A S T I G M A T I S M.

T H E S I S F O R T H E D E G R E E O F M.D.

1894.

HARRY VALENTINE McKENZIE.

M.B., C.M., (1890).

(U)

H I S T O R Y.

The fact that certain defects of vision can be corrected by optical appliances, is one that has been known from very remote antiquity. It is stated that spectacles were commonly worn in England during the reign of Richard II., but in many Eastern countries such as China, their general adoption had been effected several centuries prior to this. The glasses, however, used for the particular error of refraction we are about to study, are quite a modern development; their introduction dates from the beginning of the present century.

It was in 1801, that Dr Thomas Young drew the attention of the scientific world to a peculiar defect of his eyes. He tells us, that his "eye in a state of relaxation, collects to a focus on his retina, those rays which diverge vertically from an object at the distance of ten inches from the cornea, and the rays which diverge horizontally from an object at the distance of seven inches." Still, although he realized the fact that his eyes were malformed, he did not advance our knowledge. Moreover, though a glass was ground to correct his malady, it was not at his suggestion; nor did he seek to establish whether the anomaly were common or the reverse.

From his description it is evident that the refractive error in Young's case was an example of what we now know as Normal Myopic astigmatism.

A few years later, Prof. Fischer[2], in a letter to Gerson drew attention to the same defect in his own case. He, unlike Young, whose visual powers were not disturbed, described how his vision was distinctly diminished. When he looked at a sign-board over a shop, the board appeared more or less double, the one image standing out in bold relief, and the other displaced vertically upwards, and appearing incomplete. But apart from drawing attention to the condition, Fischer like Young, whose works were unknown to him, added no more to our knowledge.

Sachs[3] in his article on albinism incidentally mentioned the fact, that he had another fault not usually associated with the absence of pigment. From his description he evidently suffered from Hypermetropic Astigmatism.

The next case of Astigmatism, that we come across, was in the person of a M. Cassas[4], an Historical Painter, who was greatly distressed, because he could not delineate horizontal lines with the same clearness as vertical. During the course of his travels, he asked every physician and optician he met, if they could remedy this defect; it was not, however, till over twenty years had elapsed, that in 1840, an optician at Rome, Suscipi by name, made glasses for him.

Purkinje[5], wrote on this subject in 1825. He remarks, that the images of diffusion on the retina do not enlarge and diminish regularly in every direction, but in determined ones, and it is especially in these directions that they become double and even sometimes multiple. His experiments on pressure of the cornea, and its influence, are of considerable interest. Thus he tells us, that a person can be made astigmatic by pressure on the cornea from above, and from one side; or if already astigmatic, this can be partially relieved by a similar procedure, or by narrowing the palpebral aperture. Two of his figures, more or less modified are in common use to-day for testing the existence of astigmatism; viz: his rings of concentric circles, and his star-shaped figure formed by numerous lines converging to a point.

No one so far had given any indication how this defect could be remedied; several observers as we have seen had drawn attention to it, but none had been bold enough to suggest a means for its correction. In 1827, Mr Airy, the Astronomer Royal, detected astigmatism in his left eye. He did not rest content with mentioning the fact, but went a step further, and gave us a method by which the amount of the astigmatism could be measured; and also devised the peculiar form of glass necessary for its correction. To him, undoubtedly belongs the honour of being the first to indicate

cylindrical glasses, now so universally used, for remedying this anomaly. How he was led to the discovery, and his reason for adopting the cylinder are of considerable interest; no apology is, I think, necessary for giving a detailed account of his case. He described his own defect as follows:-

"Two or three years ago, I noticed that in reading I did not usually employ my left eye, and that in looking carefully at any near object it was totally useless. Supposing this to be entirely due to habit, and that it might be remedied by using the left eye as much as possible, I endeavoured to read with the right closed or shaded, but found I could not distinguish a letter, at least in small print, at whatever distance from my eye the characters were placed. Some time after, I observed that the image formed by a bright point (as a distant lamp or star) was not circular as in the other eye, but elliptical, the major axis making an angle of 35^{o} inclined to the right. Upon putting on concave glasses by which I saw distant objects distinctly with the right, I found that to the left a distant lucid point appeared as a well-defined line, corresponding exactly in direction, and nearly in length to the major axis of the ellipse. I found also, that if I drew upon paper two black lines at right angles, and placed it in a proper position, and at a certain distance from the eye, one line was seen perfectly

distinct, while the other was barely visible; upon bringing the paper nearer to my eye, the line that was distinct now disappeared, and the other was seen very well-defined. The refraction of the eye, therefore, was greater in the plane nearly vertical, than in that at right angles to it and that consequently it would not be possible to see distinctly with lenses of spherical surfaces. I found indeed, by turning a concave lens obliquely, or by looking directly through a part near the edge, I could see objects without confusion; but in both cases the distortion produced by their figure was such, that I could not hope to make any use of my left eye without some more effectual means. My object was to form a lens which should refract more powerfully the rays in a certain plane than in those at right angles to it, and my first idea was to employ one whose surfaces should be cylindrical and concave, the axes of the cylinders crossing at right angles and their radii being different; but for facility of grinding, and for diminution of the curvature, it appeared to me to make one surface cylindrical, the other spherical, both concave. To discover the necessary data, I made a very fine hole in a blackened card, which I caused to slide on a graduated scale, then strongly illuminating a sheet of paper, and holding the card between it and the eye,

I had a lucid point upon which I could make observations with great ease and exactness. Then resting the end of the scale on the cheek bone, and sliding the card on the scale, I found the point at the distance of six inches appeared a very well-defined line inclined to the vertical about 35^{o}, and subtending an angle of 2^{o} (by estimation); at the distance of three and a half inches, it appeared a very well-defined line at right angles to the former, and of the same apparent length. It was necessary, therefore, to make a lens, which, when parallel rays were incident, should cause those to diverge from the distance three and a half inches, and those in another plane from six inches."[6]

After some ineffectual efforts this lens was ultimately made for him, by Fuller of Ipswich, to his entire satisfaction. Twenty years later, Mr Airy[7] says, that although his Myopia had increased, his astigmatism had remained unaltered.

A few years after Mr Airy's publication, we hear of a case in New York, which so far as one can gather, is the first case reported from America. It occurred in the person of the Rev. Mr Goodrich;[8] he had been "short-sighted" all his life, but he noticed he had something further wrong with his eyes. Thus when he wore his distant correction (concave

spherical glasses), he perceived, that objects in a horizontal plane were much more clearly defined than those in a vertical; the yards of a ship for instance standing out in far bolder outline than the masts. With the help of a working optician he managed to get cylinders ground on to his spheres, but they do not seem to have given perfect satisfaction, as the clergyman after wearing them for some time laid them aside.

In 1849, Dr.Goode[9], a Cambridge practitioner, speaking on the subject, says, "About ten years ago, I noticed a defect of vision in my right eye, the defect being that small objects, when viewed at the distance of greatest distinctness, appeared as two. My attention having been drawn to Prof. Airy's paper, I find, that my eye tested in the manner he proposes, exhibits a similar defect; the left eye is good."

By a slightly modified form of Airy's method, he corrected his astigmatism, and wore the glasses with marked comfort to himself and benefit to his vision. Beyond the mere mention of the fact, that he had met with five other similar cases, and a suggestion as to the possible hereditary nature of the complaint, he does not further discuss the matter.

The next case we hear of, is from the Continent, and is an example of the rarest of all the forms of astigmatism.

Schnyder[10] of Mensburg, Canton of Lucerne, detected that he was hypermetropic for horizontal lines and myopic for vertical lines. He did remedy the defect, though by a very cumbersome and awkward appliance. The employment of two pairs of spectacles appeared to him the best means of overcoming the anomaly; the one pair consisting of biconvex cylinders, with their axes horizontal, the other of biconcave spheres.

The first reported case from Scotland, came under the notice of Dr Hamilton[11], of Edinburgh. The patient, a painter by trade, who also suffered from congenital night blindness, had found considerable difficulty in defining objects in a vertical plane; as for example, the hands of a clock when they pointed to twelve or six. As this greatly interfered with his occupation at times, he had learnt to resort to certain contrivances, by means of which he could overcome the difficulty. One of these that greatly improved his vision, was an inclination of the head to one or other side; another was to gently pull the lids outwards, at the same time exerting slight pressure on the globe, this converted the palpebral aperture into a chink or slit, the pressure no doubt altering the shape of the cornea. Both devices, as we shall see later on, have a considerable influence in ameliorating the more obstrusive symptoms of astigmatism.

Hitherto, cases had been reported in a sporadic fashion, and with apparently no other object in view, than the mere narration of what were supposed to be rare pathological phenomena. But M. Goulier, in 1852, put a different phase on the subject; unfortunately he does not get as much credit as he deserves, for before he could obtain sufficient evidence to justify the publication of a monograph, Donders' admirable work appeared. Still, to M. Goulier[12] belongs the credit of being the first, who sought to establish the frequency of astigmatism, and who systematically corrected it by means of cylindrical glasses. How thoroughly he worked at this subject, and the observations he deduced from his study, can be seen by a glance at his following axioms:-

1. This defect is almost general.

2. It constitutes in the case of a great many, a defect more or less grave, which interferes with vision, and which is not oftener corrected from ignorance of its real nature.

3. It can be easily enough remedied by glasses of a peculiar form.[12]

Among other facts he states, how astigmatic persons can see better by inclining the head to one side; by looking through the periphery of a spherical glass, rather than through the centre, by tilting spherical glasses, by holding

objects very close to the eye so as to get magnified images at the expense of clearness of definition.

Five years later, (1857) Knapp[13] read his researches on astigmatism at the Ophthalmological Congress at Heidelberg, and five years later still Donders' work "Astigmatismus und Cylindrische Glasser" appeared, and the subject was now advanced from one of mere fanciful theory to that of practice. These two observers, who may truly be called the "Fathers of astigmatism", placed the subject on a scientific basis, nay they did more, so completely did they work out the details that for years all the literature on the subject was more or less a repetition of their views, and even at the present day what they then formulated has not been materially advanced upon. Advance there undoubtedly has been, but one cannot but be struck on reading Donders' "Anomalies of Refraction and Accomodation"by the masterful way in which he elucidates the subject, and further by the fact that although nearly thirty years have elapsed since the appearance of his work, little new material remains to be added to what is there written.

At this point, one might almost bring the history of the subject to a close, but one can scarcely do so without referring to the various conjectures as to its cause assumed by the early writers.

Young[14] considered the cause in his case to be an obliquity of the cornea and lens with regard to the visual axis; and he rather inclined to the belief that his lens was more at fault than his cornea, for he noticed that his astigmatism remained when his corneae were immersed in water. He surmised that under these conditions, the refraction of the cornea could be ignored. Only would this be the case if the index of refraction of water and of the cornea were the same; but as we now know these indices are not identical, therefore his experiment proves nothing.

Purkinje[15] believed the phenomena of astigmatism depended on a change of curvature of the cornea, especially a flattening of this structure. This as we shall see is approximately the predominant cause, yet it was a mere guess on his part.

Airy refrained from giving any opinion as to its possible cause.

Goode[16] says, in cases of highly developed astigmatism he failed from the form of the reflected image to detect asymmetry of the cornea. He inclined to place the seat of the defect in the lens.

Prof. Thomson[17] examined Dr. Hamilton's case. Although he could arrive at no conclusion as to which of the refracting media were at fault, he found from the measurement of the base of the cornea, that it was slightly greater vertically

than horizontally; its shape being somewhat irregular, and its diameter projecting slightly upwards and outwards. Prof. Thomson thought he perceived a somewhat more marked curvature in the transverse diameter.

Wharton Jones[18] and Wilde[19] went still further. Without more accurate investigation they assumed that the foundation of astigmatism was really to be sought in the cornea, but as the sequel shows, this was mere assertion on their part. Both put it prominently forward as an established fact, that the cornea in its vertical meridian had a shorter radius of curvature than in the horizontal. So far as one can gather previous to their communication, the radius of curvature of only one cornea had been determined in the vertical and horizontal directions, viz., by Senff.[20] In this instance the radius was found scarcely shorter in the vertical meridian than in the horizontal.

How little importance was to be attached to one observation appeared from the investigations of Knapp.[21] This observer measured a series of sixteen Physiological and nine Pathological corneæ, by means of Helmholtz's Cphthalmometer, and he was led to the belief that the radius of the cornea was greatest in the vertical meridian.

This was disproved by the more extended series of measurements by Donders[22] and Middleburg, who found that the

horizontal meridian of the cornea usually has the longest curvature.

D E F I N I T I C N.

Astigmatism, being derived from the Greek A, and stigma a point, would therefore signify without a focus. This name was given to the condition by Prof. Whewell of Cambridge in 1854, and although it is not a good one, it has so long been associated with the anomaly, that no good purpose would be served by inventing a new term.

Astigmatism may be defined as that condition, in which a point is not focussed on the retina as such, but as a line, circle, or ellipse; according to the length of the antero-posterior diameter of the globe. This is brought about by the cornea, which instead of being the segment of a sphere to which it more or less approaches in normal eyes, is the portion of an ellipse. The cornea, however, does not correspond accurately to an ellipse, it is more ellipsoidal in shape with three unequal axes, viz., the optic axis, the axis of the vertical meridian, and the axis of the horizontal meridian; for clinical purposes, however, we need only consider it as consisting of two. Luminous rays emanating

from a point, and passing through the vertical meridian, can be brought to a focus on the retina, similarly with those rays passing through the horizontal meridian; but the rays passing through these two are not brought to one and the same focus, they have separate foci. It is quite different with rays passing through one of the intermediate meridians, they are nowhere brought to a focus. They intersect, but not in the same plane as do the rays that pass through the principal meridians; to this intersection the term "focal interval of Sturm" is generally given, from the observer who first mathematically demonstrated it.

Varieties.

There are two varieties of astigmatism.

I. Regular Astigmatism.

II. Irregular Astigmatism.

I. Regular Astigmatism.

By regular astigmatism is meant that condition, in which there is a maximum of refraction in one meridian, with a minimum of refraction in the meridian at right angles to it, the intermediate meridians refracting rays not so powerfully as in the maximum, and not so feebly as in the minimum. Fur-

ther every portion of the same meridian refracts rays equally, that is to say rays of light passing through any part of one meridian are brought to one and the same focus. We have therefore to deal with two chief meridians, the one of maximum and the other of minimum intensity of refraction, and these are usually designated by the term Principal Meridians. This would be the definition of true regular astigmatism, but as we shall see later, such perfecion does not exist. Every eye has a certain amount, though so small that it is negligible in a great many cases of irregular astigmatism. A straight line is seen distinctly by an astigmatic person, only when the meridian to which it is perpendicular is adapted to its distance. Some have supposed thatpersons, who suffer from regular astigmatism, obtain distorted images of objects. This is quite erroneous, as can be easily demonstrated by holding a cylindrical glass in front of one's own eye. What they do get, however, in high degrees of the defect, is elongation and flattening of objects: thus a square would appear an oblong without any twist or curve in its sides, distortion in the true sense of the word does not occur.

11. Irregular Astigmatism.

This may be defined as that condition in which the re-

fraction of the eye no longer presents any uniformity. In this case one cannot speak of the principal meridians, two meridians there may be of greatest and least refraction but not necessarily at right angles. Moreover, the refraction often varies at different parts of one and the same meridian. Here we do get distortion, in fact to such an extent, that it is difficult to conceive what the exact shape of retinal images will be; we do know, however, that they can neither be regular nor distinct. This defect is extremely common, we have it on the authority of Landolt that "every eye is tainted with it."[23] Why more people are not disturbed by its presence, can best be explained by what Landolt says on the subject:- "That it is not oftener spoken of, and that we are not more affected by it, is due to the simple fact, that all mankind is subject to the same defect, and that we only exceptionally meet with those priveleged eyes whose infinitely superior acuteness of vision, makes us feel all the imperfection of our own. And it has always been so. We have proof of this in the word Star, which has the double significance of celestial bodies and radiating figures. Now stars are spherical bodies, as can be shown by looking through a pin-hole in a card or a telescope. The rays, that almost everyone sees about stars, are in fact due to the irregular refraction that light undergoes in the eye. There are but

few cases known of men who are entirely exempt from this defect, and who see the stars without radii."[23]

Irregular astigmatism is caused by the lens, and in the higher degrees of the anomaly the defect is congenital. It may be acquired, and is then due to severe ulceration and cicatrisation of the cornea. This condition does not admit of optical correction, all one can do is to remedy the regular astigmatism which may exist with it; no clinical advance would be gained by a further discussion of it, we will therefore dismiss it, and devote all our attention to regular astigmatism.

Cause

The cause of regular astigmatism is to be sought partly in the cornea and partly in the lens; the former as we shall see being the chief factor in its production. The cornea, instead of being equally curved in all meridians, is more highly curved in one than another. The measurements of Donders,[24] which have been fully confirmed by many other observers since, have shown that the maximum curvature usually lies much closer to the vertical than to the horizontal meridian. The analysis of 1000 cases mentioned by Knapp[25] may be quoted as corroboration of this statement:-

Maximum Curvature Vertical	600 or 60%
Maximum Curvature Horizontal	110 or 11%
Maximum Curvature Diagonal	43 or 4·3%
Maximum Curvature in Various Directions	247 or 24·7%

In fact the frequency with which this distribution occurs, has led to this form of astigmatism, being known as astigmatism "according to the rule", on the other hand when the horizontal meridian has the greatest curvature, astigmatism "against the rule" is the term applied to the condition. It may roughly be said that in nearly 75% of all cases of astigmatism, the axes are vertical and horizontal, and in 60% of these the vertical meridian has the greatest curvature.

The next point to consider is, has the cornea in astigmatism a greater or less curvature in its principal meridians than in the normal eye? Donders[26] has measured a series of both, and has compared the results obtained; his conclusions are now generally accepted. He found that in asymmetrical eyes, the radius of curvature of the cornea in the horizontal meridian is distinctly greater than in symmetrical eyes, and the radius of curvature in the vertical meridian is less in asymmetrical eyes than in symmetrical. Thus we see astigmatism is brought about not by increase of curvature in one meridian only, but by increase in one, with a corresponding decrease in the meridian at right angles to it.

If this were all we had to contend with in astigmatism its study and correction would be greatly simplified. There

is another element, however, namely the lens, which exerts nearly as great an influence in the production of astigmatism as does the cornea; certain it is that the former gives rise to the distressing symptoms invariably complained of by astigmatics when they first wear cylindrical glasses. We can measure by means of the Ophthalmometer the radii of curvature of the cornea, and if simple means could be devised for measuring the same in the lens, the difficulties surrounding this anomaly would vanish. Although these radii in the lens have been measured, as we shall see the method is both complicated and tedious, and it can never hold a place among our objective tests.

The lens may exert its influence in astigmatism from a faulty position, congenital in origin, or due to an irregular action of the ciliary muscle, and from actual asymmetry of its substance. Lenticular Astigmatism may therefore be most conveniently discussed under the three following heads.

1. Congenital Malposition.
2. Malposition due to Muscular action.
3. Asymmetry of the Lens.

1. Congenital Malposition of the Lens.

Error of position on a priori grounds rather than from direct observation, is supposed to be the commonest way in which the lens contributes its share in the production of

astigmatism. The fact that the lens could if so placed, produce considerable influence, can be experimentally proved by tilting a spherical lens held close to the eye; the effect is to give this glass a cylindrical action. But we have no direct evidence that the lens is so placed, we infer from the total astigmatism not corresponding to the corneal that some of it arises from the lens. So far we are correct, but we are not justified in assuming that a faulty position of the lens is the cause of the lenticular astigmatism, we must prove that the lens is misplaced, which so far as I can gather has never been done. It would not be sufficient to prove that there was no irregular action of the ciliary muscle, and no asymmetry of the lens, and therefore deduce the only other possible alternative; this would practically amount to proving a negative, which I need hardly say is far from a scientific method of establishing facts. A few cases in which the astigmatism has progressed have been reported from time to time, and some stress has been laid on this point as confirming the malposition of the lens. There is, however, considerable doubt in the minds of not a few, whether the astigmatism in the cases mentioned did actually increase; the general opinion apparently being that it did not. In the absence of more evidence we are bound to fall back on the a priori argument of a dislocated

lens, where in certain cases not only do we get an oblique position of the lens but also a small amount of acquired regular astigmatism.

2. Malposition due to Muscular Action.

It is a much discussed point whether this can take place. Some authorities state that such a thing is impossible, while others, whose opinions carry as much weight, are just as emphatic that it can and does occur. That it does occur I am inclined to believe, for over and over again have I come across cases, which could not be satisfactorily explained on any other hypothesis. How else can one explain an astigmatism which is revealed by a mydriatic, The mydriatic has no influence on the cornea, or the lens except through the ciliary muscle. To prove that it can occur, one must first prove that certain fibres of the ciliary muscle can act either independently or more powerfully than others; this has been established. "Hensen and Voelckers have proved by experiments performed on animals and by clinical observation that the lesion of an isolated branch of the ciliary nerves paralyses, while its irritation produces contraction of an isolated portion of the sphincter pupillae, and of the fibres of the ciliary muscle." [27] If the action of an isolated portion of the fibres of the ciliary muscle can thus be brought about experimentally, I do

not think it is assuming too much to assert, that Nature to obviate and overcome a developmental defect can bring about such an irregular contraction. The effect of an irregular contraction of the ciliary muscle, that is to say an action limited to a single meridian, brings about unequal relaxation of the lens, and therefore makes it assume a more convex form in one meridian only. Clinical experience fully corroborates this statement, all of us no doubt can recall cases where the astigmatism was completely masked and cylinders rejected, but when a mydriatic was used, the astigmatism was quite apparent and cylinders were necessary to bring the vision up to the full visual standard.

3. Asymmetry of the Lens.

This undoubtedly does occur, as however no exhaustive statistics have been published we cannot draw general conclusions with any amount of certainty from the few cases in which the various meridians of the lens have been measured. The measurement of the lens is surrounded with so many difficulties, and so complicated are the calculations that have to be made, that these alone are sufficient to deter many observers from working at the subject.

It might be thoughtthat knowing on the one hand the astigmatism of the cornea, and on the other hand, the total astigmatism as found by one of the subjective methods or by the Ophthalmoscope, that of the lens could be obtained by

subtracting the former from the latter. But it is easy to understand why such is not the case. The astigmatism of the lens directly increases or diminishes that produced by the cornea, only on condition that the principal meridians of both have the same direction. In any other case astigmatism of the lens is not so easily obtained. It would be necessary either to correct the corneal astigmatism, and proceed to a second subjective examination of the refraction, which would then reveal the astigmatism of the lens, or, after having determined the curvature of the cornea, as well as the refraction of the eye successively in several meridians, to deduce from this with the assistance of rather complicated calculations the action of the lens.

Donders[28] by an ingenious contrivance, and by still more intricate calculations from the readings so obtained, has given us the measurements of the lens in twelve different meridians. His measurements extended over a series of 15 eyes. From the table given in his book we see at a glance, that the greatest curvature of the lens exists in a meridian approaching more or less to the horizontal. The actual figures are, in 13 is the maximum curvature more or less horizontal, and in 2 only does it deviate from this and approach to the vertical. Of these 15 eyes the direction of maximum curvature of the cornea is also given, in every

cases without exception does the direction of greatest curvature approach the vertical.[29] From these data, Donders brought forward the following axiom:- "That with a high degree of asymmetry of the cornea asymmetry of the crystalline lens exists, acting in such a direction that the astigmatism for the whole eye is nearly always less than that proceeding from the cornea."[29] Although no one, so far as one can gather, has since undertaken the laborious experiments by which Donders was enabled to state this proposition, a great many observers have however, corroborated it in the main and have further extended it; only in their case it has been founded on clinical experience. Thus many observers, who have worked with Javal and Schiohtz's Cphthalmometer - an instrument which measures the corneal astigmatism only, without the refraction of the eye- have all come to the conclusion that the total astigmatism is generally less than the corneal astigmatism. But they have gone a step further and state, that when the astigmatism is "according to the rule" the total astigmatism is less than the corneal; there is therefore some astigmatism in the lens which partially overcomes that of the cornea. On the other hand when the astigmatism is "against the rule" the total astigmatism is greater than the corneal; the astigmatism in the lens in this latter case adds itself on to that of the cornea.

Astigmatism may be:-

I. Congenital.

II. Acquired.

I. Congenital astigmatism.

By far the great majority of cases of astigmatism fall into this category. Apart from knowing that the child is born with the defect, and that one or other of the parents had a similar malformation, little has been established. Heredity is undoubtedly a strong predisposing cause, but possibly there may be an exciting cause; what the exact nature of the latter is has never been satisfactorily explained. Not only is astigmatism hereditary, but one can often get striking evidence of a like form of astigmatism in the various members of the same family. Javal states "In my family, nearly nine persons in ten present, in both eyes, astigmatism that is contrary to the rule. It has seemed to me that, in general among the Jews, the defect assumed preferably this unusual direction."[30] [30] Not only is it congenital, but there seems to be a tendency for the congenital character of the anomaly to be brought about by defective development.[31] [31] Landolt first drew attention to this fact, namely that in unilateral astigmatism besides the asymmetry of the face with which it is associated, the asymmetrical side is more or less imperfectly developed. We

have already considered the cause in the previous pages.

II. Acquired Astigmatism.

Acquired astigmatism dependent on the cornea, may arise from various operations on that structure, or from changes brought about in other ways. The causes producing it may be conveniently considered under the following heads:-

1 Iridectomy for Opacity of the cornea or for Glaucoma.etc

2. Cataract Extraction.

3. Other operations on the cornea.

4. Pressure on the cornea from within and without.

5. Purulent Inflammations and Ulcerations of the cornea.

1. Iridectomy for Opacity of the cornea and for Glaucoma.

Suitable cases in which after an operation for Leucoma, you do get a clear visual space, are greatly benefited by a cylindrical glass.

That we do not oftener get patients to appreciate a cylinder, is due no doubt to the Leucoma even after operation interfering with vision. It has long been recognised that patients who undergo this operation for Glaucoma, have their visual power considerably increased by wearing cylinders. Cylinders do not always improve after the operation, the reason of this is, not in there being no astigmatism, but from the fact that the optic nerve and retina have been

so damaged by this dread malady, that no glasses improve, let alone cylinders. Let us suppose, however, that you do get a case of glaucoma sufficiently early, before, that is to say irreparable damage has been done, and you perform an iridectomy and check the disease; then in every case there is measureable astigmatism, and the combination of a sphere and a cylinder will give you better vision than the sphere alone. It sometimes, though rarely, happens, that the operation exactly annuls a pre-existing astigmatism, when of course no cylinder is necessary. It is the corneal incision, and not the removal of a portion of the iris, which produces the astigmatism. A practical point, that should be borne in mind in connection with these operations is, that the axis of the cylinder is generally more or less parallel to the incision in the cornea.

2 Cataract Extraction.

We now come to the larger class of cases in which an opaque lens has been removed, and in them the best vision is almost never obtained except by the employment of cylinders. It is often asked, why Ophthalmic Surgeons of the present day get better results after cataract extraction than those of 20 or 30 years ago? It is true, that antiseptic precautions are much more rigidly enforced now than they were then, but the wound often healed quickly and with-

out surrounding inflammation in those days, yet even in these cases the vision was not so good; it is evident, therefore, that antiseptics do not explain the better results now obtained. Do improved methods of operation explain it? It is extremely doubtful if the operation now in vogue is any advance on that performed two or three decades ago, whether it is or not, is beside the question, for the operation does not seem to influence the resulting astigmatism. Landolt[32] has tried various procedures with a view to clearing up this question, and has come to the conclusion that the direction of the corneal incision makes no material difference; the resulting astigmatism is always the same. It may possibly be, that the astigmatism following cataract extraction is more generally recognised now than it was formerly, and hence is oftener sought for; but this is not all. The real explanation is, that cylinders are much less expensive and much more easily procured, so that many more observers make it a routine practice, if the visual acuity is not improved beyond a certain stage, to try cylinders; thus fewer cases remain uncorrected.

The next point to consider is, to what is this astigmatism due? It might be thought that the astigmatism was brought about by the removal of a lens, which overcame the defect. Possibly the lens has some influence, but the cor-

neal wound and its ensuing contraction play a much more important part in the production. That the cornea, and not the lens is the chief agent in bringing about this astigmatism, is easily proved. In some cases there is no astigmatism before operation, afterwards the astigmatism is considerable, indeed it is far greater than can be satisfactorily accounted for by the removal of an asymmetrical or obliquely placed lens. Or again in cases where no corneal incision is practised, the cataract being removed by repeated needlings, the astigmatism remains unaltered; if none were present before operation there is scarcely a measureable amount after. The corneal incision and contraction therefore produce the astigmatism, and not the removal of the lens.

The fact that the visual acuity of patients, who have had cataracts removed is improved by cylindrical glasses, is now so generally recognised that it is quite a routine practice to place cylinders in the trial frame in addition to the convex spheres. How marked the benefit derived from them is, can best be illustrated by the following case:-

C. W. (m) aet. 45 had a cataractous lens removed, iridectomy being done at the time of the operation, two years ago by Mr Cowper. Eighteen months after the operation, when I saw him for the first time, he returned to the Hospital, as he had broken his reading glasses and had mislaid his prescription. He was then wearing + 9.C.D.sph. for distance,

this enabled him to read $\frac{6}{9}$ imperfectly, cylinders were said not to improve him. My experience, however, was different, as with a + 8.C D. sph. and a + 3.C. Dcyl. ax. 20° down and in, he read every letter of $\frac{6}{5}$. The patient was intelligent and admitted frankly, that he had never been able to see objects so clearly since his cataract had been removed. He fully appreciated the cylinder, for not only did he get the new combination for reading, but also for distance, and returned to the Hospital to express his satisfaction and pleasure with his new glasses. He could read I J with a little difficulty with his old reading glasses, but he had told me, that his eye often ached after reading for some time. With the new combination this discomfort had entirely disappeared. I should perhaps mention that he was employed as an amanuensis to a blind gentleman, and that one of his daily duties was to read aloud the "Times" to his master.

The deduction from what has just been stated is, that it should be the rule, and not the exception as it only too often is, for cylinders to be placed in the trial frame when testing the vision of a person who has undergone cataract extraction, in fact it should be just as much a routine measure here, as in those cases where from symptoms astigmatism is more than suspected. Further it will invariably be found, that the axis of the cylinder is more or less parallel to the

corneal incision; or in the ordinary cases where this incision is made upwards, the axis of the correcting glass approaches more or less the horizontal.

3. Other Operations on the Cornea, especially those for Conical Cornea.

Many operations have been recommended,but two are now commonly performed, namely the removal of a small flap from the corneal substance, or the application of the galvano-cautery; both operations aim at a diminution of the conicity of the cornea. Without discussing the advisability of operation in such cases, we pass on to the fact, that where some operation is practised, astigmatism of such a kind is often developed, as can be overcome by glasses with beneficial results to vision. Perhaps a case in point will more easily explain this statement than a lengthy description:-

A.R. (f) aet. 28, came to Moorfields, complaining of defective vision. An examination showed typical conical cornea in both eyes. Her vision in the right, as that was the one, which was operated on, was $\frac{1}{60}$,- 9.C.D. sph. enabled her to read $\frac{6}{36}$, cylinders did not further improve her. Her refraction however, was found to be, - 8.C.D. and - 1.5 D, of astigmatism; she did not see so well with this combination although she still read $\frac{6}{36}$ There was nothing in the fundus, except such changes as are usually present with her amount of myopia. The case was thought a suitable one for operation

accordingly Mr Silcock applied the galvano-cautery to the cornea, a little below and to the outer side of the centre of the pupil. The note at the time of the operation was "free escape of aqueous." When she left the Hospital her vision was $\frac{6}{18}$ partially, with - 8.0 D. sph., six weeks after her vision had risen to $\frac{6}{12}$, and three months after the operation, when the glasses were first ordered, her vision was $\frac{6}{9}$ perfectly. The combination that gave her best vision was a -8.0 C.D. sph. and a + 3.0. Dcyl. ax. 50^{o} down and in; various other sets of combinations were tried, but the one mentioned above gave the most satisfaction. Some might argue that the relief was only temporary, in this patient, fortunately, such seems not to have been the case. After wearing her correction for six months she returned, vision was then the same, she was seen again a year after the glasses were first ordered when she could still read $\frac{6}{9}$.

4. Pressure on the Cornea from within and from without.

It is extremely doubtful, if increase of intraocular tension can give rise to astigmatism, although we have it on very good authority, that it can and does cause the anomaly. Martin cites cases in which the advent of Glaucoma has been followed by the development of astigmatism. "Helmholtz, Graefe, and Donders thought that increase of tension could only produce a progressive flattening of the cornea by uni-

form distension of the organ. This is not what actually takes place. The distension would be nearly always greatest in the vertical meridian in persons who had not lost the elasticity of their tissues."[33]

The variations ascertained by Martin[33] in glaucoma are, that an astigmatism "according to the rule", diminishes by degrees, becoming nil at a more advanced period, and more astonishing still, is replaced if the malady continue by an astigmatism "against the rule", which is in direct proportion to the tension, being higher the greater the tension. Pfalz[34] also draws attention to this fact, and says astigmatism is relatively frequent in glaucoma, but does not hazard an opinion as to which is cause, and which effect. One cannot speak with any certainty on this point, Martin's cases are not conclusive. From the paucity of the cases and the indefinite nature of the evidence deduced from them, the only conclusion we are justified in inferring is, that glaucoma may possibly cause astigmatism.

With regard to the second factor, it is known that a slight degree of astigmatism can be produced experimentally by gentle pressure on the globe, thus tumours in the upper lid should develope astigmatism. A case in point bears out this latter statement, although in this case the tumour did not give rise to astigmatism de novo, it did, what practically

comes to the same thing, change the direction of the more ametropic meridian of refraction. The case referred to is narrated as follows:- "The patient was a man aged 42, whom I had twice refracted during the past five years, finding each time the symmetrical axis of a moderate degree of Compound Hypermetropic Astigmatism to be C.D.70° C.S. 110°. Latterly symptoms of eye strain had appeared, and upon testing the refraction of the right eye, I found the axis had changed to about 110°, that of the left remaining as before. . . The explanation was found to consist, in the existence of a large Meibomiam cyst in the upper lid of the eye in question that had escaped my notice until I examined the eye more carefully. I opened the cyst etc., In a few days I re-tested the refraction and found the old symmetrical axis reinstated."[35]

5. Purulent Inflammations or Ulcerations of the Cornea.

It has long been known that severe inflammations accompanied by suppuration or ulceration of the cornea, produce a certain amount of regular astigmatism, as well as the constant and inevitable irregular astigmatism. Unfortunately in the majority of such cases the latter predominates, and so the little assistance we can give by remedying the former is more than counterbalanced by the latter. Still it should

not be taken for granted from the mere fact of the patient having suffered from an attack of inflammation of this kind, that glasses are of no avail; we undoubtedly do meet with cases where the acuteness of vision has been greatly enhanced with correcting glasses. But perhaps what is even more striking is, that the vision may not be materially benefited at the time, still after the patient has assiduously worn his correction, the sight improves; the explanation no doubt is, that they have now only to contend with their irregular astigmatism, to which in the course of time they become more or less accustomed, and are better able to read aright the distorted images it produces.

Acquired astigmatisn dependent on the Lens is brought about by a dislocation of that structure. If the dislocated lens is in an oblique position and in the same plane as the pupil, regular astigmatism results, if the dislocated lens is not in the same plane as the pupil, irregular astigmatism supervenes. This only need be mentioned as a cause; for it is evident, that a displaced lens requires other treatment than the simple correction of the astigmatism to which it may give rise.

N O R M A L A S T I G M A T I S M.

What may be considered normal astigmatism? No hard and fast line can be drawn between where normal astigmatism ends, and ab-normal begins, whatever our standard is, it must necessarily be a very arbitrary one. The human eye, with rare exceptions, suffers among other imperfections from astigmatism. Even eyes that have an acuteness of vision, which is normal according to a conventional standard, will be found on careful examination to be astigmatic in a greater or less degree. When this astigmatism is not sufficient to lower perceptibly the visual acuteness, it is considered normal. When, however, it is of such a degree that vision no longer reaches the generally accepted standard of normality, it is regarded as abnormal. Donders considered as normal any degree below one dioptre "If it amounts to $\frac{1}{40}$ (i.e. 1 D) it must be considered abnormal."[36.] Giraud-Teulon[37.] fixes the standard of normal at C. 50 D, and Burnett[38.] at C. 25 D. Although one mentions what is stated as the normal by these writers, it does not follow that errors which fall within the normal limit, must on that account go uncorrected. Far from it, one must not be guided by this, but by the various circumstances

of the case in question, each being judged on its own merits. It does not matter how small the error is, if it give rise to troublesome and distressing symptoms it calls for relief, and should be corrected.

Frequency of Astigmatism.

To prove how common it is, we have only to do the following simple experiment. Two lines which cross in a plane, the one vertical, the other horizontal, when held before the eye, are not both seen with equal distinctness. The great majority of eyes discover a shorter distance, at which the horizontal line is more distinct than the vertical. If we see the horizontal line distinctly, the vertical one tobe distinctly seen must be removed from the eye; if on the contrary we accommodate for the vertical, the horizontal must in order to obtain equal sharpness be brought nearer to the eye. But apart from restricting ourselves to such a high standard, as this would necessarily imply, that nearly every eye was astigmatic, let us base our statistics of the frequency on those cases of astigmatism, in which the defect gives rise to diminished vision, or to symptoms of more or less discomfort. Donders[39] said that astigmatism formed 2% of all refractive errors. That he underestimated it, the

following figures clearly indicate; moreover, recent articles on the subject have shown it to be nearly thirteen times as common as Donders supposed. It is not possible for astigmatism to have increased to this alarming extent, the explanation of the difference in its supposed frequency is, that a more widespread knowledge of the subject, and increased facilities for detection now bring to light many cases which formerly evaded our notice. And a further reason for the disparity between Donders' statistics and those of the present day, is undoubtedly the keener struggle for existence, which now prevails. How extremely common is asthenopia at the present time, and that too, with small errors of refraction compared with what it was years ago; and if such patients seek relief in large numbers, how much more so must they, whose visual acuteness or visual power for prolonged efforts at close work is inferior to that of their neighbours. It is undoubtedly this fact, namely that many more astigmatics now seek relief than formerly, and not any great congenital increase of astigmatism, which gives us a greater frequency.

Of Brudenell Carter's[40] 10,000 cases of refraction observed in his private practice, 1412 had astigmatism, and 4441 emmetropia. If we neglect the emmetropes we have 1412 cases of astigmatism in 5559 cases of refraction or an average of 25.4%. Pflueger[41] found a corresponding per centage; of 4664

cases of refraction, 25% had astigmatism. This approximates very closely to what I have myself observed, of 10,000 cases of refraction treated at Moorfields, 2625 had astigmatism of one dioptre and upwards, if all the cases of astigmatism in which glasses were prescribed are included, that is to say cases in which cylinders as low as a quarter of a dioptre were ordered, the total amounts to 3030. This gives an average in the former case of 26.25%, and in the latter of 30.3%. Thus we may say, that astigmatism roughly forms 25% of all refractive errors, or in other words one out of every four cases of refraction is an astigmatism.

There are Five Varieties of Astigmatism:-

1 Simple Myopic Astigmatism.

2. Compound Myopic Astigmatism.

3. Simple Hypermetropic Astigmatism.

4. Compound Hypermetropic Astigmatism.

5. Mixed Astigmatism.

1 Simple Myopic Astigmatism.

In this variety one meridian is emmetropic, and the meridian at right angles to it is myopic. It is usually the horizontal meridian that is emmetropic, hence we have

the rule that vertical lines are seen best at a distance. Parallel rays are focussed on the retina of such an eye as follows:- the focus of the vertical meridian is in front of the retina, the focus of the horizontal is on the retina; or in other words the eye is myopic for parallel rays refracted in a vertical plane, and emmetropic for parallel rays refracted in a horizontal plane.

2 Compound Myopic Astigmatism.

In this variety both principal meridians are myopic but one more so than the other, and as in the preceding case the horizontal meridian is usually less myopic than the vertical. In the usual case, parallel rays both in the vertical and the horizontal meridians are focussed in front of the retina, but the focus of the vertical meridian is anterior to that of the horizontal. The eye is myopic for parallel rays refracted in both meridians, but in a greater degree for those refracted in a vertical than in a horizontal plane.

3 Simple Hypermetropic Astigmatism.

In this variety one meridian is emmetropic, and the meridian at right angles to it is hypermetropic. It is usually the vertical meridian that is emmetropic, hence we have the rule that horizontal lines are seen best at a distance. In this instance the focus of the vertical meridian

is on the retina, and the focus of the horizontal behind it, or in other words the eye is emmetropic for parallel rays refracted in a vertical plane, and hypermetropic for parallel rays refracted in a horizontal plane.

4 Compound Hypermetropic Astigmatism.

In this variety both principal meridians are hypermetropic, but the horizontal usually more so than the vertical. The focus of parallel rays in both meridians falls behind the retina, the focus of the vertical meridian being anterior to that of the horizontal. The eye is hypermetropic for parallel rays refracted in both meridians, but in a greater degree for those refracted in a horizontal than in a vertical plane.

5 Mixed Astigmatism.

In this variety one principal meridian is myopic, the other principal meridian is hypermetropic. For the sake of example let us suppose the vertical meridian is myopic, horizontal hypermetropic, then the focus of parallel rays in the vertical meridian is in front of the retina, and the focus of parallel rays in the horizontal meridian is behind the retina; the retina being situated in the focal interval. The eye is myopic for parallel rays refracted in a vertical plane and hypermetropic for parallel rays refracted in a horizontal plane.

Figures relating to the frequency of the different

varieties are of interest, but before stating these, perhaps a word of explanation is necessary. Very few authorities have quoted statistics; although I have searched the literature most carefully, I have only been able to find two writers, who give figures for four of the varieties; possibly I have overlooked some. My own figures have been taken from a series of 2000 cases of one dioptre and upwards, degrees below this amount being neglected, so as to make the percentages relate to cases of abnormal astigmatism. Further every case was worked out under a mydriatic, the greater part of them under atropine, the remainder under homatropine. The method employed for their diagnosis was Retinoscopy, and the refraction indicated by it checked by trial glasses, where these, which was quite in the minority of cases however, did not correspond; the result obtained by the latter was taken as the correct one. Knapp[42] does not give any information either on the method adopted in his 1000 cases, or on the degrees included. Burnett's[43] 806 cases certainly comprise many who had less than a dioptre, and from what he says on mydriatics I fancy he seldom resorted to their use. It follows therefore, that the figures of the two authorities just mentioned cannot be compared with my own; as a matter of fact the discrepancy between them is very great.

Table of percentages from personal observation of 2000 cases:-

1.	S.	M.	As.	160	cases or	8.0	per cent.
2.	Co.	M.	As.	798	"	" 39.9	"	"
3.	S.	H.	As.	238	"	" 11.9	"	"
4.	Co.	H.	As.	696	"	" 34.8	"	"
5.	Mix.		As.	108	"	" 5.4	"	"

These results do not correspond with those of the authorities mentioned as the following table shows:-

		Own Results	Knapp.[42]	Burnett.[43]	Carter.[44]
1.	S. M. As.	8.0%	30.5%	37.%	———
2.	Co. M. As.	39.9.	17.5	20	———
3.	S. H. As.	11.9	25.9	26	———
4.	Co. H. As.	34.8	22.4	14	———
5.	Mix, As.	5.4	3.2	3	5.56.

Signs and Symptoms.

Persistent blepharitis and chronic hyperaemia of the conjunctiva are frequent accompaniments of astigmatism as well as of the other refractive anomalies; and, when found on an examination of a patient, should always lead to an inves-

tigation of the optical condition of the eye. It often happens, that these conditions which no amount of different lotions and ointments alleviated, disappear as if by magic, when correcting cylinders are worn.

A person suffering from this anomaly cannot see all the lines on an astigmatic fan or clock equally well, some of the lines, those at right angles to his emmetropic meridian are seen clearly, while others, those parallel to his emmetropic meridian are blurred and indistinct. It is due to this fact, that patients often tell you that objects in a vertical plane are much better defined than those in a horizontal, or vice versa; for example, the masts of a steamer may be distinctly seen, while the yards are scarcely discernible. Closely allied to this is the statement a patient sometimes makes, that he sees better during certain parts of the day than others. When you inquire into this, you find he has been guaging his standard of vision by a neighbouring clock face; he can tell the time when the hands are more or less parallel to his astigmatic meridian, but when they pass on and stand at right angles to it, he is unable to do so.

Another symptom complained of is that objects appear double. At first sight this is rather misleading, for what he calls double is really only a partial diplopia, in the sense that one image is more or less incomplete. When he looks at the letters setting forth the name of a shop, the

letters do not appear clearly defined to him, he sees them, but he also sees a prolongation of them downwards, upwards, or to one or other side, and it is upon this that he bases his complaint of seeing double. In such cases one must of course exclude any insufficiency of the various muscles, which when at fault give rise to a similar phenomenon; but there can be no doubt, that this symptom exists, when there is not even a suspicion of defective muscular action.

A very characteristic and often pronounced sign is the screwing up of the eyelids or blinking, so often and so persistently may this means be resorted to, that a patient may present a condition closely allied to blepharospasm on examination. One cannot wonder at the frequency of this contrivance, if one considers for a moment the useful purpose it serves; vision is distinctly improved by the procedure; the palpebral aperture is converted into a stenopaic slit so to speak, thus cutting off rays which pass through the more ametropic meridian, and the lids by their pressure, though this be but small in amount, exert some influence on the shape of the cornea.

Another sign and one that might easily lead one into error is the habit astigmatics acquire of holding printed matter close to their eyes, one might readily mistake them for myopes. The explanation of the habit is, that they prefer

to get magnified images of objects and indistinctness of outline, rather than smaller images and distinctness of outline.

The most prominent sign and the one which is most commonly met with, is diminished visual acuteness; on the other hand one must not take for granted if a patient read $\frac{6}{6}$ - the usual visual standard - that per se he cannot be astigmatic. And perhaps I should emphasise this latter statement, inasmuch as Hartridge lays down the dictum, if a patient read $\frac{6}{6}$ there is no astigmatism. This is erroneous, as one is constantly meeting patients with one dioptre and more of simple Hypermetropic astigmatism who do read $\frac{6}{6}$. I can distictly recall the case of a young girl, who had two dioptres of Hypermetropic Astigmatism, axis vertical, and who read every letter of $\frac{6}{6}$ and that too with the only useful eye she possessed; as the other was amblyopic from old macular disease. There is another point that must be borne in mind and that is, one must not take the patient's word that his sight is not impaired. A very considerable amount of bad vision often escapes the notice of patients suffering from astigmatism. Having never seen well at any time in their lives, they have no standard of comparison in their own experience, and a careful education of the sense of vision has made up largely for indistinct retinal images, and so it happens that they not infrsquently flatter themselves that

their visual acuteness is above the normal. "My eyesight is very good, I can often see things other people can't," is an expression heard almost daily, and great is his astonishment when an examination by the test types shows a reduction of vision to a half or a third of the normal. To such an extent may this prevail in the minds of some people that an astigmatism of more than medium degree may pass unnoticed for several years. How often is it the case, that people with a considerable amount of astigmatism reach the presbyopic age without glasses, and then only seek relief for their receding near print; and how great is their consternation and surprise when cylinders allow them to see better than ever they have during their life. Most assuredly the wearing of glasses in such people opens up a new world to them and allows them for the first time to behold the country in all its native beauty. It is truly difficult on the other hand to convince them that others see as well without glasses as they do with them, so meagre has their standard of normal vision been, and so obstinately do they cling to the belief that their standard has been the true one.

But perhaps the most obvious effect of astigmatism is to produce differences in the apparent distinctness of equal lines, which are drawn in different directions; and in this

way it produces indistinctness of some of the linear boundaries of figures, leaving others clearly defined. Thus an astigmatic person when reading the distant test-types confuses and misinterprets the vertical, and horizontal lines, that enter into the formation of the letters; he will call an O, a Z, or an H, and an F, a T etc., Similarly in reading a printed page he may be able to see clearly the vertical lines, which enter into the formation of many letters, and so, for example, to distinguish an m from an n. But he would have to place the page at a different distance, or to alter the accommodation of his eyes, in order to distinguish the horizontal lines with equal clearness, and to tell readily an n from a u. The indistinctness of many boundary lines produces a corresponding diminution in the acuity of vision, and the necessity constantly to alter the accommodation in looking at the same object produces great fatigue of the ciliary muscle. Hence arise defective vision, and weariness or aching of the eyes, of both of which astigmatic persons most commonly complain.

When the eyes are used for close work such as reading, writing, fine sewing etc., for any length of time, there is pain accompanied frequently with a sudden indistinctness of vision when the effort is prolonged. This Asthenopia may be of all degrees of intensity, from a slight feeling of fatigue

to a pain so severe as to practically make any use of the eyes for near work impossible. Two forms of Asthenopia are generally recognised:-

1. Muscular Asthenopia.
2. Nervous Asthenopia.

1 Muscular asthenopia has its seat in the muscle of accommodation, being sometimes called accommodative asthenopia, and the fatigue comes from the irregular and spasmodic contractions of the ciliary muscle. The eye instinctively endeavours to have as clear and distinct retinal images as possible. An image distinct in all its parts is impossible in astigmatism, but by a kind of "see-saw" action of the ciliary muscles, first one part of the object, and then the other, can in the majority of cases, have its image properly focussed on the retina. So long as it is possible to see more clearly and satisfactorily by this kind of muscular action, there is an irresistible temptation to use it, and, as is well known, nothing is more wearing on muscular energy. A regular systematic contraction of a muscle may be continued for an almost indefinite time without fatigue, but convulsive-like movements soon exhaust its power. The fatigue of the ciliary muscle is often followed by a suspension of its action, with consequent indistinct retinal images. In the highest degrees of astigmatism, where no

amount of accommodation can give distinct retinal images of any portion of objects, there is no temptation to strain it, and as a consequence we do not find asthenopia of this kind, so often a sympton in the higher degrees as in the lower.

2 Nervous Asthenopia.

The term unfortunately is a broad one, but it must necessarily be so, in order to cover the vagueness of our knowledge, concerning it. The pain is not muscular in character, and is not always dependent upon close application of the eyes to near work. Moreover, it is most commonly present in persons of Neurasthenic tendencies. The fatigue is a mental one, if we may so express it. Indistinct images are abhorrent to the visual consciousness, in the same manner as discordant sounds jar on the auditory sensorium, and there is an instinctive tendency to get away from them. Something of this feeling may be experienced by an emmetrope on rendering himself artificially astigmatic by a pair of cylinders. The manifestations of this form of asthenopia are frequently feelings of general discomfort, associated it may be with giddiness, nausea and even vomiting. But often it is one of actual pain, referred not uncommonly to parts not directly connected with the eyes. Besides there may be intolerence of artificial or glaring light, and all kinds of

abnormal sensations referable to the eyes and the surrounding parts.

Both forms of asthenopia sometimes make their appearance suddenly after a severe illness, or as the result of some depressing causes operating to lower the tone of the nervous or muscular systems, and may be the first intimation to the patient of the existence of an astigmatism. They continue in a greater or less degree in some cases, after the refractive anomaly has been corrected, necessitating most careful and systematic use of the eyes.

Asthenopia as well as diminished visual acuteness are more common and pronounced when the meridians are oblique, than when they are horizontal and vertical. The reason of this most probably is, that when the meridians lie near the horizontal and vertical, it is possible by using one or other focal plane to see clearly at least a part of the letters, whose strokes run usually in these directions; when the meridians are oblique the lines forming the majority of the letters are blurred.

As is the case in the other forms of accommodative asthenopia, so in astigmatism, the pain is not always referred to the eyes, but manifests itself under some form of headache. The relation of anomalies of refraction to headache, as cause and effect, has long been known to Ophthalmologists;

but the profession at large have not been impressed with the fact till quite recently, however; the latter now recognise errors of refraction as a common and potent cause of headache, quite as often as the Neurologist or Ophthalmologist. The pain may be localised in any or all of the branches of the fifth nerve, or may be frontal with a sense of constriction across the brow. But there is a form of headache, which so far as I know, is associated with astigmatism only, and which is quite as characteristic as the frontal headache, and the brow so sensitive to pressure, are of hypermetropia. It may best be described as a "vertical headache". The pain is localised to the top and middle line of the head, it does not spread forwards and become frontal, nor yet progress backwards and become occipital. It is most marked in the smaller degrees of hypermetropic astigmatisms, especially well so when only one eye is affected, and in persons who use their eyes a good deal for fine work such as dressmakers etc. That it is not always present is true, but one must not forget the fact, that in many persons it may exist, where from lack of intelligence or from want of due attention it cannot be definitely localised; and the complaint the sufferer gives you is one of general pain in the head. But of this there can be no doubt, if one does ellicit this form of headache, (I speak now of headaches due to an error

of refraction) then astigmatism is always present. I can speak with a considerable amount of certainty on this point, as I have seen many patients who complained of this headache, in every one of whom the astigmatism was appreciable and the headache disappeared after correcting glasses were worn.

Another appearance, which Landolt[31] was the first to draw attention to is the asymmetry of the face associated with unilateral astigmatism. This asymmetry is most marked and characteristic in high degrees of the anomaly, and takes the form of an imperfect development. In fact so great is this the case in some instances, that Landolt is probably correct in assuming that the astigmatism is only a part and parcel of the mal-development in which the whole half of the face is involved.

Bettriemieux[46] has pointed out, that in astigmatism restricted to one eye, one often gets a larger pupil on that side than the other. In such cases one must of course exclude all other causes, that may give rise to unilateral mydriasis, one of which may co-exist with this defect. I have been unable to establish the relationship claimed by Bettriemieux for this sign, and although I have noticed it in unilateral astigmatism, I have as often come across it, where no astigmatism was present, and where no recognised cause could be ascertained for its existence. This is certain, that given

partial unilateral mydriasis, the deduction that unilateral astigmation is present, is not tenable, but the converse may possibly be true, viz., that in a certain number of cases of astigmatism, there may be partial unilateral mydriasis.

Then there is another sign, which although it is only apparent in high degrees of the anomaly has none the less a very significant character. I refer to the shape of the globe, to which Mr Cowper was the first to draw attention. He says: "It is well known, that the cornea frequently appears, even to the naked eye, to have a greater dimension from margin to margin, in the direction of the meridian of its least curvature than in that of its greatest, in astigmatic eyes. This feature is most pronounced in Mixed astigmatism, and is associated with a yet greater deformity. The whole globe evidently departs from a spherical form. It exhibits a flatter surface, and a larger curve at the upper and lower equatorial regions than at the outer equatorial part. The vertical diameter of the globe is less than the horizontal, and the form of the eye approximates to an ellipse more than to a sphere. The name elliptiform might be applied to this type of globe, just as the elongated myopic globe is called bathymorphic, and the short hypermetropic plathymorphic."[45]

Just as one often meets with cases of Graves' Disease sine Exophthalmos, or any other disease minus its most prominent symptom, so one comes across cases of astigmatism without

characteristic symptoms, in fact it may be without any symptoms. And the fact is easily enough explained, so great may the existing error be, as to preclude the possibility of any accommodative effort improving vision. No strain of the ciliary muscle results, for the simple reason that there is no incentive to its action, and it is therefore never called into requisition. Certainly such patients possess diminished visual acuity, but few of them realise this fact until failing health directs attention to their eyes. And yet they live quite unconscious of the fact, that their sight is and has always been very defective, and that a very simple contrivance would enormously increase their visual powers, and would enable them to perceive beauties never even "dreamed of in their philosophy."

DIAGNOSIS AND CORRECTION.

We now come to the consideration of the various methods of diagnosing and correcting astigmatism; for the sake of convenience these are usually considered under the following heads:-

I Subjective Methods.

II. Objective Methods.

Before one enters into a detailed description of these, it must be clearly understood what main points have to be sought for in each case of astigmatism. What are the main factors then that have to be established? They are:-

1 The existence of the astigmatism.

2 The direction of the principal meridians, by which is meant the meridians of maximum and minimum curvature.

3 The refractive condition of the eye in each of these meridians

4 The degree of the astigmatism.

The first three need not detain us, for from what has already been said, we now know to what they refer. A word of explanation is necessary on the degree of astigmatism, or as it is often called in short "the astigmatism". The degree

or amount of astigmatism is the difference of refraction in the two principal meridians, or to put it into other words, find the refraction in the two prinicpal meridians, subtract one from the other, and the result is the degree of the astigmatism. It can be expressed by the following formula $\frac{i}{r} - \frac{i}{r'} =$ Degree of astigmatism, where r and r' are the puncta proxima of the maximum and minimum meridians of refraction respectively.

I Subjective Methods.

All of these are open to serious objections, for as the name implies, we are purely dependent for our result on the answers of our patient. Every one admits, that under certain conditions, one or other of the subjective methods are far and away the best we have at our command, but we are not always able to have these conditions fulfilled. For our result to be anywhere near the truth, the patient must possess intelligence, the power of concentration of his thoughts, and truthfulness, which qualities as we all know, are not possessed by the majority of hospital patients. A glance at once shows us, how limited the sphere of usefulness of this method becomes, for we must exclude as out of its scope all children and many others, who do not fall into this category from the ordinary standpoint of age, but still who, from their obstinacy or stupidity, give us just as unreliable answers, and

whom we are however reluctantly compelled to place in the same class. Nor do our difficulties end here, we have still to consider the influence of accommodation. Some have supposed that by making your tests at 20 ft, or 6 metres, you practically can neglect any accommodative effect; but on what grounds they have made this bold assertion it is truly difficult to understand. This supposition is falacious.

It is true you can often get sufficiently accurate results without resort to a mydriatic, and the more experienced the observer in refractions the more likely is he to come to a true estimation of the astigmatism. Still undoubtedly cases do occur, where even the most experienced observers err, and are not satisfied till a mydriatic has been used. I know it is still a much discussed point, whether the use of a mydriatic should be the rule or the exception, and so it will always be; some either from the school they have been brought up in or from considerations thought out in more mature years, adopt the former plan, while on the other hand, quite as many others who could bring just as conclusive arguments to bear on their method of procedure, adopt the latter. I fully admit that at Moorfields mydriatics are oftener called into requisition, than the necessities of the case seem to justify, but perhaps it is safer to err in this way than in the opposite. I fail to see what possible

harm the judicious use of a mydriatic can give rise to, and there are few indeed, even amongst its most boasted scoffers, who would hesitate to employ it on the score simply of the temporary inconvenience which its use entails. To my mind its employment in certain cases has advantages, which more than counterbalance its disadvantages. Let us briefly consider what these are, the advantages maybe said to be:-

1 Estimation of the Static Refraction.

2 It facilitates Estimation, and saves time and labour.

1 Estimation of the Static Refraction.

Most will admit, I think, that whenever it is possible to obtain the static refraction, it is of inestimable advantage; for once that is known you have data to work on, that can never lead you astray. There are a few however, who bring forward the absurd argument that the static refraction is of little avail, as in health you have to deal, not with the static, but with the dynamic refraction, and they thereby consider the use of a mydriatic a disadvantage. It is difficult for me to understand why they bring forward such a plea, for who would ever dream of ordering the full correction found under a mydriatic, Do we not all allow for the so-called "tone" of the ciliary muscle?. And although this "tone" is not the same in all cases, one can with very little practice learn to deduct such an amount, that will err on the side of being too much rather than too little. But apart from

the static refraction, the use of a mydriatic is a distinct gain in astigmatism, from the fact which is not sufficiently recognised, or if known is not often enough acted up to, we recognise a latent hypermetropia, why do we not as universally recognise a "latent" astigmatism; although the latter is not present in all cases, that is no reason why no prominence should be given to it. There is no need to call it "latent", call it by what term we will, that is of little moment, the important point is to be fully cognisant of the fact, that the ciliary muscle in some cases can, and does, by its action, counteract a certain amount of astigmatism; just as it does a certain amount of hypermetropia. It is in such cases as these that a mydriatic becomes so useful, nay more, essential to a diagnosis of the correct amount of astigmatism. Without its aid we cannot tell with certainty, whether the ciliary muscle is acting in a purely physiological manner or passing beyond the bounds of physiological action, it may be exerting a pathelogical influence. It is this very difficulty that makes one sooner or later resort to the use of a mydriatic, would it not be better to use it at once rather than to wait till we were beaten, and were forced to call in its assistance. Further it is our duty to do the best for our patients, why should we hesitate to carry this axiom into practice here. The "best" undoubtedly is, to reduce our patient's refraction to a state of emmetro-

pia, or to one as nearly bordering on it as circumstances permit; and how else can one, in persons with a strong active ciliary muscle, which partially overcomes their astigmatism, obtain this end except by using a mydriatic. Some might at first sight be apt to cavil as to whether this is the "best". A moment's consideration, however will convince them, that there is no real reason or foundation for their dissent. As the following clearly shows:- a person with a considerable amount of myopia will tolerate and wear his full correction always, provided you set about it in a judicious manner. But to do so, what does it entail? It means the person does not get such magnified images of objects, when he uses them for close work as he would get with a pair of glasses some dioptres less than his full correction; further he has to exert more accommodation when reading with the former than the latter. Now if a myope will wear these glasses, and it is not a question of supposition, for as a matter of fact he does, how much more so will an astigmatic who gains everything and loses nothing, tolerate his full correction.

2 It facilitates estimation and saves time and labour.

These are so self-evident that their further discussion need not detain us.

The only disadvantage that need be considered is the inconvenience caused by the paralysis of accommodation.

The inconvenience, however, is one that can usually be overcome. One way of surmounting the difficulty is to instil the mydriatic into one eye at a time. In a limited number of cases this is not possible, either from the person's occupation demanding the use of both eyes, or in the still rarer cases where only one eye is present. In those cases where one eye cannot be corrected at a time, it will be found that the majority of patients, provided the impaired vision and asthenopia are genuine will willingly submit to have impaired vision for some days. One must remember, that a mydriatic need only be used once in a life time, and while under its influence the rest is a distinct gain to the patient's eyes.

To briefly sum up, the general consensus of opinion seems to be that a mydriatic is indicated in a certain number of cases; as a rule, however, the cases get less numerous in which its use is necessary as the Surgeon grows older, not because the actually difficult cases become fewer, but because his more extensive experience, and his greater ability of estimating accurately with the direct ophthalmoscopic method, make less of these appear complicated to him. The next point is, which mydriatic best serves our purpose? The answer to this is atropine, as it is the only mydriatic that one can absolutely rely on for completely paralysing the accommodation. It is preferable to use it in the form of ointment

than of drops, for the reasons that in the first place the ointment is less apt to be washed out of the eye on to the cheek by the copious flow of tears, that follows its application, and in the second the ointment does not so frequently pass down the nasal duct, and cause that unpleasant dryness of the throat, that so often accompanies the use of the drops. It is said that symptoms of Belladonna poisoning are less rare with the ointment than the drops, that there is a possibility of alarming symptoms supervening on its use is admitted by all, still the ill effects of atropine in this direction are to my mind much exaggerated. The only other objection to it would be on the score of age, the fact that it is most unsafe and possibly dangerous in persons over 35, is too well known to need any emphasis here; it does not constitute so much an objection as a direct contra-indication, quite as much so as the reckless pushing of atropine in Iritis with Iris Bombé. In elderly people then, Homatropine should be used, but one cannot claim the same satisfaction from its use. For not only is the latter drug expensive and its properties most variable, but it is also a much less powerful mydriatic, indeed according to many authorities it never causes complete cycloplegia.

The subjective methods are most conveniently discussed under two main subdivisions:-

1 Estimation by trial lenses, and stenopaic slit.

2 Estimation by optometers.

1 Estimation by trial lenses etc.,

This method is generally carried out by placing your patient at 20 feet or 6 metres from the distant types, and making him read the letters. The examination is carried out on each eye separately, in a simple case the axis of the cylinder is easily found by merely rotating the glass, but in others the procedure is difficult, either from the uncertainty of the patient's answers, or from the vision, being so defective, that no lens seems to materially increase it. Sometimes you can, when this device fails, ascertain the axis of the principal meridians by making the patient look at Snellen's astigmatic fan, and noticing which lines appear most distinct. The lines that are most distinct are more or less at right angles to his more emmetropic meridian, and the indistinct lines are atright angles to his more ametropic meridian. If you can get some differentiation in this manner, that is to say the patient tells you some of the lines are bold and clear, while others are indistinct and blurred, the practical outcome is, that the axis of the cylinder is at right angles to the lines he sees most clearly. Still another alternative remains when both the former fail, though

it does not oftener meet with success than those mentioned. This plan is to place a stenopaic slit in the spectacle frame, either alone or together with the spherical lens, that gave the best vision, according as you are dealing with a case of simple or of compound astigmatism. Then by rotating the stenopaic slit, it will be found, that vision is best when the slit is in a certain position; here again the practical point to remember is, that the axis of the cylinder is at right angles to the position in which the slit was held when best vision was obtained. The disadvantage of this last method is, that visual acuteness is considerably reduced by the exclusion of so much light by the diaphragm, and by the circles of dispersion, small it is true, but still appreciable which come from the few rays that pass through the slit in the other meridian. Whatever method be tried, sometimes you have to try all methods in rotation and even then not always with success; the process is long and tedious. Especially is this so, when you are working out in this fashion a case of Mixed Astigmatism, if in such cases you content yourself with this plan, and do not resort to another to throw light on the nature of the case, half an hour, nay an hour may elapse, and at the expiration of that time you may be far from satisfied with the result. Not only does it try the patience of the observer, but the answers of the observed

become less and less reliable as the examination proceeds. I do not in the slightest degree mean to disparage this method, it is undoubtedly the best one we possess. It has difficulties, which are not only apparent but real, and it is chiefly in the hands of a beginner, that it so often gives faulty results. However, the method we have just been discussing has an importance and usefulness, that no one can gainsay, I refer to its general use as an adjunct to objective methods. And here it is quite the routine as well as the common practice after you have worked out your patient's refraction by one of the objective methods, to place the lenses which the latter indicates in a trial frame, and ask the patient to read the test type. It serves a double purpose, in the first place it enables the patient to thoroughly grasp the fact that he can see better with glasses than without, and secondly it acts as a check to your objective observation.

2 Estimation by Optometers.

This is the plan that was first adopted for the detection and measurement of astigmatism, and whatever else it is credited with, it can certainly claim the advantage of being the oldest. This method is based on the fact that the astigmatism of the Dioptric System can be calculated from the puncta proxima of the meridians of maximum and minimum refraction. Many instruments have been introduced, each one

taking advantage of the defects under which its predecessor laboured, and certainly from the point of view of ingenuity and workmanship, they reach perfection; still their use leaves much to be desired. Space does not permit me to enter into a detailed description of any of them, nor to discuss the merits of the various ones introduced; perhaps the best are Tweedy's[47] optometer, Wecker and Masselon's[48] astigmometer. They are all open to the serious objection, in addition to those that any subjective method may possess, that with them it is even more difficult than in the examination with the test objects at a distance to control the accommodation, so to obtain anything like accurate results it is necessary to paralyse the ciliary muscle. It is partly owing to this fact, and also because we now possess simpler and better methods that their use has not become more general.

II. Objective Methods.

As the former methods rely solely for their accuracy on the patient, so these depend entirely on the surgeon, and any error that may creep in must be laid solely to his charge. They are a sine qua non in the case of children and illiterate people, in whom the subjective method is of no avail. But they have a far wider sphere of usefulness than this, it is quite the exception not to make use of them, and it is only in those rare cases, which are simple and straightforward that we do not seek their aid. It amounts

in short to this, that the objective method is usually practised either alone as in those cases where the subjective would palpably give unreliable results, or in addition to the latter either to confirm or facilitate it. There are various methods which we can employ, let us pass on to the consideration of these:-

1. Fundus Image Test.
2. Retinoscopy.
3. Keratometry.
4. Indirect Ophthalmoscopic Examination.
5. Direct Ophthalmoscopic Examination.

1 Fundus Image Test.

This is a very good method for giving you an approximate notion of the nature of the case, but as it does not possess the means of estimating the exact degree of the astigmatism, it has never come into common use. "If the mirror be held at a considerable distance from an emmetropic eye, no image of any details of the fundus is seen, but only a red reflex; this is because only the very minute point of the fundus is seen, which lies on the axis along which light is reflected into the eye, for the rays from any other point on the fundus form a pencil of rays parallel to the axis on which the point is situated, so that by the time the rays from any two such points have reached the distance at which the observer's eye

is placed the two pencils are widely separated."[49] Now in Myopia and Hypermetropia a portion of the fundus is seen which is in direct proportion to the amount of ametropia present, and if the observer's head be moved from side to side the portion of the fundus visible will appear to move in the opposite direction in myopia, and in the same direction in hypermetropia; so that we get this rule:- "If while the mirror is held two feet or more from the eye, any details of the fundus are seen, the eye is either hypermetropic or myopic. If the vessels move in the same direction as the head, it is hypermetropic, if in the opposite direction it is myopic."[50] Astigmatism is diagnosed by the distinctness and rate of movement of the vessels in one meridian compared with another. Thus if the vessels are seen more clearly in one meridian, it indicates a greater amount of ametropia in that meridian, and similarly the vessels in this latter meridian would move more quickly than in the one at right angles to it.

2. Retinoscopy.

This method is known by many names, it was first called Keratoscopy, from the supposition that the cornea was the chief cause of its phenomena, and though later this was shown to be erroneous, it seems to me it was the chief factor in introducing into the literature scores of names by which to designate this test, some appropriate, othersinappropriate.

But if the name first given was unfortunate, it has served a good purpose, for the subject has drawn on itself much more attention than probably would otherwise have been the case, so that although the multitudinous names assigned to it have been misleading, and have not advanced our knowledge; on the other hand the principle of the subject shows a distinct gain, for all observers under whatever fanciful name they have written, have had but one and the same principle, with the result that retinoscopy is now easily understood and almost universally practised.

The growth of the method has been exceedingly rapid, the first mention we hear of it emanates from Mr Bowman, although it was not till years afterwards that it was put on a practical and scientific basis. "My friend Bowman recently informs me, that he has been sometimes led to the discovery of regular astigmatism of the cornea, and the direction of the chief meridians by using the mirror of the Ophthalmoscope much in the same way as for slight degrees of conical cornea. The observation is more easy if the optic disk is in the line of sight and the pupil large. The mirror is to be held at two feet distance and its inclination rapidly varied so as to throw the light on the eye at small angles to the perpendicular and from opposite sides in succession, in successive meridians. The area of the pupil then exhibits a somewhat

linear shadow in some meridians rather than others."[51] For some years no notice was taken of this, but in 1873 Cuignet[52] of Lille systematised the method which was given still further publicity to by his pupil Mengin.[53] Mengin introduced the method in Paris, where Parent[54] took it up, demonstrated its optical basis, described a method of using it and urged its advantages. It was to Parent's exertions that the method was introduced in England. In 1881, he worked at the Royal London Ophthalmic Hospital, and practically introduced the test there, though some notice had been taken of it previously by Forbes[55], it does not seem to have been given a place among the tests till Parent's visit, and it was certainly only after that, that English Surgeons took it up. It was shortly after this that several English observers added considerably to our then existing knowledge of the method, notably among these must be mentioned Charnley[57], Juler[58] and Morton[56]; the first of these deserves special mention for the concise and clear exposition of the subject which he has given us. Such in brief outline is the history of Retinoscopy. At the present time it is largely used in England, France and America, though strange to say it has never met with any favour in Germany; it seems difficult to explain this lack of appreciation on their part, unless it be, that so deep is the hatred for France in every German mind, that not only the French but any advance

emanating from France is necessarily tabooed.

The method is founded on the fact that when the light from a gas flame is thrown into the eye by means of a mirror, held at a distance of from 3 to 5 feet from it, and the mirror is rotated about one of its axes, a shadow is observed to pass across the bright area of the pupil. It is usually carried out as follows:-, The patient is seated in a chair, the gas flame is placed above his head rather behind than in front of the centre, so that his face remains in partial darkness. The examination is carried out on each eye separately, the eye not under examination being covered or shaded. The observer sits on another chair about 4 feet away from the patient, and throws the light from a mirror held in front of his own eye into the patient's eye. If now he rotates the mirror about its axis he will notice, besides the bright red reflex from the fundus, a shadow, which moves either in the same direction in which the mirror is rotated, or in the opposite. Without going into further detail we may say that the shadow is "simply the edge of the image of the gas flame, formed by one reflection at the mirror, and two refractions through the media of the patient's eye. The movements of the shadow are the movements of the edge of the image." [57] Similarly the direction in which the shadow moves is dependent on the same cause, namely, the result of the reflection of the mirror,

and two successive refractions through the dioptric system of the observed eye. Two mirrors are commonly used, a concave and a plane, and although it is perhaps a little more easily practised with the former; the general consensus of opinion seems to be that the plane mirror gives you more accurate results. Let us then reflect the light from a plane mirror into the patient's eye, if the shadow moves in the same direction in which the mirror is rotated the case is one of either Hypermetropia, Emmetropia, or Low Myopia; if on the other hand the shadow moves in the opposite direction the patient is Myopic. In the cases in which the shadow moves "with" the mirror, we can rapidly distinguish what the refraction of the patient's eye is, thus place + 1 D in the frame, if the shadow still move "with", he is hypermetropic, if this lens just reverse the shadow he is emmetropic, if it over-correct the shadow the patient is myopic. But we can learn something more from the shadow, the slower the rate of movement, the feebler the illumination and the more crescentic and narrower the shadow, the greater is the ametropia. Thus the direction of the movement of the shadow gives us an indication as to the kind of ametropia, while the rapidity, luminosity etc., tell us the degree of the same. Now in astigmatism one notices that the rapidity, luminosity, and curvature of the shadow are not equal in all meridians; there

is a difference in these qualities of the shadow. It is these two dis-similar shadows, which move at right angles to one another, either vertical and horizontal or oblique, that indicate the principal meridians in astigmatism.

The correction of the astigmatism is very easily carried out, suppose one is dealing with a case of Mixed Astigmatism then in one meridian the shadow moves with, in the other against the plane mirror. With a small amount of practice one can tell approximately what spherical lens corrects the shadow, or if that practice has not been attained what one does, is to start with convex lenses, gradually increasing them till one comes to the weakest lens that reverses the shadow which moves with the mirror. This lens over-corrects the existing ametropia by + 1 D, so the usual rule is to deduct 1 D, from the weakest lens that reverses the shadow. When you have corrected the one meridian, two courses lie open for the correction of the other; one can either do it with concave cylinders with the axis parallel to the meridian you have just corrected, keeping the convex spherical lens in situ, or removing the latter and ignoring that meridian for the time being, one corrects the myopic meridian similarly to the hypermetropic with the exception of using concave instead of convex spheres. In correcting the myopic meridian one does not reverse the shadow, but takes his indication

from the strongest concave lens that still makes the shadow move against. Here again this is not the absolute refraction there is 1 D of myopia in addition, so the rule is the same as in hypermetropia, you deduct 1 D; the usual practice, however, in myopia is not to add on 1 D, but to take the retinoscopy correction as the refraction. The difference between the refraction in the two principal meridians gives you the amount of the astigmatism. The procedure is the same, whatever the form of astigmatism is, I took as an example the most difficult form; in the other forms the method is more expeditiously and easily carried out.

There is another method of practising Retinoscopy, it is certainly never used in this country, but has supporters both in France and America. The patient is seated in the same way as in the former case etc., and a plane mirror is used. In the case of Myopia "Begin the examination beyond the patient's far point and slowly approach towards the patient, as long as the movement is opposed to that of the facial area, the Surgeon knows he is watching the inverted image at patient's far point. Presently the movement cannot be distinguished, the far point has been reached, coming still closer the movement becomes distinct and moves with, the patient's retina is being viewed in the erect image. By measuring the distance from this point of reversal to the

eye, he measures the distance from the patient to his far point of distinct vision and the reciprocal of this distance of course expresses the degree of myopia."[59] In the case of hypermetropia you make the patient myopic by over-correcting it, placing a strong convex lens in front of his eye + 5.D. or + 8 D, and proceed as above, then deduct the myopia found from the lens used and you have the amount of hypermetropia. It is certainly not much advance on the method previously described, in fact the reverse, for not only have you to find out the exact point at which the reversal takes place to a nicety, in itself not an easy matter, but you have also to measure most accurately the distance from the patient's eye to this point. These two reasons are quite sufficient to condemn this modification.

The series of cases in which Retinoscopy was practised by Morton and Barrett[60] and their conclusions may be mentioned in this instance:-

1 In order to be perfectly accurate Retinoscopy must be practised at the macula and with atropine.

2 Retinoscopy at Cptic Disc, in majority of cases (especially in hypermetropia) gives approximately correct results, and from the great ease with which it can be practised, its employment is justifiable in cases (such as polar cataract) in which it is necessary to estimate the refractive character

of the eye approximately, and in which Retinoscopy at the macular is difficult or impossible to practise.

3 Retinoscopy without atropine is unreliable, from above experiments it seems that if drug cannot be used approximate-results can be got at Optic Disc. The glass which reverses shadow may generally be ordered.

4 If best possible results with least trouble be required it should be practised with a mirror of 36 c.m. focal distance, at a distance a little over one metre, with as small a frame as possible; the patient should be directed to look at the small hole in the mirror, while a screen is placed in front of the other eye.

5 The two meridians of greatest and least refraction respectively should be steadily worked out, until just over-corrected. The difference between the two results gives the cylinder required which cannot vary more than 0.5 D. The spherical glass may require lowering or increasing slightly in Hypermetropia and Myopia respectively, but in the latter case more alteration is required than in the former.

There only remain now for discussion the advantages and disadvantages of this method. Let us consider the advantages first, it requires no expensive apparatus, the mirror attached to any ophthalmoscope is quite adequate for its purpose, failing this as has been pointed out by Priestley Smith[61]

a piece of ordinary plane glass with a hole in it is all that is necessary. It is very easily learnt and does not necessitate an extensive training to become an adept in its practise. But perhaps its chief advantages are its rapidity and its accuracy, the ease and quickness with which a complex case of astigmatism is solved by it is remarkable, and contrasts most favourably with any other method we possess, and it gives as accurate results, if not more so, as any other test; there is however, one exception, in hypermetropic astigmatism it gives an absolutely correct estimation, in myopic astigmatism on the other hand, the Retinoscopy does not always correspond with the glasses that give the best vision. The fact, that Retinoscopy in some cases of myopic astigmatism is unreliable is generally recognised, but no satisfactory explanation of why it should be so has ever been stated.

There are two main disadvantages to its use:-

1 It may be used to the detriment of Ophthalmoscopy.

2 It necessitates the use of atropine.

1 It may be used to the detriment of ophthalmoscopy.

It has been urged by some that in the hands of beginners, a Retinoscopy only is practised, the fundus is never examined and so opportunities are lost; but this can only take place when the method is abused. It is as easy to do a Retinoscopy and examine the fundus before or after as only the former,

there is no reason why the two should not go hand in hand.

2 It necessitates the use of atropine.

As I have said above, Retinoscopy to give correct results must be carried out under atropine so that it amounts to this that one of its disadvantages is the same as those attending the use of atropine. However, although this is the generally accepted view in this country it does not seem to carry much weight in France, where it is maintained that as reliable results are obtained without the use of atropine, and to such an extent does this prevail that atropine is seldom used there.

3 Keratometry.

The fresh impulse given to the study of astigmatism in recent times was by the measurements of the cornea in its various meridians, first made systematically by Knapp. And since the cornea has been found to play the chief part in the anomaly, the most convenient method of investigation would seem to be by some form of keratometry. And so it would be, but for the fact that until very recently no rapid and accurate method of keratometry has been at the command of the profession. The Ophthalmometer of Helmholtz is cumbersome, expensive, difficult to manipulate, and tedious to work, these disadvantages have precluded the possibility of its coming into general use. However an improvement on this instrument has now been realised and we have in the ophthalmo-

meter of Javal and Shiotz a means of diagnosis which in the opinion of some has never been equalled, certainly not surpassed by any of the other objective methods. This instrument was exhibited at the International Medical Congress in London in 1881. In France and America its success as a means of diagnosis must have surpassed even its inventors most sanguine expectations, yet in England it has met with but scant notice, and the few observers who have worked with it do not augur a very bright future for it in this country.

"The instrument of Javal and Shiotz is constructed on the well known fact that the image of an object of a certain size at a fixed distance from a convex reflecting surface grows smaller as the radius of curvature of that surface becomes shorter." And the principle of the instrument depends on the fact that "the distance separating the object and the reflecting surface may remain the same while the size of the object is varied till the standard size of image is obtained. The essential part of the instrument for ordinary use is a Wollaston's bi-refracting prism of such a power that it shall give an exact doubling of an object 3 m.m. in diameter when it is 27 cm. from the prism; the object to be measured is the corneal reflection of a fine spider's web stretched across a tube. The accessories of the instrument are the optical appliances for seeing this double image to the best advantage

and from a convenient distance; and a means for measuring the varying size of the object which furnishes the corneal image."[62]

As a means for measuring the corneal astigmatism nothing can be said against it, its accuracy and rapidity are unequalled still in astigmatism something more is needed than the mere part the cornea plays, we also desire to know the share taken by the lens in the anomaly. It does not pretend to measure the lenticular astigmatism nor yet the ametropia that may be present, these have to be obtained by other methods. Still various rules have been laid down with regard to the relationship of corneal to Total Astigmatism with the object of simplifying the prescribing of glasses but with little success. It is this latter fact that has brought it into disfavour in this country. Thus Juler says of it:- "Mr Anderson Critchett and I have used Javal and Shiotz's Ophthalmometer since /81, M. Javal states that the astigmatism of the cornea constitutes the greater part of the astigmatism in almost every case. At first such was our experience, but later in the majority of our cases the total astigmatism was either greater or less than the indication afforded by the ophthalmometer. Therefore the ophthalmometer is unreliable but is very useful for indicating the curvature of the cornea."[63] Again, Landolt says "These instruments may render service when the dioptric system of the

eye is reduced to the cornea alone. But in an immense majority of cases the determination of the curvature of the cornea is far from sufficient to acquaint us with the amount of astigmatism."[27]

These disadvantages which are not imaginary but real, combined with the expense of the instrument are sufficient to prevent its ever supplanting Retinoscopy or the Direct Ophthalmoscopic Method.

4 Indirect Ophthalmoscopic Examination.

This method of diagnosing hypermetropia and myopia was first pointed out by Hutchinson,[64] and Cowper[65] has shown how astigmatism may also be recognised by it. It is preferable to use atropine otherwise the change in the pupil might lead one to suppose a change in the size of the optic disc had taken place. The object lens must be placed as close as possible to the patient's eye, and keeping the optic disc in view, the lens is gradually withdrawn, the change in size of the optic disc being noted. If the disc remain the same size throughout, the patient is Emmetropic, if it diminish on withdrawing the lens the patient is Hypermetropic, if it increase, Myopic; in each of the latter cases the amount of hypermetropia or myopia is proportional to the diminution or increase in the apparent size of the disc respectively. It is needless to give the explanation on which these appearances depend, they are so clearly and ably expressed in our various text-

books, that another is quite uncalled for.

The appearances we obtain in astigmatism are:-

If the disc diminish in one meridian only, there is simple Hypermetropic Astigmatism in that meridian, and the amount is proportional to the apparent diminution.

If the disc diminish in size in both principal meridians, but more in one than another, there is compound Hypermetropic Astigmatism etc., If the disc increase in size in one meridian only, there is Simple Myopic Astigmation etc.,

If the disc increase in size in both principal meridians, but more in one than another, there is compound Myopic astigmatism etc.,

If the disc increase in size in one meridian, and diminish in size in the meridian at right angles to the former, there is Mixed Astigmatism etc.,

Although this is a very good test, and one that is rapidly carried out, it labours under the serious disadvantage that it is purely qualitative. Thus we are told that the amount of astigmatism is proportional to the increase or diminution in the apparent size of the disc, but we have no means of measuring this.

5 Direct Ophthalmoscopic Examination.

In estimating refraction by this method the patient and observer must be seated side by side, looking in opposite directions, and the lamp placed a little behind and below the ear of the same side on which the examination is to be made.

Then if the heads be inclined towards one another, the eyes will come into the proper position for examination, and there will be no discomfort to either party from the breathing. Thus the sight hole of the mirror can generally be placed as close to the eye as spectacles generally are worn, and the distance from the mirror to the eye can be neglected in ordering glasses, or in those cases where this near approach is unpleasant, allowance will have to be made for the glass indicated by the ophthalmoscope, being weaker in myopia and stronger in hypermetropia. To get accurate results by this method, the accommodation of both patient and observer must be absolutely in obeyance, and any error of refraction the latter may have, must be corrected with glasses, or, if this is not done, it must be known and due allowance made for it. The patient's accommodation can often be sufficiently relaxed by making him look across the dark room at a black screen, should this fail to do so, and no reliable result be obtained, one must fall back on the use of a mydriatic. It is not such an easy matter, however, for the observer to relax his accommodation. True with practice many can do so, but there are a great many more who can never sufficiently relax it. Let us suppose the observer can fully relax his accommodation, and makes due allowance for the error which he himself possesses, and

likewise the patient's is fully suspended; what we observe in an astigmatic fundus is that the edges of the disc are most distinct in one meridian than another, and the vessels running in one direction are sharply defined, while in the direction at right angles to the former they are blurred and indistinct. If the horizontal edges of the disc and the vessels running horizontally are seen most clearly without any lens, the patient is Emmetropic in that meridian; now, by rotating concave or convex lenses in front of the sight hole of the mirror, one will be found that makes the vertical edges of the disc and the vertical vessels distinct; this lens affords the measurement of the refraction in that meridian. In short by accurately focussing the vessels in the meridians of greatest and least refraction, every case of astigmatism can be worked out. In extreme cases the appearance of the disc is very significant; it was first drawn attention to by Knapp. The disc instead of being circular is more or less oval or elongated, and further the elongation of the disc corresponds very closely to the axis in which the correcting cylinder

will be taken. In fact so characteristic is this appearance of the disc, that a glance is sufficient to satisfy one of the existence of astigmatism and its direction; by beginners this appearance is often mistaken for Neuritis. Such then in brief outline is the direct ophthalmoscopic method of examination, and although every one can get approximate results with it, few indeed of us can boast of being able to estimate the absolute refraction in difficult cases.

The method labours under the serious disadvantage that the observer's accommodation must be totally suspended, A great many can relax their accommodation and know when they are doing so, but few of these have that full control over it as to be able to relax it at will, while there are quite as many more who cannot suspend their accommodation, or if they can, do so involuntarily. Further many who can relax their accommodation when not examining a fundus, entirely fail to do so when they practise the direct method. The other objections are most admirably summed up by Brudenell Carter, and one cannot do better than quote them in extenso:- "There is no object in the fundus of the eye, which is of such a nature as to show plainly, when the best definition of it is obtained. The ametropia depends on the distance between the yellow spot and the cornea, and the optic disc will not serve as the required object, because it is situated at a variable distance

from the yellow spot, and sometimes, especially in myopic eyes, is distinctly anterior to it. At the yellow spot itself there are no blood-vessels to serve as test objects, and there is nothing to be seen in the normal eye but the somewhat granulated looking surface of the pigmented epithelium seen through the transparent layers of the retina, and more or less obscured in this position by the image of the flame, which affords the necessary illumination. The appearance of this surface may vary a little when a change is made in the power of the lens through which it is seen, but there is nothing to show which variation should be accepted as the best refraction. The observer must carry his eye a little away from the yellow spot to a region where there are small retinal blood-vessels which, if he knew their diameter, might serve his purpose. But he does not know their diameter in any given case, and they are upon a background of colour only slightly different from their own. The observer cannot tell whether he is looking at a vessel of the smallest calibre, a little out of focus, and so made to appear broader by diffusion, or at a vessel of the next degree of magnitude, seen closely. The examination does in fact, test the vision of the observer instead of that of the patient; and the first essentials of accurate testing - objects of known aspect, known distance, and known magnitude, - are wanting and cannot

be supplied. I believe it is impossible to arrive within a dioptre of trustworthy results."[66]

Which of the various objective methods we have just been discussing gives the best results in practice? The easiest way to solve this problem is by a process of exclusion. The Fundus Image Test and the Indirect Method are purely qualitative tests, but we also desire a quantitative one as well, these therefore can be put out of consideration in this connection. Keratometry as a test has a very limited application and it would need to possess very special advantages, which it does not, before many observers would incur the expense, that the instrument entails. Our choice then lies between the Direct Method and Retinoscopy. The general consensus of opinion is in favour of the latter. So that the answer to the question formulated above is, that Retinoscopy in the hands of most observers gives more reliable results than any other objective method.

Treatment.

The treatment naturally resolves itself into prescribing the most suitable optical correction for each individual case. Astigmatism is corrected by cylindrical lenses. A cylinder as the name implies instead of being a portion of a sphere is a portion of a cylinder. Parallel rays of light which fall on the surface of the lens, in a plane coincident with the axis of the cylinder of which it forms a part, are

not refracted at all, but emerge as parallel rays. But the rays which fall upon the glass in succeeding planes, that is in planes perpendicular to the axis, meet with a strongly refracting surface, and are focussed accordingly. Cylinders therefore refract in one plane only; they exert no influence on rays of light which fall in a plane, corresponding to the axis of the cylinder. In cases of simple astigmatism, all that is necessary for its correction is a cylinder alone, but in compound cases something more is needed. The latter may be corrected in one of two ways, either by bi-cylindrical or spherico-cylindrical lenses; the former require such delicate manipulation in grinding, that they are universally condemned, and the spherico-cylindrical lens is the one that is invariably prescribed.

Having determined the glasses necessary for the correction of astigmatism, as has been shown under Diagnosis, there still remain one or two points which may be most conveniently discussed here. First and foremost, we should always endeavour to obtain the desired result by the simplest combination, and by means of glasses of the smallest refracting power, which will fulfil the indications in each case. But it is always proper to think over the various ways in which the correction may be accomplished, and it is sometimes desirable to try the various combinations experimentally, before deciding

on any of them. It is sometimes found, that, for no apparent reason, one combination gives better vision than another, which seems to be its optical equivalent. It seems to be laid down in the correction of Mixed astigmatism that convex sphericals combined with concave cylinders are preferable to the other alternative. The reason of this is not far to seek; it is said in the text-books that, other things being equal, the combination above alluded to should be ordered, as it is easier to grind concave cylinders on convex spheres than vice versa. I cannot find any foundation for this in practice; all the working opticians whom I have consulted have distinctly told me that the one combination is as easily ground as the other; therefore the usual procedure in prescribing glasses for this variety of astigmatism is based on an erroneous supposition. Moreover it is an undoubted fact, that better vision is sometimes obtained in children with concave spheres and convex cylinders than the reverse; it should be the rule to try both combinations and order the one that gives best vision. In the second place, in every case of astigmatism, the lenses should be put up in an adjustable trial frame, so that the axis of the cylinder may be varied after the combined lenses have been ground into one, Thus any re-adjustment of the axis if necessary, can be effected before the lenses are cut into the ordinary oval

shape. Formerly circular glasses to obviate this difficulty used to be worn; not only are they both heavy and unsightly, but they possess no advantage over the ordinary oval shaped spectacles if the expedient alluded to above be attended to.

BIBLIOGRAPHY.

1. Phil. Trans. 1801 v. 91. p. 39.

2. Dict. Encyclop. des Sc. Méd. 1867. T. VI. p. 793.

3. Schirmer, Ann. d'Oculistique, 1869. T. 62 pp. 201 - 204.

4. Javal, do. 1866. T. 55 p.107.

5. Schirmer, do. 1869. T. 62 pp. 204 - 208.

6. Cam. Phil. Soc. Trans. 1827 V. II. p. 267 - 271

7. do. 1849 V. VIII pp. 361, 362.

8. Noyes, Amer. Jour. Med. Sc. 1872 V. 63 p. 355.

9. Cam. Phil. Soc. Trans. 1849 V. viii pp. 493 - 496.

10. Javal, Ann. d'Ocul. 1866. T. 55 p. 109.

11. Month. Jour. Med. Sc. (Edin.) 1846 - 47. V. vii. pp. 891 - 898.

12. Javal, Ann. d'Ocul. 1866. V. 55 pp. 109 - 116.

13. Compte-rendu du Congrès d'Ophth. 1862. pp. 37 - 47.

14. Phil. Trans. 1801. V. 91. p. 69.

15. Schirmer, Ann. d'Ocul. 1869. V. 62 p. 208.

16. Cam. Phil. Soc. Trans. 1849. V. 8. p. 496.

17. Monthly Journal Med. Sc. (Edin.) 1846 - 47 V.vii pp. 897, 898.

18. Man. Oph. Med. and Surg. 1855. p. 500.

19. Dublin Jour. Med. Sc. 1849. V. iii. p. 224.

20. Donders, "Anom. of Refract. and Accom." 1864. p. 542.

21. Compte-rendu du Congrès d'Oph. 1862 pp. 37 - 47.

22. Donders, Loc. Cit. p. 460.

23. Landolt. "Refract. and Accom." p. 323.

24. Donders, Loc. Cit. pp. 490 - 492.

25. Tran. Am. Oph. Soc. 1892. V. ix. p. 310.

26. Donders, Loc. Cit. pp. 495 - 496.

27. Landolt, Loc. Cit. p. 302.

28. Donders, Loc. Cit. pp. 492 - 495.

29. do. do. p. 492.

30. Wecker, "Traité des Maladies des Yeux", 1867. V. ii p. 843.

31. Landolt, Brith. Med. Jour./81 V. i. p. 507 and 508.

32. Landolt, Loc. Cit. p. 301.

33. Martin, Ann. d'Ocul. /86. T. 95. pp. 206 - 209.

34. Pfalf. do. /86. T. 95. p. 271.

35. Gould. Med. News Phila. /93. v. 62 p. 598.

36. Donders, Loc. Cit. p. 456.

37. Giraud-Teulon, "La Vision et ses Anomalities". p.477.

38. Burnett, "A Treatise on Astigmatism," p.45.

39. do. do. p.50

40. Carter. Lancet /92. V. ii. p. 988.

41. Pfueger Rév. gén. d'Oph. /90. p. 456

42. Knapp. Tr. Amer. Oph. Soc. /92. V. ix. p. 310.

43. Burnett, Loc. Cit. p. 206.

44. Carter, Lancet /92. V. ii. p. 988.

45. Couper. Med. Times, /69. V. i. p.114.

46. Bettriemieux. Arch. d'Oph. /87. T. vii. pp. 519 - 523.

47. Tweedy. Lancet /76 v.ii pp. 604 - 606.

48. Wecker and Masselon. Ann.d'Ocul. /82. T. 88. pp. 44 - 46.

49. Juler "Ophth. Sc. & Pract." p. 456.

50. do. p. 457.

51. Donders, Loc. Cit. p. 490. (Foot note).

52. Cuignet. Réc. d'Oph. Oct. /73, July /74, Jan/77.

53. Mengin. do. /78. T. V. pp. 122-144.

54. Parent. do. 80. T. vii. pp. 65 - 87, /81. T. viii. pp. 238 - 246.

55. Forbes, Oph. Hos. Reports. /82. V. x. p. 62 - 75.

56. Morton, "Refract. of the Eye", p. 30 - 45.

57. Charnley. Oph. Hos. Reports. /82 V. x. p. 344 - 371.

58. Juler. Brit. Med. Jour. /84. V. ii. p.1274.

59. Jackson. Amer. Jour. Med. Sc. /85. V. 89. p. 404 et seq.

60. Morton and Barrett. Oph. Rev. /86. V. v. p. 82.

61. Priestley Smith. do. /84. V. iii. p. 266.

62. Burnett, Loc. Cit. p. 125.

63. Juler. Brit. Med. Jour. /84. ii. p. 1275.

64. Hutchinson. Oph. Hos. Reports. /63 -/65. V. iv. p. 189.

65. Couper, Med. Times. /69. V. i. p.114.

66. Carter, do. /77. p. 220.
