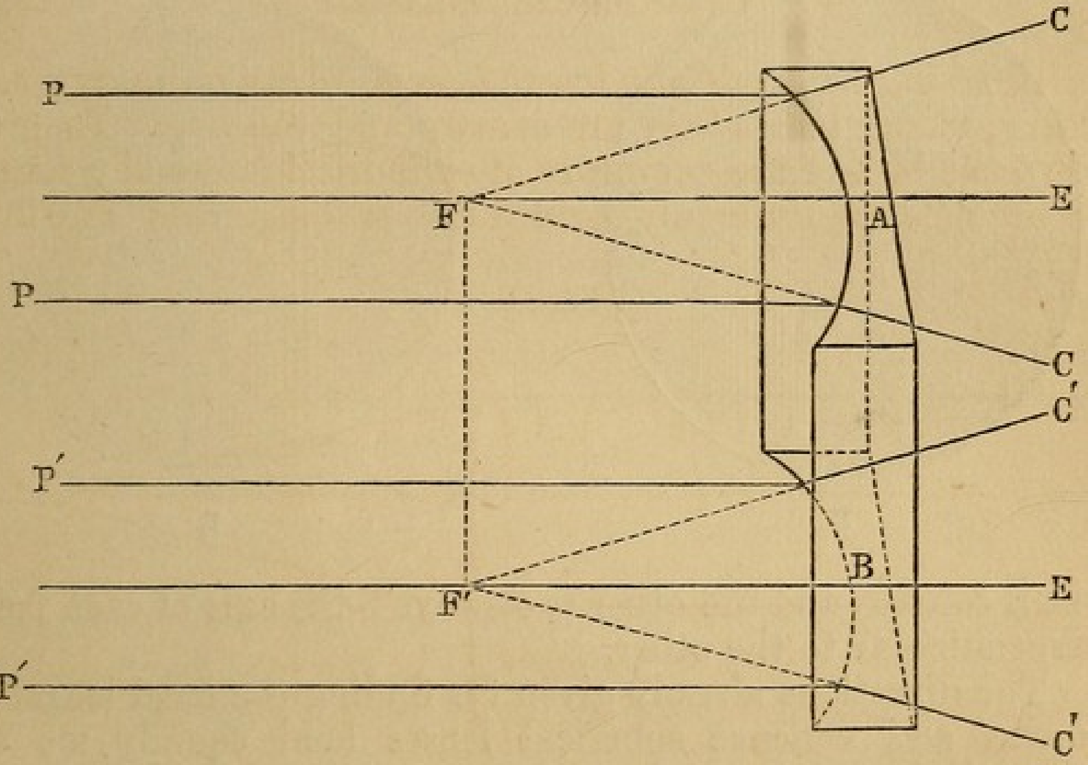
Fig. 30.



the outer surface of each segment represents the curvature of a *convex cylindrical lens:* if a glass tube be longitudinally divided into two segments (Fig. 31), the inner surface of each segment represents the curvature of a *concave cylindrical lens.*

Principles of Refraction.—I pointed out, in describing the refraction by ordinary spherical surfaces, that rays of light are variously refracted according to the obliquity of the refracting surface. We found that a surface which is the segment of a sphere refracts rays to or from a *point,* according as the surface is convex or concave. If, in place of the refracting surface being the segment of a sphere, it is the segment of a cylinder, as the curvature exists only perpendicular to the axis, so refraction only takes place in that direction, and the focus of the rays will be a *line*. To take our former illustration of the segment of a round glass rod as representing a convex cylindrical lens, let A B (Fig. 30) be such a segment, P P P′ P′ a pencil of parallel rays incident upon it, F F′ is the

Fig. 31.



focus of such rays after refraction. Let A B (Fig. 31) be the segment of a glass tube as representing a concave cylindrical lens; P P P′ P′ a pencil of parallel rays incident upon it; F C F C and F′ C′ F′ C′ are the courses of the rays after refraction, and F F′ is their virtual focus.

I show you here a plano-convex and a plano-convcave lens made on this principle. (Figs. 32 and 33.) V R in each figure represents the axis of the lens, which is a line drawn parallel with the cylinder, or perpendicular to the surface of curvature. When we look through such glasses—with convex, objects appear to be magnified in the direction perpendicular to the axis—with concave, objects appear to be diminished perpendicular to the axis.

There are several modifications of cylindrical lenses.

First Variety.—One surface only may be cylindrical, either convex or concave, and the other plane; or, both surfaces may be cylindrical—both surfaces in each lens being either convex or concave, with the axis of each surface parallel.

Second Variety.—One of the surfaces of the lens is the segment of a sphere, and the other is the segment of a cylinder, both being either convex or concave.

Third Variety.—Both surfaces are cylindrical, but the

Fig. 32.

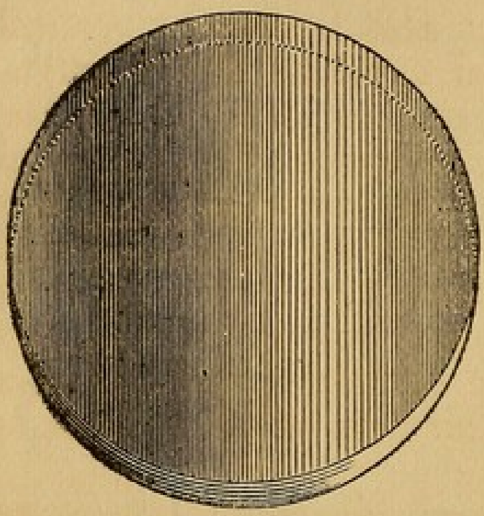
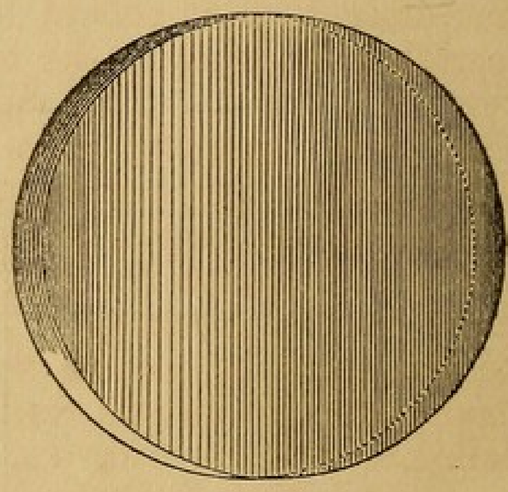


Fig. 33.



one is convex, and the other is concave—the axis of each being perpendicular to the other.

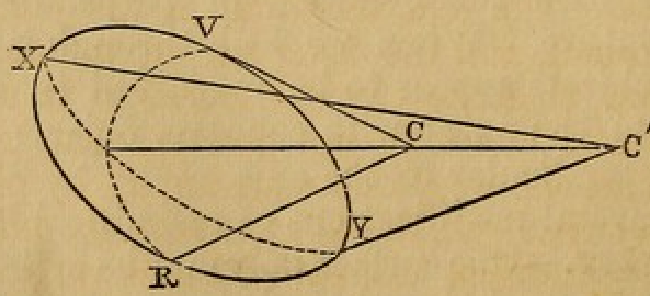
The directions already given for finding the focal length of convex and concave spherical lenses hold equally for the cylindrical.

Let us now enquire into the defects of the eye for which cylindrical glasses are used. They collectively go under the name of

Astigmatism,

a word which signifies that rays emanating from the point of an object are not brought to a point in the image.

Fig. 34.



The seat of astigmatism most frequently resides in the cornea. Let Fig. 34 represent the cornea, V R the vertical meridian, X Y the horizontal meridian. The radius of the cornea in one or both of these meridians is more or less than it should be; but the one meridian is essentially different from the other. C is the centre of the radius of curvature of the vertical meridian, while C′ is the same of the horizontal meridian. There are several forms of this disease.

First Form.—The cornea is *more* curved in one of its meridians than it should be. Let this be in the vertical meridian V R, while in the horizontal meridian X Y the curvature is normal. The vision of one so affected may be illustrated by placing before a model eye a convex cylindrical lens with its axis horizontal. Or the cornea may be *less* convex in one meridian than it should be. Let this be in the horizontal meridian X Y, while in the vertical meridian V R the convexity is normal. The vision of one so affected may be illustrated by placing a concave cylindrical lens before a model eye with its axis vertical. This form of the affection is called SIMPLE ASTIGMATISM.

Second Form.—Both meridians of the cornea are more convex than they should be, but the one is more so than the other.

Suppose, *first*, that the cornea is more convex than normal in both meridians, but in the vertical it is more convex than in the horizontal. The vision of such an one would be represented by placing a convex *spherical* lens, and a convex cylindrical lens, with its axis horizontal, before a model eye, which render the vision myopic and astigmatic.

Or suppose, *second*, that the cornea is less convex than it ought to be in both meridians, but the horizontal is less convex than the vertical. The vision of such an one would be represented by placing a spherical concave lens before a model eye so as to render it hypermetropic, over and above which a concave cylindrical lens with its axis vertical. This form goes under the name of COMPOUND ASTIGMATISM.

Third Form. The one meridian of the cornea is more convex than normal, and the other less convex than normal.

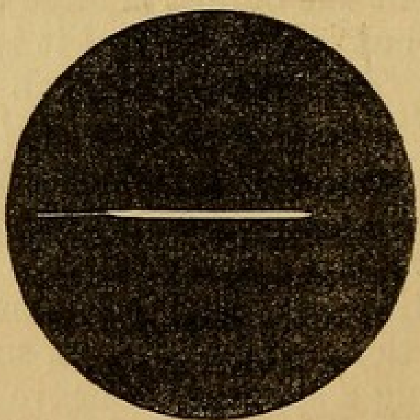
Suppose, *first*, that the vertical meridian is more convex, and the horizontal meridian less convex, than normal. The vision of such an one would be represented, by placing before a model eye a convex cylindrical glass with its axis horizontal, and a concave cylindrical lens with its axis vertical.

Or suppose, *second*, that the cornea is more convex in the horizontal meridian, and less convex in the vertical meridian, than normal. The vision of such an one may be imitated by placing a convex cylindrical lens with its axis vertical, and a concave cylindrical lens with its axis horizontal, before a model eye. This form is called MIXED ASTIGMATISM.

How is Astigmatism recognised?

(*a.*) The vision has not become obscured lately, but has been defective from youth. (*b.*) On the astigmatic person looking through a small aperture in an opaque disc, vision is somewhat improved. If the opaque disc be advanced to the distance of 4 or 5 inches from the eye, and looked at with one eye against a clear sky or bright light, the aperture will not appear round as it really is, but oval. (*c.*) Horizontal and vertical lines about the $\frac{1}{12}$th of an inch thick, placed at the distance of 20 feet from the eye, are not seen with equal distinctness. At one distance the horizontal lines are seen distinctly, at another distance the horizontal lines are not seen, but the vertical lines are distinct. In most cases of astigmatism the horizontal lines are seen nearer than the vertical. (*d.*) Ascertain the refractive power of the lenses of the eye in the vertical and horizontal, meridians, separately. For this purpose, take a diaphragm having a slit of about $\frac{1}{10}$th or $\frac{1}{20}$th of an inch wide

Fig. 35.



(Fig. 35), and place it before the eye to be examined, which confines the refraction to whichever meridian of the eye the slit is turned. Place No. 20 of Snellen's test types, or any letters $\frac{3}{8}$ths of an inch square, at the distance of 20 feet. In the first place, hold the slit vertical before either eye, and beyond it a convex and concave *spherical* lens, alternately. If the vision of 20, Snellen, is improved by a concave glass, say of 20 inches focus, then there is excess of refraction in the vertical meridian of the eye equal to a convex lens of 20 inches focus (page 53). After this has been ascertained, place the slit horizontal, and beyond it a convex and concave lens alternately, as before. In this meridian we shall suppose that vision is rendered confused and dim both by the convex and concave lenses, and that it is acute without any lens, which shows that refraction is normal in the horizontal meridian of the eye. If such were the results found in any particular case, the defect would be made out to be one of "Simple Astigmatism." If, on the other hand, the vertical meridian were found to be as above stated, but the horizontal meridian improved by a convex lens of 20 inches focus, then the refraction in that meridian would be minus that of the model eye, the diminution of refraction being equal to a convex lens of 20 inches focus. The defect in that case would be made out to be one of "Mixed Astigmatism." In making the examination just described, it is well to have the accommodation subdued by the sulphate of atropia. (*e.*) When these results have been obtained there can be little doubt about the disease. All doubt will be removed by placing a cylindrical glass, convex or concave, as the case may be, before the eye so defined. As the glass is rotated before the eye, vision will be improved when its axis is in one position, and dimmer when it is in every other.

The Selection of Glasses of the Proper Form and Focus for Astigmatism.

If the examination which has just been described, has been carefully conducted, not only will the nature of the disease have beenaccurately ascertained, but the proper glasses which correct the defect will also be made out.

(*a.*) Suppose the case has been made out to be one of simple astigmatism, with the curvature of the cornea normal in the horizontal meridian, and an excess of refraction equal to a convex lens of 20 inches focus, in the vertical meridian. Simple concave cylindrical glasses of 20 inches focus, with the axes of the glasses placed horizontal, are indicated. On the other hand, if the curvature of the cornea is normal in the vertical meridian, but in the horizontal meridian there is a diminution of refraction, equal to a convex lens of 20 inches focus, then convex cylindrical glasses of 20 inches focus, with their axes placed vertical, are indicated.

(*b.*) The case, we shall suppose again, has been made out to be one of compound astigmatism.

Suppose there is myopia in both meridians: in the vertical, the excess of refraction is equal to a convex lens of 20 inches focus, and in the horizontal, the excess of refraction is equal to a convex lens of 10 inches focus, then a concave glass, *spherical* on one side, of 20 inches focus, which completely neutralizes the myopia in the vertical meridian, and reduces that of the horizontal by one-half; the other surface of the lens being concave *cylindrical*, of 20 inches focus, with the axis placed vertical, will completely correct the remaining myopia.

Suppose there is hypermetropia in both meridians. In the vertical the diminution of refraction is equal to a convex lens of $\frac{1}{10}$, and in the horizontal it is equal to a convex lens of $\frac{1}{20}$, then a convex glass, *spherical* on one surface, of 20 inches focus, will completely correct the hypermetropia in the horizontal meridian, and reduce that of the vertical to $\frac{1}{20}$; the other surface of the lens being cylindrically convex of 20 inches focus, with the axis placed horizontal, will correct the remaining hypermetropia in the vertical meridian.

(*c.*) The case is made out to be one of mixed astigmatism, the refraction being *minus* in the one meridian, and *plus* in the other. Let us suppose that in the vertical meridian the *excess* of refraction is equal to a convex lens of 10 inches focus, and in the horizontal the *diminution* of refraction is equal to a convex lens of 24 inches focus; then, a bicylindrical lens, having one surface concave of 10 inches focus, the axis of which is horizontally placed before the eye, and the other surface convex of 24 inches focus, with its axis placed vertical, will correct the defect.

LECTURE III.

Improper Illumination as a cause of Impaired Vision—The means whereby the sun's light is utilized to us for visual purposes—Comparison between Day-Light and Gas-Light—Various means of ameliorating the injurious effects of Gas-Light—The degree of illumination which should be used in the vision of near objects—Means of Modifying the Light in Diseases of the Eye—Overuse of the Eyes as a cause of Impaired Vision—Various directions as to the use of the Eyes—Faulty position of the body and head when the Eyes are viewing near objects, and the too close approximation of the object, as causes of Impaired Vision—The normal near point of Distinct Vision—The causes of Strabismus or Squint, and how they may be obviated—Injuries of the Eye, and what should be done in the emergency—Noxious habits, such as "Smoking," "Drinking," &c., which are prejudicial to the healthy condition of the Eyes—Atmospheric Influences and Contagion as causes and means of propagation of Diseases of the Eye — Reaction of disorders of the system on the Eye.

I HAVE occupied so much of our time in the consideration of spectacles, because wide-spread fallacies regarding them are prevalent, and because they are a prolific source of impaired vision. This has left us only a limited space to consider what remains of our course; which brings me to say what I intended as preliminary to this evening's lecture, that the brevity with which I shall be obliged to treat of the various subjects that are to come under our attention, is to be taken as no measure of their importance.

The subject in our list which now falls due to be discussed is—

II.—Improper Illumination as a Cause of Impaired Vision.

As the ordinary light of day is the natural stimulus of the eye, we may compare our artificial lights with it; and if we cannot imitate in the latter the process by which nature renders the former harmless to the eyes, we may at least derive some useful lessons by the comparison.

The means whereby the light of the sun is utilized to us for vision are (*a*) the atmosphere which is supposed to surround the sun, and (*b*) the atmosphere of our own planet.

The light as it is immediately emitted from the sun is probably not quite colourless. All white lights are made up of seven colours. This is shown in the simple experiment of decomposing the direct rays of the sun by a prism. Circumstances will not permit me to perform this experiment before you, but it may be imitated by looking through a prism at any bright light, in which case the spectrum of the seven colours is portrayed on the retina of our eyes, in place of the white screen in the ordinary experiment. Now, to produce white light, these seven colours must be combined in definite proportions. If any one be superabundant, the light will be tinged by that particular colour. Light, as it is thrown off from the sun, has probably one or more of the colours of the spectrum in excess; but it immediately encounters the sun's atmosphere, which absorbs part of each of the colours, some more and some less, the ultimate effect of which is, that the sun's light on emerging into space is pure white. This is the explanation of Frauenhofer's lines, which are simply dark bands intersecting the different coloured spaces of the sun's spectrum where the rays are wanting, and which represent the absorption of so much of those colours by some medium before the light reaches the earth.

In passing onwards to our planet the rays of the sun further encounter the clouds which float in the firmament, and the infinitesimal atoms which compose our atmosphere. Some of the light is intercepted by these media, though the greater portion of it passes uninterruptedly to the surface of the earth. From this light which is intercepted, a trace of each of the colours of the spectrum is again absorbed, but especially the red and orange, leaving the colours at the blue end of the spectrum in preponderance. This bluish light then which is left, is reflected hither and thither by the atoms of the atmosphere, constituting ordinary daylight. Hence the blue colour of the sky in a clear day; and the atmosphere of our dwellings would also appear blue, if it were in sufficient volume.

The direct beams of the sun contain rays of heat as well as rays of light. This is of universal experience. But when the beams of the sun are acted upon by our atmosphere, and transformed into the ordinary light of day in the manner presently to be described, the latter does not sensibly affect the thermometer. For the watery vapour and particles of the atmosphere, as they reflect the rays of light in every direction, absorb those of heat, so that pure daylight is not at all heating to the eyes.

The atmosphere further utilizes the sun's light by toning down its brilliancy to the proper degree. The greater portion of the sun's light which reaches our planet, as I have said, passes on to the earth, and there serves other purposes than those of vision. Indeed, a fractional part of it only is intercepted by the clouds and the atmosphere; but these few sparse rays, spread hither and thither in all directions by a never-ending reflection, which reflection breaks up the original *rays* into a multitude of others, each of the latter into a multitude more, and so on. Thus, by an exalted numerical progression, the luminous effect of those few original rays is so enhanced, that they are sufficient to light up the entire hemisphere of our globe in the day-time, yet so diluted as to feel pleasant to the eyes.

This luminosity of the atmosphere is the source, then, whence we derive the light which illuminates our apartments during the day, and but for which everything around us, both inside and outside of our dwellings, would be in complete darkness, save those on which the direct rays of the sun shine. And it is from the same source that light streams into our eyes from every side, and excites to action all their functions—a condition which is as essential to the healthy action of the eyes, as is the atmospheric air to the lungs.

Comparison between daylight and our artificial lights, having special reference to gaslight. Now, in all of these respects our artificial lights are different. They all contain a superabundance of the red and orange colours. They are all heating both to the atmosphere and the eyes; for the same chemical action which produces the rays of light produces also those of heat. Moreover, since both the rays of light and heat are almost, without exception, governed by the same physical laws—for example, the velocity with which they travel, their reflection by bright surfaces, &c., being the same for both—it follows from the nearness of our artificial lights to us, that both sets of rays must strike the eye at the same time. Lastly, the intensity of the illumination of our artificial lights, from the manner in which they are customarily used, is greater than the ordinary light of day.

But what are the effects of these differences on the eye, and how may they be removed or obviated? The chief effects on the eye of excess of the red and orange colours contained in our artificial lights are, first, that they necessitate a greater exercise of the accommodating power of the eye to bring them to a focus on the retina, for they are less refrangible than the blue colours at the opposite end of the spectrum, the latter of which predominate in ordinary daylight; second, that they are particularly irritating to the retina, producing impressions which, speaking relatively, are with difficulty effaced. Hence, after much use of the eyes in artificial light, spectra of the bodies contained in the humours of the eye are seen, and often complementary colours, which arise from the irritable condition of the retina so produced.

Of the rays of heat which are given off from our artificial lights, some fall upon the surface of the eye, rendering it dry and the motions of the eyelids painful, a condition which is much enhanced by the heated atmosphere which surrounds the combustive process. But some of the rays of heat also penetrate the eye along with the rays of light, which, judging from the effects of heat on other parts of the body, are likely to give rise to congestion of the retina. There are also some grounds for belief that the rays of heat which enter the eye, in those exposed to strong fires, such as blacksmiths, furnace-men, &c., have some effect in causing cataract—the crystalline lens, which is the part affected in cataract, being coagulated by heat like "white of egg."

The superabundant colours and rays of heat in gaslight are to some extent counteracted and removed by the glass globes which usually surround the flames, and by effectual ventilation. Some also attempt to heighten the beneficial effects of these means by tinting the glass globes with cobalt blue, which absorbs the superabundant red and orange colours; and by placing over the top of the globe a covering of porous clay, with sufficient space between the two to admit of the free passage of air, so as to absorb part of the heat thrown off by the flame. These efforts to ameliorate the injurious effects of gaslight on the eyes, are very praiseworthy, and should be encouraged; but we shall find that more benefit is to be derived from reducing the degree of illumination and removing the flame to a sufficient distance, questions which now fall due for our consideration.

Of all the injurious effects of our artificial lights, probably none equals those produced by excessive illumination. The number of rays of light which are made to fall on objects in gaslight during observation of them, is ordinarily much greater than when those objects are illuminated by daylight in our apartments. This arises simply, of course, from having the flame too near, or the jets too numerous for the distance at which they are placed. There can be no doubt but that the habit of most individuals is, to use a too bright light for the vision of objects which requires close use of the eyes. I speak especially to those whose habit it is to employ much of their time in looking at near objects; not so much to those who only use the eyes occasionally on near objects in gaslight. Now, what are the effects on the eye of excessive illumination?

The amount of light which the eye demands in viewing objects depends much on habit; for the retina, which is the percipient membrane of vision, is able to bear a gradually increasing degree of illumination, even until the light becomes excessive, without pain or inconvenience. This simply arises from the sensibility of the retina becoming dulled, so that a greater degree of stimulation is required to rouse it into action, just in the same way as the sense of touch of the blacksmith's hand becomes less and less acute, from the rough objects which he handles. And thus, it is different with the organs of the special senses than it is with the muscular system of the body. Within a certain limit, a muscle becomes developed and its power augmented, by increased action; but with the retina and other organs of special sense, the greater the degree of stimulation to which they are subjected, the less acute do their perceptions become. The least of the evil results, then, which follow the prolonged use of a too bright light are, that small objects are not seen unless highly illuminated, and the difference between delicate shades of colour becomes imperceptible. Those who would wish to preserve in themselves acute vision till a good old age, let them imitate the practice of Herschel, who, by habitually using his eyes in weaker degrees of illumination, was able to outstrip his contemporaries in astronomical research.

But the habitual exposure of the eyes to a bright light ultimately does more, in most cases, than merely dulls the sensibility of the retinæ; it actually brings on diseases of the retina and optic nerve, which sometimes end in partial or total destruction of sight. One of these diseases is a low kind of inflammation of the parts named; and as its accession is very gradual, and is accompanied with no pain, it may be working its baneful effects all the time silently, but not the less surely, that the person is unconscious of its existence. This disease is called "night-blindness," because the person affected with it is unable to see after sunset, or in a moderately lighted room, but requires strong degrees of illumination for the vision even of large objects. It is very common amongst European settlers in the East and West Indies, where the light of the sun is excessive; and sailors after their return from tropical climates often complain of it. Blacksmiths and others much exposed to the heat and light of strong fires are sometimes affected with it.

Besides its injurious influence on the retina, an excessive amount of light calls into unusual action the accommodation and convergence of the eyes. The contraction of the pupil, the accommodation of the eye for near objects, and the convergence of the optic axes, as has been already pointed out, are under the control of the one pair of nerves, the third pair, and are called into action by the influence of light on the eyes. This direct effect of light on these functions is especially seen in infancy and childhood, functions over which such individuals have no voluntary control, and, therefore, in them an excessive amount of light produces great contraction of the pupils, coincident with which such a degree of convergence as gives rise to an inward squint (page 82).

The influence of strong light on the accommodation of the eye is sometimes taken advantage of, though quite unconsciously of the explanation, by those somewhat advanced in life, who, from a retiring modesty to begin the use of "spectacles," or other causes, bring the flame of the gas very near the eyes, or hold the book or object in a very bright light. By these means, a flood of light is thrown into the eyes, which causes great contraction of the pupils, stimulating at the same time, the accommodation to excessive action, and thus enables the person to do without convex glasses.

But an opposite condition is also injurious—namely, that of exercising the eyes on near objects in a too feeble light. If the contrast of the degree of illumination between that of the room in which we sit or work, and the light outside, be great, an unpleasantness is produced in going suddenly from the former into the latter, until the pupils of the eyes become habituated to the change. Otherwise, however, it does no harm, but rather good, to habituate the eyes to a feeble illumination, provided that the eyes are not exercised on minute objects at the same time, for the sensibility of the retinæ are thereby increased. It is different, however, when the eyes are used for the vision of minute objects, such as reading small type, when the light is too feeble. One moment the pupil contracts from reaction upon it of the accommodating power to see the print, the next moment it dilates from the feebleness of the illumination, the accommodation relaxing with it. Intermittent vision is the result, the words appearing and disappearing alternately, a condition which is very fatiguing to the eyes. Ultimately a spasm of the ciliary muscle may come on, causing pain and a feeling of heat and tension in the eye and eyebrow, spasmodic closure of the eyelids, and a profuse flow of tears, symptoms which, in such circumstances, are not uncommon in young myopic and hypermetropic individuals. These effects, however, are the least of the evils which arise from using the eyes on near objects in a too feeble light, for they may readily subside after the eyes cease to be so used. A more serious effect is the nearness that the object requires to be held. To make up for the feeble illumination of the object, the latter, such as a book or a "copy," is brought nearer to the eyes than it ought, the head stooping over the object at the same time. This causes unusually great convergence of the eyes, injurious pressure on the globe, by the action of the internal recti muscles, and congestion of all the parts in and around the eye. This subject, however, will be more fully considered further on.

Now, since a too feeble as well as a too bright light is injurious to the eyes, when they are at the same time exercised on near objects, *What is the degree of illumination which should be employed in such circumstances?* In giving an answer to this question, it must be understood that, in the use of the eyes, light enters them from two sources—first, the reflected light of the atmosphere, which streams into the eyes from every side, causing the entire retinæ to vibrate, and excites to action the accommodation and convergence of the eyes; and second, the light from the object under observation. While the latter is the only light essential to vision, the former effaces or modifies the visual impressions produced by the latter. One or two illustrations will perhaps render this more clear.

Stand in a dark room, and, while the eyes are directed to a clock or other lustrous substance, strike a light and momentarily extinguish it, watching the effect. Immediately an exact spectrum of the face of the clock in its real colours will appear before the eyes in the dark, followed by the same spectrum, passing through all the colours of the rainbow in succession, before it finally disappears. Now, it is the same part of the retina which always receives the images of objects in direct vision, the central spot of the retina, a space, moreover, which does not exceed the one-eighth part of an inch in diameter. If, therefore, the same phenomenon as that mentioned, recurred every time the eyes were directed to a fresh object, which might be 15 or 20 times in a minute, the visual impressions from the different objects would become mixed up together. But this is ordinarily prevented by the lateral light which enters the eye, stimulating the whole retina around the central part where the images of external objects are depicted, and thus the visual impressions of the latter are modified, for a like reason that chalkings on a light board are less glaring than on a black one. Obviously, therefore, the necessary degree to which objects are illuminated for distinct vision, will depend much on the amount of lateral light which enters the eye at the same time. If the latter be in moderation, the former may be also considerably reduced, and thus it is possible to have equally good vision with a relatively fainter image, and consequently with a less expenditure of nervous action. Let me give you a more practical illustration. If you place an object between two windows in a room, and look at it from such a position that the light from the windows falls at the same time upon the eyes, the object will be imperfectly seen unless it is very brightly illuminated, whereas if the two side windows are darkened and the object illuminated from a third window behind, it will be more distinctly seen, and that with a much more feeble light than by the previous arrangement. This also explains the reason that persons, in whom the sensibility of the retina is impaired, generally see better in looking from a dark room to objects outside.

The inference from all this is plain, which is, that if we sit with our backs to the light when reading, writing, or examining minute objects, the intensity of the light by which they are illuminated may be considerably modified. Taking these considerations into account, in connection with the degree of illumination which we should employ, it should be the nearest approximation to the light admitted into a room by a north window, which is not subject to the influence of every passing cloud, and which is sufficiently toned down for vision. If this degree of light gives pain, or if clear, distinct vision is not obtained thereby, when the back is turned to the source of the illumination, it will in all likelihood be found that there is some defect of the eyes requiring remedial agencies. Our artificial lights can be toned down to this degree by means that all are acquainted with—by diminishing the number of jets, and having the flames at a sufficient distance. The effect of the latter expedient depends on the well-known law, that the intensity of light is in an inverse ratio with the distance which it travels. To illustrate this law, let a point of light be surrounded by two spheres, the one double the radius of the other, and consequently the former having four times the extent of surface of the latter. Now, if all the rays which emanate from the point of light be diffused over each of the spheres, it is clear that it will be four times denser on the lesser than on the greater, that is, each square inch of the latter will only receive one-fourth of the number of rays that fall on each square inch of the former, and, therefore, it will have only one-fourth of the degree of brightness. This law of light, which also obtains for that of heat, is of universal experience, and gives us a ready means of diminishing the illuminating and heating powers of our artificial lights, which, from their nearness, are usually relatively greater than the diffuse light of the atmosphere. It is but seldom, however, that this law is taken advantage of, or rather it is acted upon adversely to the advantage of the eyes, by bringing the flame too near—there being an almost universal desire for too much light. In the use of gaslight, we should imitate as far as possible the luminosity of the atmosphere, by diffusing it throughout the apartment. Let me remind you again, that it is the light of the atmosphere falling upon objects from every side, which renders them visible in the day-time. If an object so illuminated be shaded on one side, it is still visible by the light which strikes it from the other sides, though, contrary to what might be expected, it is not all visible now. Allow me to explain. The surface of no object is perfectly smooth. Take a piece of white paper, place it under the microscope, and it will appear, even with a low power, raised into ridges, and depressed into hollows, not unlike the photographs of the moon's surface. The surface of every object in the same way is more or less rough. Now, if the light which illuminates such surfaces falls upon them from one side only, it is evident that only one side of the ridges (if I may so name the minute irregularities of apparently smooth objects) will be illuminated, and the other will be in shade. When, however, objects are illuminated by the atmosphere, light strikes them from every side, bringing out all their irregularities. It is otherwise with artificial light. Such light strikes the object, for the most part, from one side only, so that it is, as has been explained, only partially illuminated, and hence let the artificial illumination be increased to any degree, such perfect vision of the object will not be obtained as if it were illuminated by the reflected light of the atmosphere. This is one of the reasons why the textures, colours, and other visible qualities of objects cannot be so clearly made out, even when more highly illuminated, by gaslight than by daylight. Our gaslight hides many inequalities of surface, and that both with respect to individuals as well as things.

It is not possible entirely to obviate this defect in the use of gaslight. Something, however, might even be done in this respect, if, in place of the customary habit of having one large gas lamp suspended from the centre of the ceiling, as is commonly done, or a single jet placed upon the table, isolated jets were distributed over the walls. Also, as a means of enhancing the same effect, the walls of our sitting-rooms used in gaslight might be painted or papered of a light colour, which, when done, have the effect of throwing back the light into the centre of the room, but which they absorb if of a dark colour, as is often the case. Besides acting as a substitute for the luminosity of the atmosphere, this arrangement of the gas jets would prevent much of the harm which arises from their heating propensities.

By various means, then, many of the evil effects of gaslight on the eye, may be obviated; but, after all that art can do, it forms but an indifferent substitute for the pure light of day. Consequently schools, offices, and rooms in which the eyes are much used on minute objects, should be so situated and constructed as to admit of daylight freely, that artificial light may not require to be used, before the usual time of sunset.

In some diseases of the eye, light, even when toned down to the extent I have indicated, in place of giving pleasure to the eyes, as in health, produces pain and injury. Thus in some of the inflammations of the eye in childhood, the light must be greatly modified, and in some cases excluded altogether, not only to ensure comfort, but to allow the eyes to get well, and to prevent squint from supervening (page 82). In the severest forms of such inflammations, the faintest ray of light, is attended with pain, causes a flood of tears to gush out of the eye, and the child to burrow his face in his hands or the pillow. One of the first means of treatment which should be adopted in such cases, is to pad the eyelids with cotton wool, retaining the latter in its place by means of a light bandage applied round the head. The cotton wool is apt to become soaked with the tears, and, therefore, should be renewed several times a-day to prevent scalding of the eyelids and cheek. This is a better plan of excluding the light than that of darkening the room, as the health, which in such cases is often already somewhat impaired, suffers from the want of light. When, however, intolerance of light comes on with measles, scarlet-fever, small-pox, or other acute febrile diseases, it is well to exclude the light from the room, as darkness is usually soothing to the patient, and is not unfavourable to the fever.

In cases of ophthalmia in which the intolerance of light is not so severe, shades made of thin cloth or fine wire gauze may be sufficient. The same practice is generally also sufficient in adults when the eyes are inflamed, as the light is seldom so intolerant in them as in children. Cobalt blue, or London smoke glasses may be worn out of doors. The London smoke glasses are best when it is simply required to diminish the amount of light admitted into the eye, such as when glasses are used as masks for Alpine travellers, and for those much exposed to bright reflections from water, sand, &c.; whereas, when the intolerance of light arises from congestion of the retina, brought on by over-exercise of the eyes in artificial light, the cobalt blue glasses, by excluding the extreme red and orange rays of the spectrum, have the most soothing influence.

III.—Overuse of the Eyes as a Cause of Impaired Vision.

A frequent cause of impaired vision is the insufficient amount of rest which is given to the eyes.

The use of the eyes on near objects is an active state. The muscular systems of the eye are thereby called into action—the ciliary muscle and the internal recti muscles—and that in a direct ratio with the nearness of the objects which are viewed. On the other hand, the use of the eyes in looking at distant objects, is a passive state, so far as the muscular systems of the eye are concerned. Consequently, a certain amount of relaxation is given to the eyes in directing them to distant objects, after having occupied them for some time on near ones.

But by this means the retina is not rested. It remains active so long as the eye is exposed to light. Sleep, which is the great restorer of our wearied frame, is the means which nature adopts for giving rest to the percipient membrane of vision, which it does by securing to it nearly complete darkness. The requirements of a certain period of repose in sleep, in order to maintain a healthy condition of the system, are based on fixed laws of the economy, and there is no immunity from harm if these laws are systematically ignored. Fortunately, this is a subject on which I do not require to enlarge, as the requisite amount of sleep sufficient for the restoration of the system, is determined by feelings within ourselves, and which are elicited as readily as those of hunger or thirst. Now, it will be apparent to every one, that if the eyes are overexerted at the same time that the body gets an insufficient amount of sleep, the reaction must fall doubly upon the eyes. Indeed this, with a combination of other conditions which usually go together, such as the use of artificial light, is often a cause of impaired vision, and of the origin of a disease of the eye which sometimes goes on to complete blindness. I refer more especially to optic-neuritis, which, before the introduction of the ophthalmoscope, was classed with other diseases under the general title of amaurosis.

When there is active inflammation of the eye, there should be complete exemption of the use of the eyes on near objects. The necessity for this is apparent. In inflammation of the eye, the tissues are surcharged with blood, and if the muscular structures of the eye and the retina are tasked at the same time, this latter will cause a determination of more blood to those parts, and be a means of feeding the inflammatory process. This is more especially the case with the internal inflammations of the eye.

A pause in the use of the eyes on near objects is beneficial. In those who are affected with hypersensibility of the retina, a condition which sometimes happens in individuals who are subject to recurrent attacks of ophthalmia, it is of much importance to pause in the work every now and then. By this means, not only will the eyes do a greater amount of work, but harm will be prevented from arising. The same practice should also be adopted by those who have strong eyes, but who subject them at certain times to unusual exertion, such as in microscopic or astronomical investigations; and this will be all the more required if, in these investigations, the head is either thrown much back or forward. In such circumstances also, it will rest the eyes still more, and increase the acuity of vision, if the eyelids are closed at the same time.

In examining objects through the microscope or telescope, no straining of the accommodating power of the eye is required ; it ought to be relaxed as much as it is when looking at a distant object. If the object is not seen distinctly, the focal adjustment of the instrument should rather be altered, than the accommodation brought into action in its place. Care to prevent this is most required in using the former instrument, as the apparent nearness of the object is apt to produce an involuntary convergence of the eyes, in which the accommodation follows as a natural consequence.

In those who have weak eyes, or who use them much on near objects, it is very bracing to sponge the forehead, temples, and eyelids occasionally with Eau-de-Cologne. A very grateful application is the following :—

"℞ Aceti Aromatici guttas quinque,
Spiritus Ætheris Nitrici drachmam,
Aquæ ad uncias sex. Misce."*

The visual impressions of both eyes used at once are not double those of either used singly. In binocular vision, objects are only $\frac{1}{13}$th brighter than in monocular vision, and the pupil in the latter is nearly double the size that it is in the former. This may be expressed in another way. In monocular vision the work of both eyes is almost entirely thrown upon one. Hence it follows, as a natural consequence, that since in using both eyes at once there is a division of labour, so there will be a division of the wear and tear of the tissues engaged. As far as practicable, therefore, one eye should not be used to the exclusion of the other. On this account, single eye-glasses, as a rule, are objectionable, while on another account they are positively condemned—namely, that the range of the accommodation of the two eyes becomes different, which will afterwards prevent the eyes being fitted with spectacles with double lenses. In some occupations, however, in which the objects are so minute that they require to be brought close to the eye, one eye can only be used at a time. Such are the occupations of watchmakers, engravers, &c., who to focus the object when brought so near, attach a convex lens to the eye. All who occupy themselves much in investigations in which only one eye can be used at a time, should accustom themselves to bring the eyes into use alternately. Orthoscopic lenses may be had to enable watchmakers, engravers, &c., to use both eyes at once without harm.

IV.—Faulty Position of the Body and Head when the Eyes are viewing Near Objects, and the Too Close Approximation of the Object, as Causes of Impaired Vision.

If the head bends much over the object, the jugular and other large veins of the neck are compressed, and the blood is

* Mackenzie on "Diseases of the Eye," 4th Ed., p. 1097.

thereby prevented from returning to the heart, but accumulates in the parts most easily distended about the head. Now, the eyeball is filled with fluid (Fig. 2), which is directly poured out by the blood-vessels in the neighbourhood. As the amount of this fluid is directly proportionate to the pressure of the blood within the vessels, it follows that if the latter are habitually too full, occasioned by causes which prevent the return of blood to the heart, the consequence must be an increased flow of fluid into the eye.

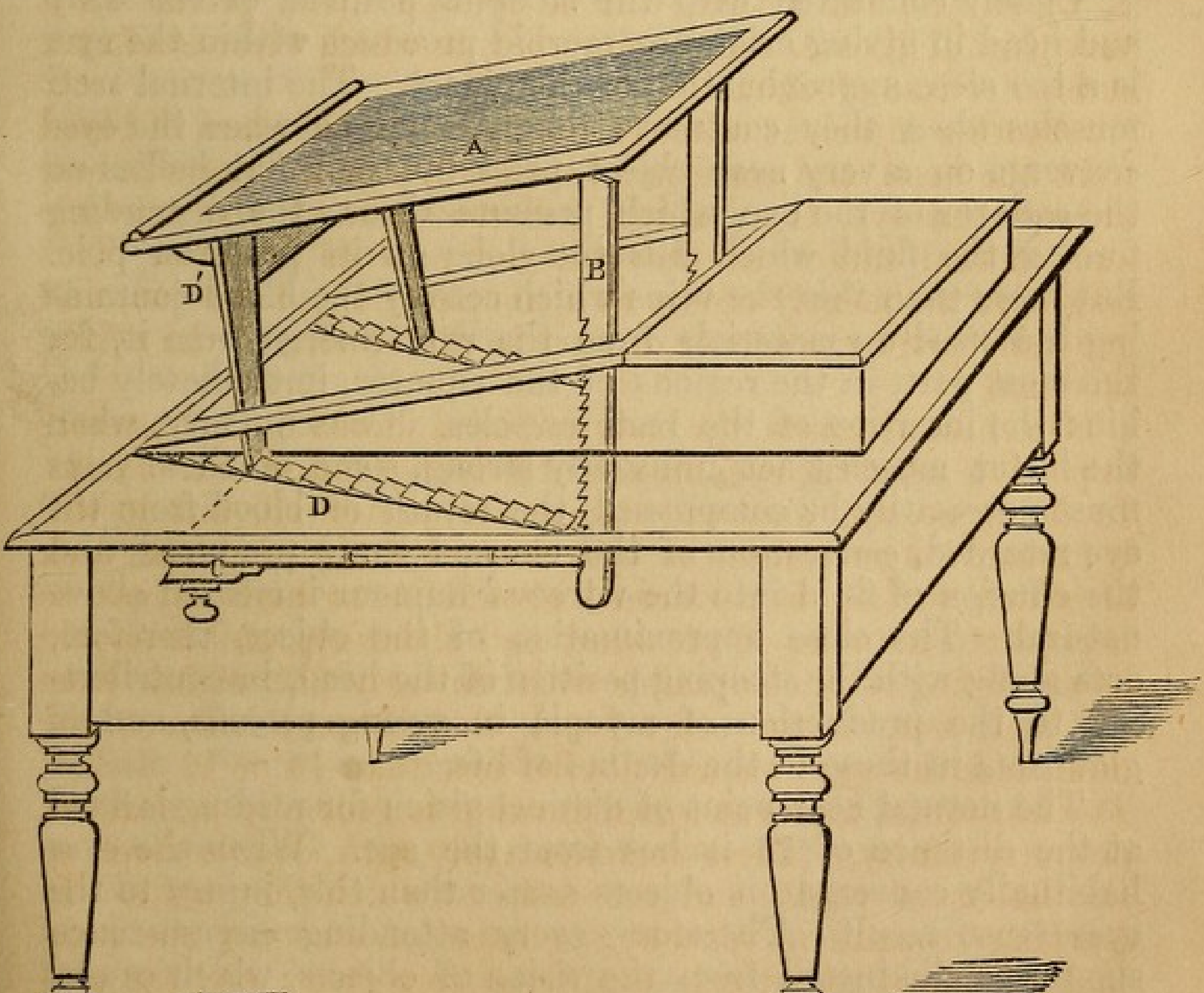
If this occurs in young individuals, in whom the tunics of the globe are soft and yielding, the effect will be an enlargement of the globe in its weakest direction, which is its antero-posterior axis, and the production of myopia. If, on the other hand, this hypersecretion of fluid occurs in individuals upwards of 40 years of age, in whom the ocular tunics are rigid and unyielding, distension of the latter cannot occur, but the tender nerves which pass between the sclerotic and choroid membranes on their way to the iris and ciliary muscle (Fig. 1, 6), as also the retina, will be pressed upon, producing a very painful disease, called *glaucoma*, in which there is often a sudden eclipse of sight.

Another injurious effect of the interrupted return of blood from the head, and consequent congestion of the parts in and around the eye, is an actual inflammation of the sclerotic and choroid tunics, at the posterior pole of the eye. This condition frequently occurs as a complication of myopia, and generally gives rise sooner or later to diminution of the acuity of vision.

On these accounts, the body and head should be kept as erect as possible when the eyes are attentively engaged on near objects. In doing so, not only will danger be prevented, but it will be much longer before the eyes become fatigued. The desk at which writing is performed should be so high as not to necessitate stooping of the head and shoulders, and it should be as sloping as is compatible with the easy flow of ink from the pen; but, on the other hand, the distance between the desk and the eyes should not be less than 14 or 16 inches. The horizontal tables at which drawing is generally performed, are very faulty. These remarks apply with double force to the habits of youth, and the desks at which they write. In learning to write in schools, the habit of stooping the head and leaning it to one side should be corrected; and the construction of the desks should be particularly attended to. Pupils should be taught to write in an upright position. It is the want of attention to these and similar circumstances, elsewhere mentioned, which give rise to the prevalence of short-sightedness in the educated classes.

Reading should be performed in the erect posture of the body, with the book, if possible, held before the eyes. With ponderous tomes this is not possible; while, to lay them on a flat desk or table, if the height of the body is adjusted to the upper half, the head requires to bend over the lower half, of the page, and *vice versâ*. In such cases the upper and lower edges should be raised or lowered as necessity requires, rather than that the position of the head should be accommodated to that of the book. This may be readily done by various means, such as by smaller books. Or the desk at which reading and writing are performed may be so constructed that the lid of the desk can be raised or depressed, and inclined to any plane, at pleasure. Fig. 36 is the design of a desk which I have had con-

Fig. 36.



structed on this principle, and which I have found to answer the purpose named. A, the lid of the desk raised to its full extent; B, upright *rack* for raising the lid of the desk; C, a spring-frame to check rack B; D, a *second rack* on incline to check fly-legs D′. When the desk requires to be raised it is done by lifting the upper edge of the lid. Any inclination may be given to the desk by shifting the fly-legs D′ in the rack D. The motor apparatus might be improved by raising or lowering the rack B by means of a small wheel and pinion.

From what has been said it will be understood that the practice of reading in a recumbent posture, such as when lying on a sofa or in bed, is condemned.

In those who use their eyes much on near objects, and in weak-sighted or myopic individuals, determination of blood to the head produced by other causes than those named, are equally injurious. As instances, I may mention a tight neck-tie, sleep after a full meal, cold feet, intemperance, and costive bowels.

Closely connected with the stooping position of the body and head in giving origin to morbid processes within the eye, is a too close approximation of the object. The internal recti muscles when they contract strongly, such as when the eyes converge on a very near object, press by their flat bellies on the equator of the eye, which pressure throws the distending force of the fluid which fills the globe on its posterior pole. But more than this, the veins which convey the blood containing the used-up materials from the eye, emerge from it, for the most part, in the regions of the equator, immediately behind the insertion of the recti muscles. Consequently, when the latter muscles act unusually strong, some of these veins must necessarily be compressed, the return of blood from the eye retarded, congestion of the choroid tunic produced, and the effusion of fluid into the vitreous humour increased above natural. The close approximation of the object, therefore, acts along with the stooping position of the head, in contributing to the production of myopia in young persons, and of glaucoma in those in the decline of life.

The normal near point of distinct vision for reading is fixed at the distance of 14 inches from the eye. When the eyes habitually converge on objects nearer than this, injury to the eyes must result. Therefore, every attending circumstance should be eliminated from the vision of objects, which causes the near point to be diminished within the distance named. School books should be printed in a good-sized type, as there is an instinctive desire on the part of youth to bring the book near when the type is small. For a like reason the ink used in writing should be jet black, and children should be taught to write in a bold round hand. The effect of deficient illumination has already been considered as one of the conditions which contribute to the too close approximation of the object.

The inclination to bring the object too near is still more felt by children who have specks on the cornea, or who are affected with a species of congenital cataract. More than ordinary care is required in such cases to prevent confirmed myopia from supervening. Myopic individuals generally prefer to read very small type, that their diminished field of vision may be compensated by the shortness of the lines. This is injurious, inasmuch as the near point of distinct vision is at a shorter distance from the eye than with large type. And, therefore, if in myopia the near point is at a less distance than 12 inches, weak concave glasses should be used in reading and writing. The manner of finding the focus of such glasses has already been pointed out (page 54).

Sometimes the myopic and hypermetropic individuals attempt to do without glasses by bringing the objects nearer than their near point of distinct vision. By so doing, they increase the size of the retinal image, which enables them to make out the object notwithstanding that the image is much out of focus. In order to prevent harm arising, glasses of the proper form and focus should in such cases be procured without loss of time.

V.—The Causes of Strabismus or Squint.

When the centre of each retina is impressed by an image of the same object, only one combined image is seen. This is called *Binocular vision*. If one eye be turned aside so that another part of its retina, while the centre of the other, is impressed, double vision or *Diplopia* is the result, and this though both images are exactly alike. But the eyes have a great abhorrence of seeing double, and, therefore, in the normal state, in every movement of the two eyes, their axes are turned directly upon the object under observation. This is accomplished by the ocular muscles (Fig. 3). Each eye has four muscles, which, acting singly, turn it in four different directions, called the external (2), internal (5), superior (3), and inferior rectus (4). The eyeball has other muscles attached to it, but its motions are sufficiently represented by the four recti muscles. But the movements of the two eyes are associated. Both eyes move to the right or to the left, upwards or downwards, at the same time. For the right or left movement, the external rectus of the one and the internal rectus of the other, are required. For an associated upward or downward movement, the superior or inferior rectus of both eyes respectively act in concert. Besides these associated movements, however, both eyes also converge at the same time when fixing an object as it approaches. This is performed by the internal recti muscles, which in that case act together.

The recti muscles of the eyes, in order to perform their associated movements, are governed by nerves in a particular manner. The third pair of nerves govern all the muscles which act in concert to produce binocular vision—viz., the internal rectus of both eyes, the superior rectus of both eyes, and the inferior rectus of both eyes. The external recti muscles are governed by separate nerves, the sixth pair.

The principal varieties of strabismus or squint are the convergent and the divergent. For the first, one of the internal recti, for the second, one of the external recti, acts too strongly. In consequence of this the axes of the eyes, in place of both being directed to the same object, one only fixes it, the other deviating outwards or inwards. In such a case, double vision exists at first, but soon the deviated eye becomes insensible, and takes no share in vision, unless when the other is closed. Some of the essential qualities of vision *then* are lost: the power to determine visually the third dimension of objects can only be acquired by shifting the position of the head, and stereoscopic vision cannot be accomplished.

Strabismus Convergens. An intimate connection subsists between some of the other functions of the eye and the convergence of the eyes. The third pair of nerves which preside over the convergence of the eyes, also supply nervous action to the sphincter muscle which contracts the pupil to screen the retina from excess of light, and the ciliary muscle which changes the form of the lens in the accommodation of the eye for near objects. As proximate causes, then, of convergent squint, we may note,

First. The exposure of the eyes to a too bright light. If the eyes of an infant are exposed to a bright light, or if when the retinæ of children are more than usually sensitive to luminous impressions, their eyes are exposed to the ordinary modified light of day, along with the excessive contraction of the pupils so produced, both the accommodation and convergence of the eyes will be at the same time unusually stimulated, the latter of which actions will occasion for the time being an internal squint. This is matter of common observation. Thus an infant, which has little voluntary control over the movements of the eyes, turned with the face to a bright light, will squint inwards, and by continuing such a practice the squint may be made permanent. It is seldom that a mother or a nurse is so imprudent; but in childhood the action of light on the eye is not unfrequently the cause of squint. A child, for instance, has inflammation of the eyes, and the retinæ are so intolerant of light that the faintest ray produces the outward symptoms of spasm of the eyelids and a flood of tears; but more important actions are going on within the eye. The pupil contracts to its smallest diameter, spasm of the accommodation comes on, and the internal recti muscles, which, being supplied by the same nerve, participate in the spasm, and carry either eye forcibly inwards. In such cases, imprudently exposing the eyes to even a moderately bright light may have this effect, and which, therefore, should be guarded against for this as well as other reasons (page 74).

Second. Excessive action of the accommodation of the eye for near objects sometimes produces convergent squint. Indeed this is probably the most frequent cause of it. I have already stated (page 41) that in hypermetropia the accommodation is called into excessive action to make up for the deficiency of the static refraction of the eye. Now, as the accommodation and convergence of the eyes are under the control of the one nerve, the excessive action of the former is accompanied by excessive action of the latter. The young person in reading or looking at near objects, holds the book or the object to one side, so that it is only seen with one eye, which enables him to converge the eyes to a nearer point than that at which the object is placed, producing a squint, the constant practice of which soon causes it to become permanent. The use of convex glasses of the proper focus prevents this (page 43).

The reaction of the accommodation on the convergence of the eyes in other defects of sight, sometimes gives rise to internal strabismus. I refer to specks on the cornea and congenital cataract. The explanation is, that the vision in such cases being very defective, the object requires to be held very near the eyes, which calls forth a corresponding amount of accommodating power to render it distinct, in which action excessive convergence of the eyes is implicated.

Third. Besides these causes of convergent strabismus, it has sometimes its proximate cause in the intimate union which subsists between the third and the sympathetic nerve. The sympathetic nerves, one on each side of the body, consist of 24 pairs of ganglia, arranged on each side of the spinal column, for its whole length, from the cranium downwards. These ganglia give off numerous branches, which follow the courses of, and are distributed upon, the walls of the arteries in their varied ramifications throughout the organs of the head, chest, and abdomen. Each ganglion is an independent centre or *little brain* where nervous force is generated, and supplies the arteries in its immediate neighbourhood. On the walls of the arteries are coils of muscular fibres which surround the tubes, not unlike the spiral threads of a screw, and which, by contracting, narrow the channels of the vessels, so that the stream of blood through them is diminished. It is to supply power to these muscular fibres that is the chief function of the sympathetic nerve. When it acts, therefore, it reduces the bore of the arteries; and when there is a cessation of its action, or when the distending force of the blood is supreme, the arterial tubes dilate. Besides this, a nervous cord passes between neighbouring ganglia, above and below, so that the entire series, arranged along the spinal column, are enchained together. From these connections very important actions take place. A vast system of nervous inter-communication is established between different organs of the body, even those remote from each other, so that disturbance of the circulation in one, produces a disturbance of the circulation in another. Thus is explained why undue action of the heart causes engorgement of the blood-vessels of the face in the act of *blushing*, and the opposite condition from *passion* or *fear;* thus are explained the dryness of the tongue and throat, and other morbid sensations and appearances, in disorder of the stomach; headaches, giddiness, &c., from constipation of the bowels, and a thousand other coincident complaints, which it would be tedious to name. But there is still another system of communication, and which is the one that more especially concerns our present argument, namely, the communications between the sympathetic and other nerves of the body. These are very numerous, but we have only to do with the communication between the sympathetic and the third nerve. Some of the branches which are given off from the upper end of the sympathetic nerve in the neck, enter the cranium along with the large blood-vessels. The greater number of these, as has been stated, are distributed upon the walls of the arteries, but a few *filaments* again pass out of the cranium into the orbit, one of which unites with the third nerve, so that the action of the latter, besides its ordinary volition derived from the brain, may be incited by nervous force derived from any of the ganglionic centres of the sympathetic nerve in the neck, chest, or abdomen.

From this description of the distribution and connections of the sympathetic nerve, we can understand why passion in children sometimes gives rise to strabismus convergens; for, the same exalted energy of the sympathetic nerve which diminishes the caliber of the arteries, and causes paleness of the face, is also communicated to the third pair of nerves which preside over the convergence of the eyes. Where such takes place, it evinces an evident want of training. Worms and other sources of irritation of the intestinal canal, by communicating morbid action through the same channels, sometimes produce strabismus convergens in children. In the incipient stage of a squint produced by this cause purgatives and anthelmintics are indicated.

Divergent Strabismus. The convergent squint which I have just described is most frequent in children; the divergent squint, which I am about to describe, is most frequent in adults. Two-thirds of the cases of divergent strabismus come on as the result of myopia; but it sometimes simply arises from weakness of the internal rectus muscle, so that the latter fails to be a sufficient antagonist to the external rectus. It is the divergent strabismus produced by the latter cause that I have to speak of here; that which occurs as a consequence of myopia having been already sufficiently noticed (page 57).

When divergent strabismus arises from weakness of the internal rectus muscle, there is a premonitory stage in which much may be done to prevent it. In this premonitory stage (*a*) the person experiences tension and pain in looking at near objects, and he finds it impossible to converge the eyes nearer than a certain point; (*b*) when both eyes are directed to a near object, on the affected eye being covered, so that binocular vision is no longer an incentive to convergence, it rotates outwards; (*c*) when a prism, with its refracting angle upwards or downwards, is placed before an eye of normal muscular power in every direction, it produces double vision—the double images being displaced simply vertically. But if one or other of the internal recti is not a sufficient antagonist to the external rectus of the same eye, the latter will rotate outwards—the direction of the strongest muscle, and the images of the two eyes will be displaced not only vertically but laterally. This latter symptom is a certain test of the weakness of one or other of the internal recti muscles.

This weakness of the internal rectus muscle does not remain stationary. If the weakness increases beyond a certain extent, so that binocular vision ceases to be accomplished, the eye becomes permanently directed outwards, forming a divergent squint.

When this affection is taken in its premonitory stage, or even after the squint is fully formed, provided binocular vision still continues, it may be sometimes cured by means of prisms. For this purpose the angle of the prism is placed towards the nose, and should be of such strength that the internal rectus is just able to overcome the double vision which it produces. It should be worn for some hours each day, and a stronger one substituted for it again and again as the power of the internal rectus increases, until the divergent squint is prevented or removed, as the case may be.

VI. Mechanical Injuries of the Eye. What should be done in the emergency.

In Glasgow and neighbourhood alone, in connection with various crafts, probably not less than one thousand injuries of the eye are received in one year ; and I do not think that I exaggerate the facts when I say that, about one-half of these might be prevented by the exercise of a due amount of care and the use of proper means. For example, a common class of injuries of the eye arises from the spurting of molten lead upon the face : A workman is in the act of pouring molten lead into a mould *not quite dry,* steam is instantaneously generated, and an explosion takes place, spurting the metal in his face, some of which gets into the eye. If such an one escapes with simply an impairment of vision he would be considered fortunate. A number of workmen are engaged in removing slag from the bottom of a blast furnace, in order to which they are blasting it with gunpowder. The furnace *not being quite cold* the powder explodes unexpectedly in the faces of the men, who are all, without exception, stooping over it. Their faces are scorched, and the eyes of all are completely destroyed, save one who recovers a partial amount of sight by an operation subsequently performed. A fruitful cause of injuries of the eye is from the throwing of "squibs" and other preparations of gunpowder, but which might be prevented by the prohibition of such articles being made, or, at all events, used in a crowded city. A young man is walking leisurely with his companion along a street, and is struck on the eye with a "squib," by which vision is instantaneously eclipsed. A boy is handling a preparation of ignited gunpowder; it explodes in his own face, permanently injuring one of his eyes, and deforming him for the rest of his life, by the impaction in his face of hundreds of grains of unexploded powder. But I might multiply instances without number in which, by carelessness or recklessness, vision of one or both eyes is destroyed.

As instances of neglect of the proper means of protection, are those injuries of the eye received by engineers, boiler-makers, iron-turners, chippers of granite and of millstones, &c., from a fragment of the metal flying from before the tool and striking the eye. The serious nature of such injuries will be at once apparent when I tell you that, in almost all cases in which a foreign body penetrates the eyeball, and in this class of artizans such injuries are very frequent, immediate and irreparable loss of the injured eye follows, and after some months the sight of the other eye sometimes rapidly follows in the train, from sympathetic inflammation. The loss of sight of the second eye arises from the intimate nervous union which subsists between the two eyes. Now, if this class of workmen, when "chipping" or "turning," were using "wire-gauze protectors," nearly all such injuries might be prevented. These protectors are no impediment to vision, and they do not require to be worn the whole day, but only during work which is dangerous; but there is such an antipathy to their use, sometimes by the "masters" or "foremen," at other times by the workmen themselves, that they are very seldom employed.

But when an eye is injured, what should be done in the emergency as a means of preserving the sight? If it is simply a "fire," as it is called, which adheres to the cornea, it may be removed at once by a fellow-workman. The upper and lower eyelids are to be raised and depressed by the fore finger and thumb respectively of the left hand, and with a pen-knife or cataract needle in the right hand, to detach the foreign body. In doing this no scraping is allowed, and in order to form a source of attraction to the foreign body at the same time, the needle or blade of the knife may be magnetized by drawing a magnet or loadstone along it several times in the same direction. A convenient magnet for this purpose is that in Faraday's magneto-electric machine.

When we intently gaze at an object, "winking" is not performed, and in these circumstances an insect, or fragment of unburnt coal from the funnel of a steamer or railway engine, may be projected "into the eye." When on the receipt of such an injury no foreign body is discovered upon the surface of the cornea, it will, in all probability, be found adhering to the inner surface of the upper eyelid. A popular and very good method for detaching and removing a foreign body from this situation is, for the person himself to grasp the eyelashes of the upper lid between the finger and thumb, to draw it down over the lower eyelid so as to make the one overlap the other, and then to allow the former, by its own resiliency, to regain its own place. By this means the eyelashes of the lower lid sweep the inner surface of the upper, and sometimes detach and retain the foreign body. If this is not sufficient a second party must *evert* the upper lid, which may be readily done in the following manner:—The two individuals facing each other, the operator taking a few eyelashes of the upper lid of the injured eye between the finger and thumb of the left hand. With a "tooth-pick," "bodkin," or other convenient instrument held in the right hand, he lays it across the lid, and draws the latter a little forwards, making pressure downwards with the instrument at the same moment. He then with ease tilts the edge of the lid upwards towards the eyebrow, exposing its inner surface, on which, if the foreign body exists, it will be readily seen, and may be detached by the same instrument that is employed to evert the lid.

But often the injury which the eye has sustained is of a far more serious character. A fragment of iron, stone, wood, or other substance, may have wounded the eye, or become embedded in one or other of its chambers; or the eyeball may have been pierced by a penknife, scissors, &c. What should be done at the moment? If much of the fluid of the eye escapes, the eyeball afterwards shrinks to a small nodule, vision of course being entirely destroyed; or the intraocular pressure being, by the escape of the fluid, suddenly removed, bleeding may take place into the interior of the eye, destroying vision which otherwise would have been saved. Or the iris may be floated into the wound with the escape of the fluid, if the wound is in the cornea, complicating the injury, and making the chances of recovery of vision more remote. Consequently, in any case in which the globe of the eye is penetrated, the retention of the *humours* is of the first importance. For this purpose the injured individual should be directed to keep his eyelids closed, and a bandage should be placed over *both* eyes, so as to keep the wounded eye at rest until medical aid is obtained.

Plasterers, slaters, and masons, often get "quick" or "slaked" lime "into the eye." Usually the first instinct on getting any foreign body in the eye is to rub the eyelids over the globe with the hand. This should be avoided. No time should be lost in removing every particle of the lime, especially if it be unslaked, as it is a powerful caustic, and quickly destroys the eye. After it is removed a few drops of any kind of sweet oil should be dropped upon the globe, and rubbed over its surface, through the medium of the eyelids.

VII. Noxious Habits which are prejudicial to the healthy condition of the Eyes.

(a) The smoking of tobacco is hurtful to the eyes in some constitutions. This substance contains a powerful poison, and when it is used, the effects of the latter must expend itself on some organ or organs of the body. The part so selected is often the conducting apparatus between the eye and the brain—the optic nerve—in which case the latter either partially or wholly fails to communicate the visual impressions to the sensorium. I have often seen nearly complete blindness produced by this cause.

(b) Intoxicating drinks, when excessively used, are often a cause of degenerative changes in the retina and optic nerve. We can readily acknowledge this, considering the great effects of those stimulating agents on the nervous system generally. What seems most strange, both with respect to the use of tobacco and ardent spirits is, that they manifest their evil effects on the eye, very frequently, not in those who use their eyes much, and who, therefore, we would expect to be most susceptible of diseases of the eye, but in those who seldom read or write. It must be conceded, however, that the use of tobacco and intoxicating drinks, especially whisky, generally go "hand in hand," and that the evil effects in such particular cases, may be attributable to the combined operation of both septic agents.

(c) Impure atmosphere, &c., as causes of disease of the eyes. It is hurtful to the eyes to live or sit long in an atmosphere charged with chimney or tobacco smoke. Such is sometimes the cause of very troublesome inflammations of the eyes. Many of the Laplanders and Greenlanders are blear-

eyed, which is said to arise from the smoky huts in which they live—the smoke of their fires only escaping through a hole in the roofs of their huts.

Filth, want of cleanliness, insufficient nourishment and clothing, in the poorer classes, are sometimes causes of inflammation of the eyes and eyelids, which, so long as such habits are continued, resist all medical treatment.

VIII. Atmospheric Influences and Contagion: as Causes and Means of Propagation of Diseases of the Eye. Reaction of Disorders of the System on the Eye.

Some inflammations of the eye are brought on by atmospheric influences. These may operate on a number of individuals in the same community and at the one time, which give such inflammations the appearance of being epidemic. I refer to the inflammatory affections of the conjunctiva. One particular element in the production of this class of diseases, and which we are able in some measure to guard against, is the sudden transitions of temperature which occur at certain seasons of the year, such as when the days are warm and the evenings cold. Another, is damp, foggy weather, especially if combined with lowness of temperature. With regard to the means of preventing such inflammations, a certain amount of care is necessary in avoiding exposure to the variations of temperature and unfavourable weather; and the precaution is doubly required in those who have already suffered from such inflammations of the eyes, for a first attack predisposes to a second. Cold sponging, which operates beneficially in guarding against cold to the body generally, is also beneficial in warding it off from the eyes. In using cold water for this purpose, it is not necessary to keep the eyes open in the water; it is sufficient if the forehead, temples, and eyelids, be well douched with it.

Certain of the ophthalmiæ are contagious, against which it is well for us to be on our guard. Generally speaking, every inflammation of the eye which throws off mucus or pus, is more or less contagious, the matter from which, if applied to the surface of a healthy eye, will excite in it the same disease. In all such cases a separate towel should be kept specially for the person affected. This precaution is especially necessary in a severe inflammation which sometimes manifests itself in infants about three days after birth. The disease referred to is characterised by great swelling and redness of the eyelids, and by a profuse flow of matter from the eyes; and if the disease is allowed to proceed unchecked the corneæ ulcerate, the humours become evacuated, and the eyeballs shrink to nodules, without the faintest hope of the restoration of sight. It often arises from washing the head with whisky immediately after birth, exposing the eyes to a draught of cold air, to a too bright light, or to the heat of a fire. The matter which exudes from the eyes is so contagious that, if the smallest quantity be communicated accidentally to the mother's or nurse's eyes, it will reproduce in a few hours the same disease in either of them.

Many diseases of the system, such as rheumatism, gout, scrofula, measles, and scarlet-fever, manifest themselves in the eyes as well as in other parts of the body. But, irrespective of these, which probably no care on our part can prevent, the eyes are sometimes sympathetically affected by general disorders of the system, very much under our own control. I have already pointed out that the sympathetic nerve, which has its origin in the neck, throat, and abdomen, chiefly expends itself on the walls of the arteries of the system, and that by this channel, organs very remote from each other sympathize both in their functions and disorders. The action of the sympathetic nerve on the arteries is to diminish their capacity, which force may be imitated by pricking, irritating, or galvanizing the nerve. The opposite condition is produced by agencies which depress the action of the nerve below its normal standard, such as may be accomplished by disease or sedative medicines. The caliber of the arteries which are distributed to the eye is, like that of the arteries of every other part of the system, governed by the sympathetic nerve; but besides the arteries, the muscular fibres of the iris which dilate the pupil are in dependence upon it also. Hence it is that an operation on the eye is sometimes succeeded by vomiting; and conversely irritation of the stomach, liver, or bowels, are the proximate causes of several morbid affections and sensations of the eye. Illustrations of the latter are styes, tumours of the substance, and inflammation of the borders of the eyelids, dimness of sight, flashes of light before the eyes, and other aberrations of vision. It would be impossible in a lecture like this to give the *modus operandi* of the morbid action necessary to the production of all these disorders. Let one illustration suffice—namely, the manner in which dimness of sight is produced by disorder of the stomach, liver, or bowels. The irritation produced by the latter is conveyed to the eye, as well as other parts, by the sympathetic nerve. The effect of this irritation is to diminish the amount of blood which flows through the vessels. The retina, which is the percipient membrane of vision, suffers from the sanguineous deprivation, the effect of which we know, from direct observation, to be dimness of sight. If the abdominal disorder continues, the dimness may remain stationary, but more probably it will increase, whereas by the removal of the primary disorder, vision again becomes acute.

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