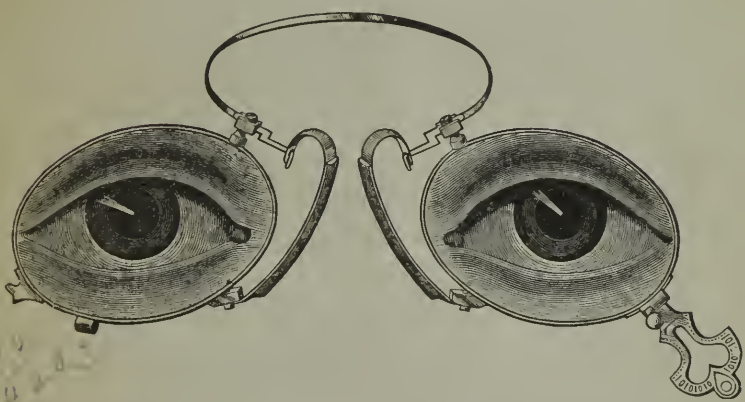
COMPLIMENTS OF THE AUTHOR.

THE EYE,

ITS REFRACTION AND ACCOMMODATION.



A Brief Description of the Mechanical Conditions which make Spectacles a Necessity.

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THE AIM OF THE AUTHOR is to produce a brief yet clear and comprehensive statement of the "mechanical conditions," normal and abnormal, which make spectacles a necessity, that shall be entirely free from all technicalities, and within the easy comprehension of all thinking readers, to many of whom that part relating to light and its refraction may seem unnecessary. I have added it for the benefit of those whose school education did not include this subject since its elementary details so completely underlie the whole subject of refraction.

Authors to whom the writer is indebted,

DONDERS. Accommodation and Refraction.
HARTRIDGE. The Refraction of the Eye.
VILAS. Spectacles and how to choose them.
BUFFUM. Diseases of the Eye.
JOHNSTON. Eye Echo, Practical Optics and Eye Studies.

INTRODUCTION.

Sight is the noblest of man's physical senses.

Taste occupies the humblest position among them.

A step above this we find the sense of feeling.

At the third step the delicate sense of smell confronts us.

Taking a fourth step brings us to a power of still greater value to us, the hearing ear.

At a fifth step, we reach the highest physical plain, and stand face to face with the sense of sight.

A hint of its supreme position among the senses, may be noted in the naturalness with which we speak of sight, as the agency of desiring facts really learned through the other senses.

For example, we say that the flavor is agreeable, the velvet soft, the odor pleasant, the sound melodious, and when a matter becomes clear to the judgment, we say, "I see the point," even the blind say "I see, I see."

The supremacy of the visual sense may be seen also by contrasting it with the other senses.

For instance, the palate can make no report as to taste till the flavored substance has passed within the lips. The sense of feeling can say nothing of an object till the latter has touched the nerves of sensation. The nostril can descern the fragrance of a flower at a distance very short. The ear can report upon the cause of a sound at a distance somewhat greater, and yet within limits very narrow.

But the eye, with its imperial sweep of glance, can peer through measureless space, and report upon the location of a fixed star.

This preeminence of the visual sense, and the almost entire dependence of civilization upon it, renders the eye an attractive and deserving subject of study. Each one has a personal interest in it, whether conscious of it or not, as every eye, sooner or later, will need the help of glasses, unless death closes it in early life.

As age advances, a gradual change in the structure of the eye invariably takes place.

This change involves loss of perception, and necessitates compensating aid, lenses properly ground and adjusted replace this loss.

Optical glasses then are necessary factors. In an enlightened civilization, the first knowledge of their value is generally attributed to Rodger Bacon, whose death occurred in 1292.

From that time until the present century, very little advancement was made. The use of them remained confined entirely to supplying the deficencies of the eye consequent on age.

During the last half century, and especially during the last few years, the subject has been carefully studied by men eminent in the sciences. Their researches have shown that a large class of troubles, heretofore numbered among the incurable, are readily amendable to treatment by spectacles alone. Diseases formerly allowed to go on for the want of a remedy, are now by their use promptly arrested.

Many who are totally unconscious that their vision is defective, are made to see far better than they deemed possible. Those who have been obliged to abandon occupations on account of poor vision, are now enabled to return to them.

It was but recently that the inheritance of an optical defect, was one of the most unfortunate of hereditary calamities. It is now known that these defects are purely mechanical, and that they can be corrected by the proper adjustment of spectacles, so that their effects will be entirely obviated.

No age is now implied by their use. They may be worn by anyone, young or old, for one or more of the many affections to which they give relief.

It is as useless to expect to do without them, for eyes impared by age, as it is foolish to attempt it.

The value of spectacles then to every one at some period of life, and the absolute necessity to many at all times, should do away with all prejudice against their use.

It is possible to do without them. It is also possible to do without books and schools.

The physiological change in the eye, consequent upon age, makes every person a present, or prospective wearer of glasses.

Those having a knowledge of the eye and of its structural changes, will realize the danger of postponing the fitting of them until sight has been impaired, or if they wear glasses already, to have them regularly refitted, as advancing years gradually modify their structure.

Every eye, even if normal, is subject to these structural changes. There are also abnormal structural conditions affecting a large proportion of our people. These abnormal conditions are usually inherited or developed in early life, and so require the early attention of an optician or oculist.

Children as well as adults suffer from these abnormal conditions. For this reason all parents and instructors, especially the latter, employed in our public schools should never be ignorant of optical defects of the eye, for by proper and timely advice they may be the means of relieving their children or pupils of much physical and mental suffering.

Many a pupil has been charged with stupidity and perhaps punished for idleness, who was suffering from defective vision, which if corrected would have placed them at the head of their class.

The brightest of students may be so hampered by errors of refraction "abnormal conditions," as to be classed with the dullest.

A child may hold its book too close, or push it too far away, or look askant at it. Round objects may look oval, straight lines irregular, or they may see "double," or differently out of the two eyes. If so, weak or painful vision or possibly cross-eye may be developed.

For these and other reasons, some of an urgent nature, we should all become familiar with optics.

To promote this end by giving needed information, and for the purpose of answering briefly a few of the many questions which we are frequently asked, we issue this little pamphlet, sincerely hoping that it may serve both of these ends.

LIGHT AND ITS REFRACTION.

Rays of light from an illuminated object diverge in all directions. They proceed or travel in perfectly straight lines, until deflected by some reflecting or refracting medium or are absorbed.

Opaque bodies absorb a portion of the light falling upon them. The unabsorbed light is dispersed or scattered by the numberless minute faces constituting the surface of that object.

These faces that disperse the light, lie at all possible angles of inclination to each other, and so scatter the light in all directions.

Without this property of dispersion, objects would not be visible. An object absorbing all light falling upon it, would be invisibly dark. Also a surface reflecting perfectly all light falling upon it, would be invisibly bright.

A ray of light, meeting with a body which it is able to pass through, may be bent or refracted, and all rays passing through a transparent medium into another of a different density, are bent or refracted, except the ray that falls perpendicular to the surface of the refracting medium.

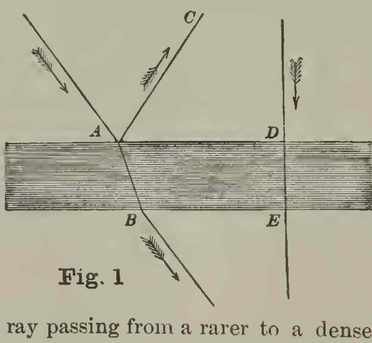

Fig. 1

For instance, a ray passing from a rarer to a denser medium, as from air to glass, is bent towards the perpendicular, (as shown at A Fig. 1), and in passing from a denser to a rarer medium, as from glass to air, it is bent from the perpendicular, as shown at B.

Reflection accompanies refraction, the ray dividing itself at the point of incidence into a refracted portion A B, and a reflected portion of A C.

A ray falling perpendicular to the surface as at D, passes through the denser medium without changing its course, and if the two sides of the refracting medium are parallel, as in the illustration, it passes into the rarer medium, as at E, without altering its course. But if the two sides of the refracting medium are not parallel, as in a prism, the ray cannot be perpendicular to more than one surface at a time. Therefore, all rays falling on a prism undergo refraction, and the deviation is always towards the base or thickest part of the prism.

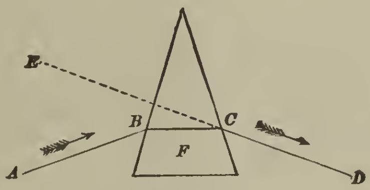

Fig. 2

Let A be a ray falling on a prism, "Fig. 2," as at B. It is bent towards the base of the prism, and on emergence it is again bent as at C. An observer placed at D would receive the ray as though it came from E. An object situated at A would appear to occupy the position of E.

It is this property of light called refraction that enables us to make what are called refracting lenses. It is also the means by which the eye is enabled to perform its function of making surrounding objects visible to us. Refracting lenses are made from but two difierent materials, glass and transparent stone called pebble.

Those used to improve vision are divided into three classes, prismatic spherical and cylindrical.

Prismatic lenses are wedge shape. (Fig. 2.)

Spherical lenses are segments of a sphere.

Cylindrical lenses are segments of a cylinder.

Spherical and cylindrical lenses are each divided into two classes, convex

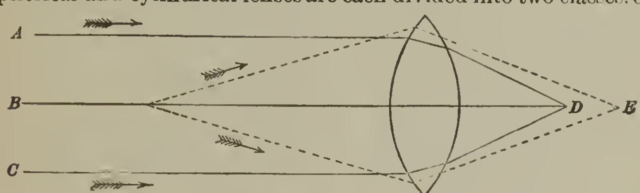

Fig. 3

or converging, and concave or diverging. A convex spherical lense, (Fig. 3) causes the rays that pass through it to converge to a point, as shown in the illustration at D. This point is called its focus.

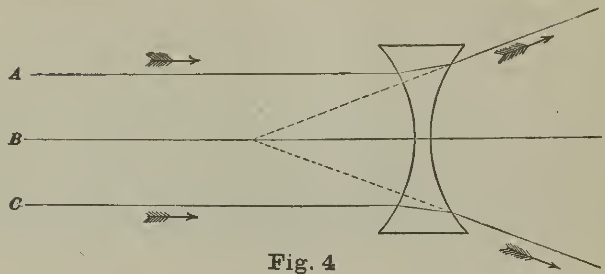

Fig. 4

A concave spherical lens (Fig. 4) causes the rays that pass through it to be divergent, as shown in the diagram.

The focus of a concave lens lies where the rays would meet if continued backwards, as shown by the dotted lines in the illustration.

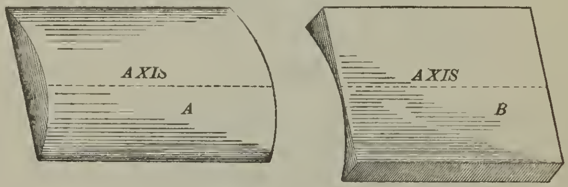

Fig. 5

A convex cylindrical lens (A, Fig. 5), causes the rays that pass through it to converge to a line parallel with its axis.

A concave cylindrical lens (B, Fig. 5), causes the rays that pass through it to diverge from a line parallel with its axis.

Spherical and cylindrical lenses may be looked upon as made up of a number of prisms with different refracting angles, convex lenses of prisms with their basis together, and concave lenses as prisms with their edges together. The refracting power of a lens depends upon the curves of its surface.

The more convex or concave their surfaces, the greater will be their refracting power.

A lens may be spherical on one side and cylindrical upon the other, or it may be spherical on one side, and prismatic on the other. Cylindrical lenses may be combined with prisms also. They are then called compound lenses. These different lenses and their numberless combinations, are used to increase or decrease the refracting power of the eye, and thereby improve and preserve its acuteness of vision.

Until recent years only spherical lenses were used for the above purpose. The great value of prismatic and cylindrical lenses and their combinations with sphericals not being known.

As before stated, rays of light proceed from all points of an object as divergent rays. All rays are then slightly divergent. The amount of their divergence is proportionate to the distance of the point from which they came, as illustrated in Fig. 6.

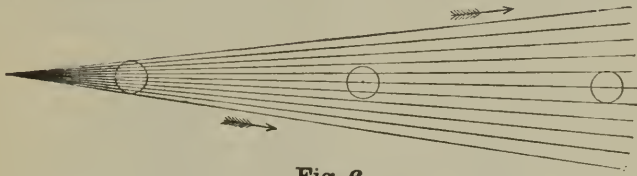

Fig. 6

The circles in the illustration, represent the pupil of the eye. It will be seen that the greater the distance between the eye and the object from which the light proceeds the more nearly parallel the rays are that enter its pupil. Rays of light coming from an object 20 feet or more from the eye, are assumed in optics to be parallel when they enter it.

Fig. 3 illustrates a convex spherical lens, the lines A B C represent parallel rays of light, "those from distant objects." The dotted lines represent divergent rays, "those from near objects." Now it is evident that this lens exerting the same amount of refracting power in both cases and being obliged in the case of the divergent rays to overcome their divergence, cannot cause the divergent rays to unite or focus at as near a point as it can the parallel rays so that the two sets of rays are caused to focus at D and E respectively. The point D where the parallel rays meet is called the principal focus of the lens. The point E where the divergent rays meet is called its secondary focus. If the object from which the light proceeds be located at D, the principal focus of the lens, the diverging rays from it after passing through the lens would emerge as parallel rays, the lens having just sufficient refracting power to overcome their divergence.

If the object be nearer the lens than its principal focus, then the rays will issue from the lens divergent, though less so than before entering it. Modern lenses are ground and numbered in dioptres.

One dioptre expresses a certain amount of refracting power. For instance the principal focus of a lens called one dioptre, lies at forty inches from the lens. In other words, a lens sufficiently convex to cause parallel rays of light passing through it to unite or focus at a point forty inches from it, is called one dioptre. Two dioptres, or twice the refracting power, will cause them to focus at one-half that distance. Four dioptres will cause them to focus at one-fourth, ten dioptres at one-tenth, etc. Two dioptres will then focus them at 20 inches, 10 dioptres at 4 inches, 40 dioptres at one inch, etc.

A concave lens of one dioptre causes parallel rays that pass through it to be as divergent as they would be if they came from an object only forty inches from the lens. Parallel rays after having passed through a five dioptre concave lens, would be as divergent as though they came from an object only eight inches distant, five being one-eight of forty inches, and ten dioptres would cause them to be as divergent as though they came from an object only four inches distant.

Lenses are also made which possess only one-fourth of a dioptre of refracting power, also those possessing one-half, three-fonrths and one and one-fourth dioptres, &c., &c.

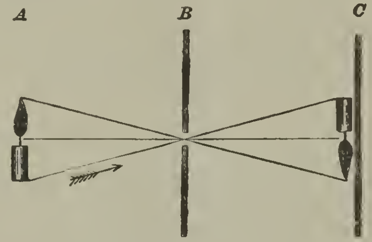

Fig. 7

Fig. 7 illustrates in a simple manner the formation of images.

On one side of a screen (B) having a small perforation in it, we place a candle (A) and on the other side a white cardboard (C) to receive the rays from the candle that come through the perforation.

The rays diverge from all points on the candle in all directions. Some fall on the screen and are intercepted by it, but a few rays from all points on it pass through the perforation and form an inverted image of the candle on the card-board. The image being inverted because the rays cross each other at the orifice as shown in the illustration.

Images or pictures are formed on the retina of the eye in the same manner as on the card-board. Visible objects represent the candle; the perforation in the screen the pupil, and the card-board the retina of the eye.

Simply speaking, the eye is a dark chamber with an opening or window at the front to admit the light. In form it is a globe, whose average diameter in an adult is seven-eights of an inch.

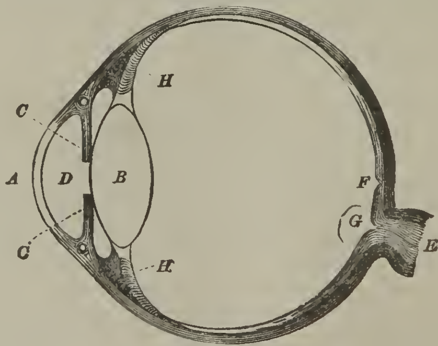

Fig. 8

In Fig. 8 we present a horizontal sectional view of it, showing the cornea at A, the crystalline lens at B, the iris at C, the pupil at D, the optic nerve at E. This delicate and highly sensitive nerve enters the eyeball at the back of the eye, and then spreads itself out all over the inner surface of the posterior part of the eyeball, and forms the retina or screen upon which the rays of light that enter the eye through the pupil form an image or picture of surrounding objects. At F is shown the macula lutea or yellow spot. This yellow spot is by far the most sensitive point on the retina. It lies directly back of the pupil. To have vision very acute, the rays must fall upon this particular spot. A line drawn from it to the cornea directly through the pupil represents the optic or visual axis of the eye. The length of this line would also represent the optical length of the eye.

The space between the cornea and the crystalline lens is occupied by a transparent liquid called the Aqueous Humor. That between the lens and the retina is also occupied by a transparent liquid called the Vitreous Humor.

Immediately behind the transparent retina is a layer of pigment, a substance which absorbs the light as soon as the picture is formed.

The space at G occupied by the optic nerve where it enters the eyeball is called the blind spot, there being no vision when the rays fall upon this particular space. This you can prove by closing your left eye, holding both thumbs side by side about twelve inches in front of the eye, and while looking steadily at the left thumb nail moving the right thumb a few inches to the right. the nail on the right thumb will be visible until the rays from it reach this blind spot, then the nail cannot be seen, but by moving it a little farther it again appears.

For distinct and accurate vision, the following conditions are necessary:

1st. That a sharply defined image be formed on the retina at the yellow spot.

2nd. That the impression there received be conveyed to the brain.

3rd. That the brain be able to receive and interpret correctly the impression transmitted to it.

When these conditions are all complied with, good vision is the result.

In a work of this character the first of these conditions alone concerns us, and for the carrying out of this, three important factors call for separate description, viz: *Refraction*, *Accommodation*, and *Convergence*.

REFRACTION.

This term is used to express the optical condition of the eye when in a state of complete repose. There are three refracting surfaces in the eye, the anterior surfaces of the Cornea, Crystalline Lens, and Vitreous Humor, and three refracting media, the Aqueous Humor, the Lens, and the Virtreous Humor. These acting together make up the refracting system of the eye, and may for the sake of simplicity be looked upon as forming a convex lens of about 45 dioptres or seven-eigths of an inch focus. What was said about convex lenses applies equally to the eye as an optical instrument. Every eye when at rest possesses a certain fixed amount of refracting power, which should exactly correspond with its length.

An eye is said to be normal when its length, through its visual axis, exactly corresponds with its refracting power, when that power is at rest. For instance, let us suppose that the diameter of an eye through its visual axis "from its cornea to its retina" measures exactly one inch. Such an eye to be normal must have, when in a state of complete repose, precisely the same refracting power as a convex lens of forty dioptres or one inch focus, no more or no less.

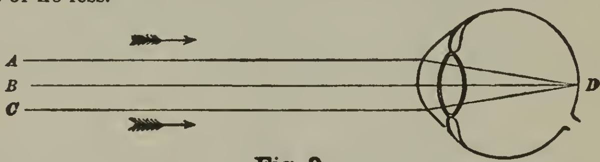

Fig. 9

Fig. 9 illustrates such an eye. The parallel lines, A B C, represent parallel rays of light. They are brought to a focus exactly on the retina as shown at D.

EM-ME-TRO-PI-A.

When the length of the visual axis and the refracting power, the eye being in a state of complete repose, thus exactly correspond, the eye is spoken of as being *em-me-trop-ic* or *in measure.* If the refracting power and the length of the visual axis do not thus precisely correspond, the eye is said to be *am-e-trop-ic* or *out of measure.* The retina then of an *emmetropic*, or normal eye, lies exactly at the principal focus of its refracting system. Parallel rays of light (those from distant objects) after passing through that system, are brought to a focus exactly on its retina. The focus of divergent rays (those from near objects) would then fall back of it, and unless the eye possessed within itself the power of bringing rays of different directions into union on the retina, near objects would not be clearly seen. An eye, during the spring time and summer of life, does possess this power. It is able to increase its refracting power, and thereby overcome the divergence of rays from near objects. This increase of the refraction of the eye is called *accommodation*, as it accommodates the refraction of the eye to rays that enter it at different angles.

This increase of the refraction, (accommodation), is brought about by the action of the ciliary muscles represented at H H, Fig. 8. These muscles by contracting change the form of the crystalline lens making it more convex, thereby increasing its refracting power. They do this instantly with marvelous perfection, increasing it just sufficient to overcome the divergence of the rays coming from the object looked at, no matter what distance that object is from the eye. In early life the crystalline lens is very elastic, so much so that a child by exercising its accommodating power can increase the refraction of its eyes to the extent of 16 dioptres. This enables it to bring very divergent rays to a focus on the retina, enabling it to see distinctly very small objects when held only two and three-fourths inches from its eyes. As age advances the elasticity of the crystalline lens diminishes, and in some cases the muscles that control it become less vigorous, so that by the time we reach the age of seventy the lens has become so firm that the accommodating muscles are unable to make any change in its form. All accommodating power is then lost. Donders, "our master," estimates that this power is diminished to the extent of about one-fourth of a dioptre each year.

At this rate we possess, at the age of ten years, about 14 dioptres of this power. At twenty years it will have dimished to about 10, at thirty years to about 7, at forty years to about 5, at fifty years to about 3, and at sixty-five or seventy years, all accommodating power will be lost.

According to these estimates the near point of distinct vision at the age of ten years would be at 3 inches; at the age of 20 it would have receded to 4 inches: at 30 to 6 inches; at 40 to 8 inches; at 50 to 14 inches; at 60 to 80 inches, and at 70 to anywhere beyond 20 feet. This hardening of the crystalline lens is perfectly natural, as much so as the hardening of the bones. It begins very early in life and continues steadily, becoming more and more solid as the years go by. This solidifying of the crystalline lens and through it the loss of accommodating power, cause the near point of distinct vision gradually to recede. When it has receded to about 8 inches the eye is said to have become *pres-by-op-ic*, or in other words *pres-by-o-pi-a*, "old-sight" has set in. The age at which the eyes assume this condition is arbitrarily placed at 40. Although vigorous persons do not as a rule notice its presence until the age of 45. At that age the accommodating power has been reduced to four and one-half dioptres. It requires the exercise of this power to the extent of three dioptres to overcome the divergence of rays from objects situated at the usual reading distance, "thirteen and one-third inches" from the eye.

As stated, an eye at the age of 45 possesses only four and one-half dioptres of this power. We then when reading at the usual distance, exercise two-thirds of the total amount remaining at that time. Under this tension the ciliary muscles soon become weary, pain or blurred vision will then ensue.

As a rule only about one-half of the accommodating power remaining at any one time can be exercised for sustained vision; fatigue soon resulting when nearly the whole of it is put in force, the ciliary muscles like all others soon tiring when exerted beyond a certain amount. The true function of the accommodating power is to increase the refraction of the eyes sufficiently to overcome the divergence of the rays from near objects.

Convex lenses act the same as this power; they increase the refraction of the eye and adapt it to near vision.

An emmetrope (a person with normal eyes), at the age of 70 will have lost all power of accommodation. His near point of distinct vision will have receded to about 20 feet. Objects at and beyond that point will be distinctly seen, no accommodative effort being necessary to focus parallel rays on the retina. When wishing to see clearly objects within that distance, he will be obliged to place in front of his eyes convex lenses of sufficent refracting power to cause the rays from the objects viewed to enter his eyes as parallel rays; they will then be brought to a focus on his retina and the objects will be clearly seen. If the object be 80 inches from the eye a convex lens of one-half of a dioptre will cause the rays from them to enter his eye parallel; if 40 inches a one dioptre will be required; if 20 inches a two dioptre; if 10 inches a 4 dioptre, &c.

While the refraction of an emmetropic eye can be increased by the accommodating power to the extent of three dioptres for sustained vision, no lens will be required. When but two dioptres of this power can be held in force, a one dioptre lens must be used; when only one dioptre is available a two dioptre lens will be required.

Thus it will be seen that just in proportion as the accommodating power of a presbyopic eye decreases, the power of the lenses must be increased. The distance at which persons read or work will determine the amount of this power required. For instance if they read or work at 16 inches, two and one-half dioptres will be required; if at 20 inches, two dioptres; if at 10 inches 4 dioptres, &c.

The symptoms which indicate a condition of presbyopia are first difficulty in reading fine print with artificial light, followed by a sense of strain in using the eyes for near work. Frequently the eyes become irritable and the lids smart or burn. These symptoms arise from the fatigue of the ciliary muscle resulting from the effort to maintain the accommodation at a nearer point than its power will admit. When the eye cannot sustain the accommodative effort necessary without weariness, and consequent eye strain, the relief to be obtained from convex glasses should not be delayed. In fact, the early use of glasses to relieve the strain results in giving comfort to the eye, retains the strength of the eye for the future, and at the same time lessens the rapid increase of the presbyopia. On the other hand, if the proper lenses are not used, the presbyopia increases more rapidly. Pain and discomfort are symptoms of a mis-fit.

An emmetrope cannot see clearly distant objects through the glasses that give him good near vision, for the reason that the refracting power of the lens added to that of the eye refracts the parallel rays so much that the focus falls in front of the retina.

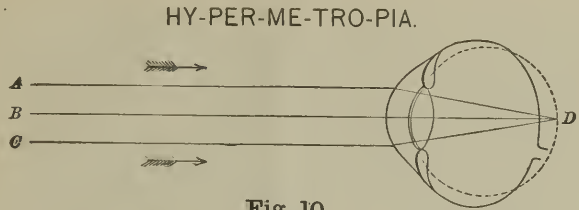

Fig 10

Fig. 10 illustrates a *hypermetropic* or far-sighted eye.

We have seen that the refracting power and the length of the visual axis of an *emmetropic* "normal" eye at rest exactly correspond. In this eye they do not thus correspond. The refracting power in a passive condition, that is when the crystalline lens has assumed its least convexity, is insufficient to focus parallel rays on the retina.

Hypermetropia may be defined as a condition in which the eyeball is so short through it visual axis, or the refracting power so low when the accommodation is at rest, that parallel rays are brought to a focus behind the retina as shown in the illustration, and the focus of divergent rays would fall still farther back of it.

We may say then that the retina of an *hypermetropic* eye lies within the principal focus of its refracting system, and that only convergent rays can be brought to a focus on it. All rays of light in nature are divergent; some so slightly so that they are assumed to be parallel. They can only be made convergent by means of accommodation or by a convex lens held in front of the eye. A *hypermetropic* eye then in a passive condition sees all objects indistinctly. Therefore, the accommodating power of this eye must be called upon when looking at distant objects, and still farther exerted when looking at near ones. Consequently the ciliary muscles of an *hypermetropic* eye are kept in a constant state of contraction, and the eye subjected to unceasing strain during waking moments, whether the hypermetrope is looking at a distance or near at hand, the involuntary persistence of the eye in trying to see clearly renders this inevitable.

A *hypermetropic* eye, having to use a part of its accommodation for distant objects, starts out with a deficit for all other requirements just equal to the amount of its hypermetropia. Thus supposing an individual hypermetropic to the extent of 4 dioptres and at the age of 35, possessing only 6 dioptres of accommodating power, he will, by exercising this power to the extent of 4 dioptres, be able to bring parallel rays to a focus on the retina, and so see distant objects clearly. This leaves him only 2 dioptres for near vision. This amount would only bring his near point to twenty inches, a distance at which he will be unable to do near work. He then suffers the same discomforts at the age of 35 that the emmetrope does at 50. It is clear then that a person suffering with hypermetropia will become prematurely *presbyopic*, and that he will be obliged to resort to glasses younger than an emmetrope. They usually require them one year younger for each one-fourth of a dioptre of *hypermetropia* that they possess. For instance a hypermetrope of two dioptres will be obliged to resort to glasses eight years younger than an emmetrope, and if his hypermetropia amounts to four dioptres, 16 years younger.

It is a fact however that he ought to wear constantly from childhood glasses that would neutralize his hypermetropia. Such glasses will increase the static refraction of his eyes sufficiently to produce artificial emmetropia. The accommodating power will then only be called upon when looking at near objects, allowing it to be at rest when looking at distant ones.

Such glasses will relieve him of a large amount of physical force, which would otherwise have been expended in accommodation. *Hypermetropia* is much more common than is generally supposed. It is looked upon as a congenital defect, being born with the child frequently; also it is hereditary, several members of the same family suffering from it.

Most people who have been obliged to resort to glasses early in life, suppose that they have weak eyes or that they have abused them while young.

The latter is often the case, but not the cause which made spectacles necessary early in life.

An examination usually discloses hypermetropia.

The only reasonable treatment for it is convex lenses. As a rule the most powerful ones through which distant objects can be clearly seen, are prescribed for constant use.

Where the hypermetrope is under 40 years of age the same lenses will usually answer for both near and distant vision. When presbyopia sets in a stronger pair will be required for near work.

An emmetrope at the age of 53, will have become presbyopic to the extent of two dioptres; he would then require a two dioptre lens to read with.

A person whose eyes are deficient in refracting power, "hypermetropic" to the extent of three dioptres, will require at the above age a three dioptre lens to compensate for this deficiency, and also a two dioptre lens for his presbyopia. He then, at the age of 53, requires a 5 dioptre lens to read with. Thus it will be seen that two persons of the same age may require widely different glasses.

Hypermetropes of any considerable degree, especially those whose occupation is such as to require the exercise of their accommodation for near objects constantly, as when reading or sewing, are liable to suffer from asthenopia, "weak and painful vision." They complain of dimness of sight, their eyes ache, water, &c. Frequently headache supervenes, and there is a feeling of weight about the eye lids and a difficulty of opening them in the morning. When the hypermetropia is of high degree, the patient may be said by his friends to be near-sighted, because when reading he holds his book close to his eyes.

They are also especially liable to convergent stra-bis-mus "cross-eye." Hartridge attributes 80 per cent. of this disease to hypermetropia alone. A few of the reasons why excessive accommodation produces the above results will be given under the head of convergence.

MY-O-PIA.

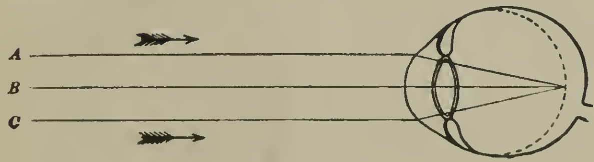

Fig. 11

Fig. 11 represents a *myopic* or near-sighted eye.

We have seen that the diameter of an emmetropic eyeball, through its visual axis, exactly corresponds with its static refraction, and that a hypermetropic eyeball is too short through its visual axis, for its refracting power. Just the opposite is the case with a *myopic* one, the eyeball being so long through its visual axis, that parallel rays are brought to a focus in front of the retina, "as shown at D in the illustration," and any exercise of the accommodating power only increases the error by bringing the focus still farther in front of it.

We may say then that the retina of a myopic eye lies at the secondary focus of its refracting system, and that only divergent rays can be focused as far back as it lies. This being true, objects must be brought close to the eye so that the rays from them will be divergent, the focus will then be thrown farther back, and if divergent enough onto the retina; near objects will then be clearly seen, and distant ones also will be seen, provided the rays from them be made divergent before they pass into the eye.

We are able to make them divergent by passing them through concave spherical lenses. Let us suppose that the refracting power of an eye, when at rest, is two dioptres too great for the length of the eyeball, the focus of parallel rays would then fall in front of the retina. This eye then would be *myopic* to the extent of two dioptres. Its far point of distinct vision would be at twenty inches, objects located that distance would be clearly seen. Now if we make the rays from distant objects as divergent as they would be if they came from an object situated only twenty inches from the eye, the patient will see the distant objects as clearly as he did near ones; or if his far point of distinct vision be ten inches we must make parallel rays as divergent as they would be if they came from a point only ten inches from the eye.

Thus it will be seen that a concave lens can be selected that will exactly neutralize the myopia, and that such a lens will place the *myopic* eye artificially in the condition of an *emmetropic* one, just as a convex lens will place an *hypermetropic* eye in that condition. The refracting power of one being increased, and that of the other decreased by means of the lenses.

As stated, the near point of distinct vision steadily recedes. This is true in all eyes, no matter what the condition of the refraction. It is also true that the far point usually remains stationary. This being the case, it will be seen that a *myope*, whose far point is thirteen inches or less, can never become *presbyopic*, that is he will never require glasses to see to read with. It has been stated that *hypermetropes* require glasses younger than *emmetropes*. It is also true that *myopes* will be able to read without them one year longer than *emmetropes* for each one-fourth of a dioptre of *myopia* that they possess.

Most people imagine that those who do not require glasses with advancing age have very strong eyes.

We frequently hear when inquiring into the family history of a patient.

Oh my father had excellent vision; he was able to read at sixty without glasses. This is proof positive that he had *myopia*, and always needed glasses for distant vision.

Persons having from three to four dioptres of *myopia* are able to read at a great age without glasses, their far point of distinct vision being situated at the usual reading distance.

Myopia in many cases has been inherited, but in a large majority of them it has been acquired. It is generally considered a disease, and in many cases it is a progressive one; that is the myopia increases with the age of the patient, it is then a source of great anxiety to him.

Hartridge says that in a great number of cases the factor which produces it is the prolonged use of the eyes on near objects, especially while young. Excessive convergence and the stooping position that many *myopes* take up, also tend to its production.

When once established it is very likely to advance.

The result of the very numerous statistics that have been collected recently, both in this country and Europe, point to its production in direct proportion to the amount of education.

We may set down myopia then as one of the results of civilization and in these days of high pressure and competitive examinations, it is constantly on the increase.

It is almost unknown among the savage races.

Erisman, a celebrated author, has come to the pleasant conclusion that if it increases in the same ratio as it has done in the past fifty years, in a few generations the whole population will have become *myopic*.

It behooves us then to do all in our power to control the onward march of the disease. The first object sought in its treatment should be to check its progress. To do this we must remove as far as possible the factors that produce it; such as looking at near objects too long at a time, taking up a stooping position, excessive convergence, &c.

We can best do this by compelling patients to wear glasses constantly that give them good distant vision. A new world will then be opened up to them, and they will devote a part of their time to looking at it. The glasses will also enable them to hold their book or work farther from their eyes. This is very important, as it does away with excessive convergence, a very potent factor in the production of this disease.

Myopes should never read in a poor light or in a railroad train. They should do as little as possible by artificial light, and should especially avoid stooping, a habit very common among them.

One prominent writer says that it has been noticed that in those who have worn glasses, that correct the full amount of their *myopia* from childhood; their *myopia* had generally remained stationary.

A-STIG-MA-TISM.

There is an abnormal structural condition affecting many eyes called *astigmatism*. So far we have been dealing entirely with the length of the eyeball through its visual axis, as compared with its static refraction. We have now to deal with the shape of its cornea.

As stated, the first condition necessary to good vision is that a sharply defined image be thrown on the retina at the macula.

All the rays of light that pass from an object through a perfectly spherical lens, are brought to a focus at the same point. At this point there would be thrown upon a screen a distinct image of the object from which the rays came. If the lens is not perfect, that is if it is not curved exactly alike in all its meridians, the rays would not all meet at the same point, some of them being refracted more than others, the image would then be indistinct.

The eye acts the same as a convex lens; so we see that if its cornea is not spherically perfect there cannot be a sharp clear-cut image thrown on the retina. The cornea of an *astigmatic* eye instead of being curved alike in all its meridians, is shaped something like the side of an egg or spoon bowl. This being the case, rays of light passing through the different meridians are not focused at the same point; those passing through the meridians most sharply curved, come to a focus before those do that pass through the meridian less sharply curved.

There is then no perfect image formed on the retina of an astigmatic eye, neither distant nor near objects being clearly seen, nor can any exercise of the accommodation overcome the difficulty.

Astigatism is always present in a slight degree but not enough practically to interfere with perfect vision. There are, however, many cases where the departure from the spherical shape is so marked as to render it impossible to see lines running in certain directions.

An *astigmatic* eye looking at a circle of radiating lines, (Fig. 12 on back cover) will see those running in certain directions more distinctly than the others. For instance, if the vertical lines "from 12 to 6" are clearly seen, the horizontal ones "from 9 to 3" will be more or less indistinct, according to the amount of the astigatism; or the horizontal lines may be distinctly seen while the vertical ones are blurred. Sometimes the oblique lines in one meridian are clearly seen, while those at right angles to them look gray.

An eye may be hypermetropic and astigmatic, or it may be myopic and astigmatic; that is it may be too short or too long, and have an irregular curved cornea also. This makes five varieties of astigmatism possible. They are called simple and compound hypermetropic, simple and compound myopic and mixed astigmatism. In the simple hypermetropic variety one set of rays, we will assume those from the vertical lines, are brought to a focus on the retina, while those from the horizontal lines are focused back of it. The vertical lines will then be distinctly seen, and the horizontal ones will look blurred.

This eye then would be emmetropic in one meridian and hypermetropic in the other. For this reason it is called simple hypermetropic astigatism.

If this eye had been too short through its visual axis in addition to its having an irregular curved cornea, it would have had compound hypermetropic astigmatism. It would then have been hypermetropic in both meridians, but more so in one than in the other.

The simple and compound *myopic* varieties may be explained in the same manner: It being understood of course that the focus falls in front of the retina in the myopic varieties, instead of back of it as it does in the *hypermetropic*. In the mixed variety the focus of the rays in one meridian falls back of the retina, while those in the other fall in front of it.

In this variety the cornea is curved too sharply in one meridian and not sharply enough in the other. This makes the refracting power insufficient in one meridian and excessive in the other.

The latter variety, we are happy to state, is comparatively rare, the others are quite common. Simple astigmatism requires for its correction a cylindrical lens; that is one which, instead of being the segment of a sphere, as is a spherical lens, is a segment of a cylinder. It may be either concave or convex, and the result upon rays will be that those which pass through the cylinder parallel to its axis undergo no refraction, all other rays are refracted; those most so which pass at right angles to the cylinder. It thus possesses the power of exactly neutralizing the astigmatism.

Compound cases require for their correction compound lenses; that is a lens ground spherical on one side and cylindrical on the other. The axis of the cylinder must always lie exactly parallel with the meridian of greatest or least refraction as the case requires. The mixed variety can also be corrected with compound lenses. Persons suffering with astigmatism must have glasses made purposely for them, there being no two cases exactly alike, even companion eyes usually differ. If the refraction is the same in both of them the meridian of greatest or least refraction would hardly be at the same angle in both. Therefore, spectacles must be made especially for each case.

Compound cases may be partially corrected with plain spherical lenses. For instance, let us suppose an eye hypermetropic to the extent of two dioptres in the horizontal meridian and three in the vertical. A two dioptre convex spherical lens will bring forward the rays in all meridians two dioptres. The meridian of greatest refraction (the horizontal) would then be corrected, the other also to within one dioptre. The astigmatism would then be reduced by the convex lens to the simple variety. This must be corrected with a cylinder. Astigmatism is the commonest of all the refractive errors, and yet it is the least understood of any of them. Persons suffering from it to any extent complain of poor vision and pain in and about their eyes. Headache is also quite a marked symptom of it. They are always trying to procure glasses that will give them good and comfortable vision, but are generally unsuccessful, because dealers in spectacles, as a rule, are as ignorant of this abnormal condition of the refraction and of the means used to detect and correct it as are the persons seeking its correction.

Correctly fitted glasses are of great and lasting benefit to all those so unfortunate as to be sufferers from this abnormal structural condition.

CONVERGENCE.

There is a factor in bi-nocular vision, "vision with both eyes," called convergence. It is the power of directing the visual axis of both eyes toward the same object so as to have the retinal images formed upon the yellow spot in both of them. This produces bi-nocular or singleness of vision, diplopia or double vision at once resulting when the image of an object is formed on parts of the retina which do not exactly correspond in the two eyes. Convergence is brought about by the action of the internal recti or converging muscles.

When these muscles are completely at rest, the visual axis of the eyes lie practically parallel. The eyes are then adjusted for distant vision.

The converging and accommodating muscles are very intimately connected, so much so that usually for every increase of the convergence, a certain increase of the accommodation takes place.

For instance when the eyes converge to a point, say ten inches from the eyes, they also accommodate for that point. Four dioptres of convergence and four of accommodation are then put in force.

Thus it will be seen that it is natural for these muscles to act in unison. This is true in cases of emmetropia only, as will be seen by the following: When an emmetrope (a person with normal eyes) is looking at distant objects, his converging and accommodating powers are both at perfect rest; when looking at near objects, these powers are exercised equally.

When a hypermetrope is looking at distant objects, he is obliged to exercise his accommodation, yet his convergence must be held passive, and when looking at near objects his accommodation must be used in excess of his convergence.

When a myope is looking at near objects, the eyes must converge to them, yet no accommodating power can be exercised.

Thus it will be seen that the ocular muscles of ametropic eyes are subjected to an unnatural and unceasing strain during waking moments.

This unequal tension to which they are subjected causes asthenopia, "weak sight," stra-bis-mus, "cross-eye," headache, dizziness, and many other ocular troubles, nearly all of which can be relieved or permanently cured by wearing properly adjusted spectacles. The refraction is not always the same in both eyes; one may be *hypermetropic* the other *myopic;* or if they are both *myopic* one may be so to a slight degree while the other may be to a very high degree.

When this is the case, good bi-nocular vision without correction would hardly be possible. Such eyes are especially liable to strabismus. In fact any cause which renders the image less distinct in one eye than it is in the other is likely to produce it.

Of strabismus we have four varieties convergent or internal. Divergent or external, sursumvergent or upward, and deorsumvergent or downward.

Of these the most common is convergent, it usually appears between the age of three and five years. At first the squint is only periodical, but it soon becomes permanent.

Bi-nocular vision is far more acute than mo-nocular or "vision with one eye only." There is then a stimulant in the former to hold both eyes in their proper position.

When this stimulant from any cause does not exist, one eye is liable to stray. Straying eyes for want of use, especially those of children, gradually and often rapidly become am-bly-o-pic, "sightless." The brain soon learning to suppress the image formed upon the retina of the straying one.

Anxious parents often attribute strabismus to something that the nurse has done, or possibly hold the child itself responsible for it, which is all wrong. In nearly all cases it is errors of refraction, which if corrected in time the strabismus will correct itself.

All children suffering from this disfiguring and sight-destroying defect who are too young to wear glasses, (under three years), should have the true eye covered up for a few hours each day, they will then be compelled to use the straying one. Its vision can thus be preserved until the child is old enough to wear glasses.

Nearly all cases can be cured by wearing them.

If glasses do not improve the condition, an early tenotomy (separation of a tendon) should be resorted to.

This operation is performed in a few moments; it is accomplished without pain or the use of chloroform or ether.

The necessity for early treatment in these cases arises, not for the relief of the deformity, but to preserve the eyesight.

SPECTACLES AND EYE-GLASSES.

Persons with emmetropic "normal" eyes require no glasses until presbyopia, "old sight," sets in, and then only for near vision. Their eyes should receive the aid that lenses afford as soon as fine print cannot be seen distinctly at the usual reading distance, and as the eyes gradually loose their accommodating power, the lenses should be replaced by those of greater strength. It is a good plan to use the old ones for day and the new ones for night work, lenses a little stronger than would be comfortable by day-light being required when using artificial light. Emmetropes rarely need glasses for distant vision. Every eye is subject to the physiological changes that produce presbyopia. It is not an error of refraction but simply a loss of accommodative power due to a hardening of the crystalline lens.

Hypermetropia, myopia and astigmatism are optical defects due either to deformities of the eye-ball or irregularities in the refracting media. These anomalies cause errors of refraction.

Persons suffering from any one of these to any considerable degree should wear glasses from childhood, not alone for the purpose of making them see well, although good vision is almost priceless, but mainly for the purpose of improving and preserving the acuteness of their eyes and relieving them of the many troubles these errors produce. The acuteness must not be confounded with the refraction, for an eye may be very defective in its refraction and yet have an acuteness of vision equal or perhaps superior to normal. An individual may see very poorly without glasses and yet exceedingly well with them.

Acuteness of vision must be defined as that degree of sight which an eye possesses after any error of its refraction has been corrected.

Cheap, poorly-made or ill-fitting spectacles should never be worn; they may distort the rays of light, disturb the angles of vision, cause pain and discomfort and injure the eye-sight. Lenses to be perfect should be made of pure white crown glass, with acurate curvatures and highly polished surfaces. They should be mounted in light, well-tempered frames that fit the face perfectly; they will then rest easily yet firmly on the head and look well, "an essential feature." The bridge must suit the nose and be of such a height and length that each eye shall look exactly through the center of its glass. It is quite as essential that the frames fit the face perfectly as that the proper lens be selected.

Spectacle frames should be made of fine, well-tempered steel or gold Eye-glass frames may be made of gold, steel, rubber or zylonite.

Please remember that lenses are made from but two materials viz: glass and transparent stone, called pebble, those made from pure white crown glass are preferred by most opticians as they refract the light more regularly than pebble lenses.

There is no such thing as medicated or electric lenses. I should also beware of those offering *diamantie or para bola* spectacles, Bohemian crystals, eye clearers, &c., &c.

These high sounding names are all nonsense, they are used for purposes of deception only.

There is no peculiar kind or particular make of lens or spectacle that can be especially recommended. (Popular opinion and flowery advertisements notwithstanding) the result always desired, is good and comfortable vision. The selection of a lens of the correct refracting power, and the proper adjustment of it before the eye, have far more to do with arriving at the above result, than the name by which the spectacle goes, or the material used in its manufacture.

If we do not see well at all distances, something is wrong, and if possible that wrong should be righted.

When the eyes are treated fairly, they are strengthened, not weakened by work, just as the arms of a blacksmith grow stronger for his trade, so the eyes of all those who work under healthy conditions, are found to improve and not deteriorate in vigor and quickness.

It is the abuse of the eyes, not their use, which is to be avoided. If a man is aware either that his eyes need no artificial correction, or that they have received the proper adjustment, and if his work be literary or mechanical and is done in a light both steady and sufficient, and with due regard to ordinary sanitary rules, he may feel sure that he is strengthening his eyes not weakening them by hard work. Men of intellectual pursuits sometimes are afraid of losing their mental power in old age because they have drawn so much upon it when young. The reverse is nearer the truth, and if they have not overtaxed the brain, the fear is absolutely groundless. The man whose intellect goes first in old age, is generally some one who has never strengthened and invigorated it by use, not the tireless student. So with the eyes, those who have strengthened them by using them properly keep keen sight longer than those who have never trained them. In short if people will only learn to use their eyes wisely, there is no reason why mankind should not increase, rather than lose their power of seeing.

Many persons who evince a decided repugnance to wearing an ill-fitting garment, select their own glasses without a thought as to their appearance or of the danger of ill-treating an organ whose mechanism is of the most delicate nature and whose use to most is as valuable as life itself.

It must not be inferred that I think that all suffer from such a course but that many do there is no doubt. An emmetrope may possibly with safety select his own glasses but it must be remembered that emmetropia in a strict sense is very rare. It is now recognized by every thoughtful physician that the fitting of glasses should be intrusted only to a thoroughly practical and painstaking optician or an oculist.

It requires great skill and experience together with a complete set of instruments and a thorough knowledge of optics, and the eye, to correctly fit any case of astigmatism, and I might say any case where errors of refraction exist, there are many ways of measuring these errors open to a specialist or practical optician.

The ophthalmoscope in skillful hands furnishes several; with it all of the anomalies of refraction may be correctly measured; with it children from three to six years of age may be correctly fitted. This is very important as it is at about this age that strabismus, "cross-eye," is developed.

With the ophthalmoscope a thorough examination of the interior of the eye can be made. This is also important as diseases may be discovered that would otherwise have been overlooked.

A complete set of test lenses when properly used in connection with Snellens' standard test types also furnish important factors in arriving at correct results. An individual possessing normal vision will be able to see distinctly the large letters on back cover at a distance of 20 feet, a few people will be able to see them at a distance of 25 feet, they possess an acuteness of vision 25 per cent. in excess of the standard as adopted by our schools of ophthalmology.

If 15 feet be the greatest distance that an eye can see them clearly, 75 per cent. would represent its acuteness of vision; if 10 feet, 50 per cent. &c.

If all the lines in the dial are not clearly seen, that is, if they do not look equally black when viewed from a distance of 10 feet, astigmatism exists.

Test your eyes and those of your friends, hold a card over one eye while you test its companion. Do not close one eye. If your eyes are defective, vision poor or painful, or if you wear glasses and they do not give you good and comfortable vision call at my office and have your eyes examined.

You will there find a complete assortment of superior spectacles and eye glasses suitable for presbyopia, hypermetropia and myopia, in gold, steel, rubber and zylonite frames in all the various styles, shapes and sizes. We also make to order everything needed by those who cannot be correctly fitted with regular goods. Our stock of colored glasses, shades, eye glass, chains, hooks, repairs, &c., will always be found complete. Devoting as we do our entire time and attention to the optical business, we believe that we can make it to your advantage to call upon us when in need of anything in the optical line. We make no charge for examinations and guarantee satisfaction. Our prices shall always be as low as those of any responsible dealer in these goods.

Defects of eyesight requiring correction by the use of spectacles are purely mechanical, and can be so corrected by the proper adjustment of perfectly made lenses that their efforts will be entirely obviated.

The smallest size letters on this page should be read easily at fifteen inches from the eye. If you cannot do so you should wear spectacles. It does not pay to buy cheap spectacles. They distort the rays of light, disturb the angles of vision, cause pain and discomfort and injure the eyesight. When it is necessary to hold work or reading matter farther than fifteen inches from the eyes in order to see distinctly, it is a sure sign of failing vision, and much annoyance.

Discomfort and pain will be prevented by having a pair of glasses fitted. Pain in the eyes when wearing spectacles is usually caused either by improperly fitted lenses, or from the centres of the lenses not corresponding with the centres of the eyes. To be perfect, a lens must be made with highly polished surfaces of accurate curvatures. Our lenses are the best in the market. They are made from the clearest and finest material obtainable and are warranted to be of absolutely perfect construction.

V T F B N L C D E S
M O H A G K Z R P W

TEST TYPE.

An eye possessing normal vision will be able to see distinctly the letters at the top of this page a distance of ten feet, and those at the bottom of the page will be clearly seen a distance of twenty feet.

Fig. 12

ASTIGMATISM.

If some of the lines in the above figure appear more distinct than the others, when viewed from a distance, the presence of astigmatism is indicated. This defect can only be corrected by cylindrical lenses, carefully ground to the optician's order. (See Page 18.)

F A E L Z B P O
R T N G H U V K