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1874.

ON A VISIBLE STELLATION OF THE NORMAL AND OF THE CATARACTOUS CRYSTALLINE LENS OF THE HUMAN EYE.

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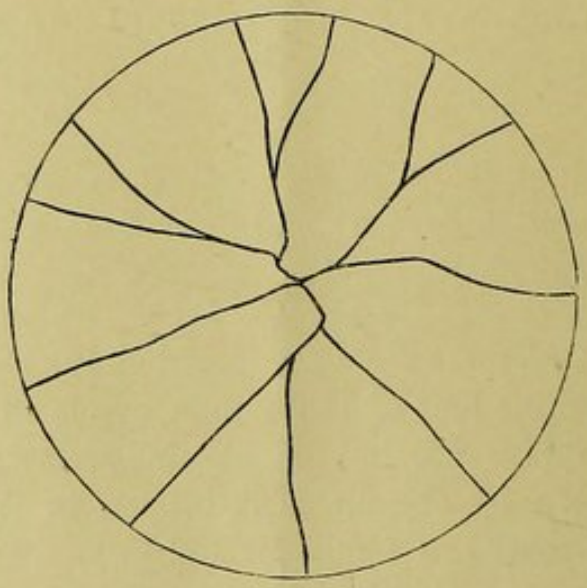
The striation, or, more correctly speaking, the stellation of the normal crystalline lens of the human eye is well known as a *post-mortem* appearance, but few persons are aware that it can readily be seen by oblique illumination in the living eye. Nearly three years ago I described elsewhere* this stellation as observed in the healthy human eye, and endeavoured to explain the method by which it may be brought into view. The latter was by no means an easy task, for I could only give general directions as to plan to be adopted, and could not definitely state how the rays of the stella could be surely and certainly seen. The mode of procedure, however, is that employed in ordinary oblique illumination of the anterior parts of the eyeball by the aid of artificial light. The observer must endeavour to obtain the greyish glistening reflection from the anterior capsule, and must look more obliquely along the anterior surface of the crystalline lens from the side opposite to that on which the light falls than in the ordinary oblique illumination. If by this means a view be obtained of the anterior stella of the lens it will be found to consist of fine, dark, radiating, and slightly undulating lines, about ten in number, extending from near the centre of the anterior surface of the crystalline lens to its extreme periphery. It will be seen in Fig. 1, which has been taken from a normal eye, that, although the rays are united towards the centre of the anterior surface, they do not all start from

* Lancet, 1871, vol. ii, p. 776.

exactly the same point, as is usually represented in drawings taken from the lens after death.

Fig. 1.



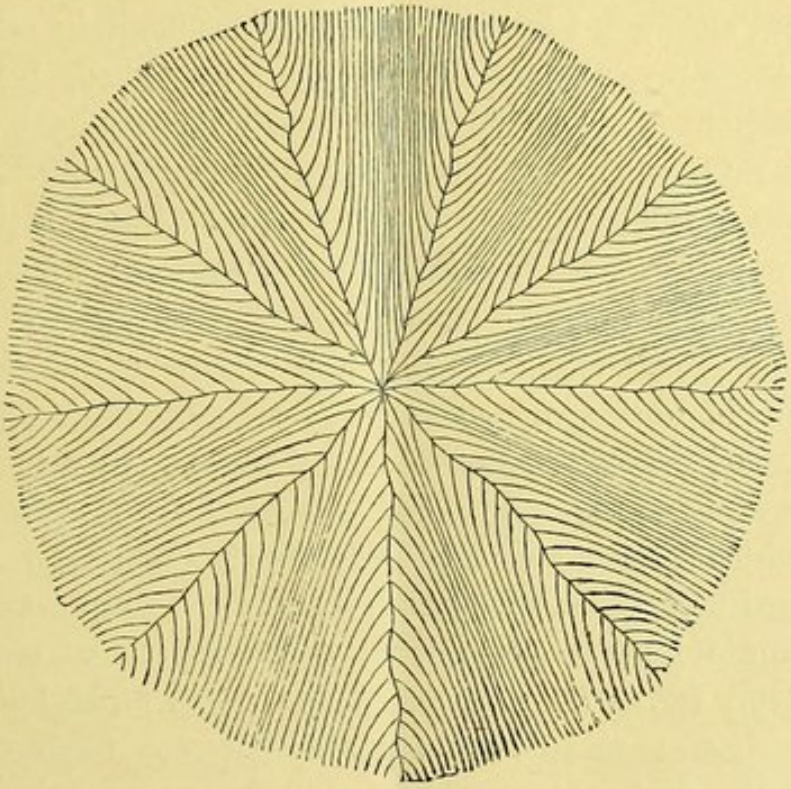
The precise manner in which the rays unite at the centre varies very much, but in every case a conformity to a particular plan may be observed. I have never yet seen the arrangement figured in Stricker's Histology.* In the accompanying woodcut (Fig. 2), for which I am indebted to the Council of the New Sydenham Society, it will be seen that all the rays of the stella, except one, are represented as converging to the same point in the centre of the anterior surface of the lens.

Without wishing to impugn the accuracy of the representation in this particular instance, I must say that such an arrangement is exceedingly rare, and has never been seen by me in the large number of examinations which I have made.

But in addition to main rays which converge towards the anterior pole there are secondary rays which branch from the primary ones, and which have their vertices at varying distances from the pole. Sometimes there are tertiary branches, and in the diseased eye I have seen even quaternary rays.

* Stricker's Histology, vol. iii, p. 364. New Sydenham Society's translation.

FIG. 2.



Before proceeding further in the consideration of the relation which the rays of the stella bear to the nutrition of the lens and of their influence on vision, I must in justice to others and to myself refer to a question which has been raised as to my claim to have been the first to describe these rays as objectively seen in the living eye. At the time that I published my first article on this subject I had reason to believe, from the assurances of some of the most eminent anatomists and ophthalmic surgeons in London, whose names I need not here mention, that a visible striation of the living normal crystalline lens had never before been described. But within two days of the appearance of my article I found, in reading the chapter on Entoptics in Professor Donders' work, what I believed to be a confutation of my priority; for, after describing certain entoptic appearances of his own crystalline lens, Donders says, "These phenomena are connected with the composition of the lens of the so-called sectors, which, as Helmholtz showed, can be very well seen with the mag-

nifying glass, with lateral focal illumination in the living eye."*

Now, although I knew that the sectors could be seen without the fine rays themselves being distinguished, I felt that the excellent observer referred to could scarcely have failed to see the rays when examining with a high magnifying power the lens sectors; but being unable to find any satisfactory statement in Professor Helmholtz's work on Physiological Optics, I, at the recommendation of Professor Sharpey, wrote to Professor Helmholtz to ask him where he had described the visible normal striation of the living lens, as I was desirous of publicly disavowing my claim. In the kind and speedy reply to my query I was assured that, although the lines which I had figured were evidently identical with those described by Listing,† and mentioned by Helmholtz himself‡ as entoptic images, yet not only had he never seen them objectively in the living eye, but that, as far as he knew, they had not been seen in such a manner by any other observer. But Professor Donders, whose acquaintance I subsequently had the honour to make, and to whom I am indebted for several of the subjoined references, has informed me that he was well acquainted with the stellation which I had figured, and that he had been led into the error of ascribing the first description of them to Helmholtz by the fact that the latter had stated that by oblique illumination he was able, in some instances, to make out the sectors of the lens, and that it was in looking for these that Dr. Donders had observed the rays of the stella, and naturally concluded that Helmholtz had also seen them.

But apart from these trivial concerns, the lines have I think an importance which has hitherto been imperfectly understood. This, therefore, must be my excuse for bringing before the members of the profession, and especially before

* Refraction and Accommodation of the Eye. New Sydenham Society's translation, p. 201.

† Beitrag zur Physiologischen Optik, Göttingen, 1845.

‡ Physiologische Optik, p. 152.

Ophthalmic surgeons, some of the results of my examinations and the conclusions which I have drawn therefrom.

In the normal eye the rays of the stella vary in number from eight to twelve, including the primary and secondary rays. In a child two and a half years of age I was able to count nine rays, but I have not, for obvious reasons, succeeded in seeing any rays in younger children, so that I cannot say when the three primary rays found in the fœtus begin to divide, or at what rate the division and ramification of the rays take place.

In children of about five or six years of age I have, however, frequently seen the commencement of the branching of a primary ray, and I am inclined to believe that the ramification is always centrifugal, that is, commences from near the pole, or in the case of a secondary ray, that it commences from a primary ray and extends towards the periphery, and never from the periphery towards the centre. In the diseased eye, however, especially where the lens is beginning to undergo cataractous changes, the number of the rays may become greatly increased. For instance, in a patient whose lens showed signs of the commencement of posterior cataract from disease in the posterior segments of the globe, there were twenty of these rays.

The rays also may be shown objectively and subjectively to be of a different refractive power from the interlinear sectors. But at present I wish to speak only of the objective appearance, and shall refer more in detail to the subjective phenomena in a subsequent part of this article. In an ordinary eye the rays appear black or brown in colour, the particular shade varying with the general pigmentation of the eyeball, but in the albino they are red. In the first albino that I examined they appeared as clear red lines on a duller red ground, and in an albino that I recently saw they showed themselves as clear red lines without the glistening satiny haziness which the interlinear portions of the lens presented.

Perhaps the most interesting result of the regular and

methodical examination of the rays is the knowledge afforded of the inception of cortical striated opacities at the anterior part of the lens. But before we can profitably engage in the consideration of this question, we must stop to consider briefly the anatomical structure of the healthy lens. The earlier histologists, Henle, Kölliker, but especially Becker,* asserted that the ends of the fibres of the lens do not come in immediate contact at the rays of the stella, but that there is an intervening space, filled with structureless or granular matter, to which and to the supposed interfibrillary passages, Becker attributed great importance in the changes undergone by the lens in accommodation. But this has been shown by Zernoff,† Babuchin,‡ and others, to be erroneous. The microscopical examinations of these gentlemen have proved that the rays of the stella are merely the seams formed by the apposition of the ends of the fibres, and that under high powers these rays appear as fine sinuous lines, without the interposition of any material whatever. With the statement made by the latter authorities, the result of my examinations of the living lens *in situ* entirely accord.

The error of regarding the stellate fissures as spaces filled with granular matter doubtless arose from the fact that "the superficial fibres are usually very soft and delicate, and easily break up in macerating fluids into detached drops of various sizes (hyaline drops), but partly also into a finely granular or structureles mass. This breaking-up occurs also spontaneously after death, and inasmuch as it chiefly affects in the first instance the extremities of the fibres, it is intelligible that the products of the breaking up must principally accumulate in the stellæ of the lens."§ From this it will be evident that the opinion of those who regard the rays of the stella as actual structures, and capable of undergoing cataractous changes, cannot now be accepted, the rays themselves

* Arch. für Ophthal., t. ix, A 2.
† Arch. für Ophthal., t. xiii, A 2, p. 521.
‡ Stricker's Histology, vol. iii, p. 365.
§ Stricker, vol. iii, p. 369.

being, as it were, negative structures, mere fissures or seams, formed by the apposition of the ends of the fibres. Nevertheless, every ophthalmic surgeon is acquainted with radiating striated opacities, which bear a close relation to the rays of the normal stella. How are these to be accounted for? Whatever may be the imperfections in our knowledge of the actual processes which determine the molecular changes that give rise to cataractous opacity, we know that they are, directly or indirectly, the result of altered, perverted, or impaired nutrition; and as the lens is entirely extravascular, it must depend on the structures and fluids immediately surrounding it for its nutrition-supply. The interchange of material between the lens and the surrounding tissues, therefore, takes place by processes of endosmosis and exosmosis, and if either of these processes be interfered with by the imposition of mechanical and physical obstacles, or by an alteration in the surrounding tissues or fluids, we can easily understand that the parts most likely to be primarily affected are those which adjoin the rays of the stella—the fissures formed, as it were, by the discontinuity of the lens fibres, where the endosmotic process are most active. These are in fact the parts of greatest vulnerability, and are most liable to become affected by disturbed nutritive changes. As a proof of this we may note that in the earliest stages of senile cortical opacities, or of opacities accompanying inflammation of the vascular tunics of the eyeball, that these are always the parts primarily affected. Of this I have become convinced by numerous examinations.

The earliest perceptible cataractous changes in the cortical layers of the lens, especially of old people, show themselves in the ends of the fibres adjoining the rays, and the clear dark line of fissure may frequently be seen to border the opaque ends of the fibres, or even to pass between the opaque ends of the two opposing sets of fibres. Even in the cortical opacities of young children, a ray of the stella may often be observed bordering a cataractous stria, or passing down its middle if the fibres on both sides be involved. Often in iritis,

where the aqueous humour becomes turbid, a haziness may be observed in the end of the lens fibres, adjoining the rays of the anterior stella, and in choroiditis, and acute affections of the vitreous, a similar condition may be observed in the posterior stella. This haziness often, however, entirely disappears when the inflammatory condition has subsided. The temporary haziness is evidently due to altered nutrition conditions existing during the inflammatory state of the surrounding parts. But sometimes the haziness thus induced continues steadily to advance to thick opacity. Quite recently an interesting case of posterior polar and stellar cataract came under my observation, through the kindness of Mr. John Couper. The patient was a man aged 32, who had suffered from nystagmus and impaired vision for about 16 years. On examining the crystalline lenses, a well defined posterior stellar cataract could be seen in each eye. In the right eye, including secondary and tertiary branches, there were fourteen rays, and in the left eye there were twelve. The rays were of a dark grey tint, and extended from an opaque mass at the posterior pole outwards to the periphery, where they abruptly terminated, none of them passing round the margin of the lens on to the anterior surface. Running down one or two of the opacities, a fine dark line could be seen, but whether these dark lines were the remains of the original fissures, I cannot say. Although the interlinear sections appeared slightly hazy by oblique illumination, the fundus oculi could easily be seen by direct examination with the ophthalmoscope. In both retinæ and choroids there were large irregular proliferations of pigment. It is, therefore, in the highest degree probable that the cataractous changes were primarily induced by the altered nutrition relations existing between the vitreous and the posterior segment of the globe and the lens, and that the effects of these showed themselves in the parts of greatest vulnerability, namely, the rays of the posterior stella.

But it is only up to a certain stage that the original rays of the stella may be distinguished in cataractous striæ, for, sooner or later, the retrogressive changes extend, so that the

line of the ray ultimately becomes obliterated by the disruption of the lens tubule, and destruction of its contour.

From what I have alleged, it will be seen that I dissent from Professor Stellwag who, in speaking of the senile changes of the lens, says: "Most frequently we meet radiated striæ which usually follow the course of the lens-filaments, and depend on cloudiness of the lens-filaments themselves, and on depositions of molecular masses in the interspaces."* If what I have asserted be correct, it follows that the "radiated striæ" are formed by the opacity of the ends of the lens fibres, and that they do *not* follow the course of the lens-filaments which would really give them a bi-penniform arrangement with the ray of the stella as a stem, unless the opacity were confined to the few fibres which converge to the pole. I must also protest against the strict accuracy of the following statement made by Professor Stellwag in the last edition of his excellent and learned work:—"In rare cases . . . some or all of the rays of the star-shaped figure become bluish-white and hence become distinct from the still transparent surrounding parts."† But here I cannot but think that the illustrious Vienna professor refers to the same appearances which I have described, but has not recognised the real relation which the rays of the stella bear to the opacity.

With all humility I must also demur to the opinion of that accomplished physiologist and ophthalmic surgeon, Mr. Bowman, who, in speaking of the cataractous striations of the lens in middle or declining age, says:—"Now I can entertain no doubt that the streaks in these cases are sets or bundles of the superficial layer of lenticular fibres reduced to a state of opacity by some nutritional change. There seems to be a disposition in the fibres of the lens to become opaque in their entire length when once they are altered at a single point, and hence the linear figure of the opacity. The opacity probably commences in the middle part of the fibres near the margin of the lens; and the arrangement of the fibres would

* Diseases of the Eye; 4th edition, p. 591. American translation.

† *Loc. cit.*, p. 604.

account for the different length of the streaks, some approaching nearer than others to the central point of the surface."* Now although I grant that when a fibre is once affected at one point, the change is liable to extend itself through the entire length of the fibre, yet I believe that in most cases the opacity occurs primarily in the ends of the fibres adjoining the rays, and that the different lengths of the cataractous striæ are to be accounted for by the different length of the primary, secondary, and tertiary rays. But it is only just to add that Mr. Bowman seems to have been the first to recognise the multiplicity of the rays of the stella, and has indeed given a very accurate representation of them,† with the exception that he has not followed the divisions of the rays to the periphery of the lens. Mr. Bowman did not, moreover, overlook the significance of the rays in formation of cataract, for he says, "In another variety of opacity in adults, there are streaks visible either on the anterior or posterior surface, before the nucleus manifests any tendency towards dulness, but instead of converging from the border of the lens, they rather diverge from the central point. These streaks are also irregular in number and direction, and it has never occurred to me to distinguish in them any exact representation of the edges of the mesial planes as they are seen on the surface of the prepared lens; never, certainly, any trilinear figure. But a glance at the representation above given of the complex arrangement of the mesial planes of the adult human lens, will suffice to explain why they are rarely seen in such opacities. In the healthy lens they are in reality too near together, and too irregular to be detected without a glass. The triple divergence can even then only be recognised for a short distance, beyond which the planes seem to diverge and branch without any attempt at geometrical precision. We cannot, therefore, wonder that an opacity, spreading from the centre of the lens, and which consists of broad, ill-shapen streaks, should fail to disclose the radiation of the mesial planes, although it

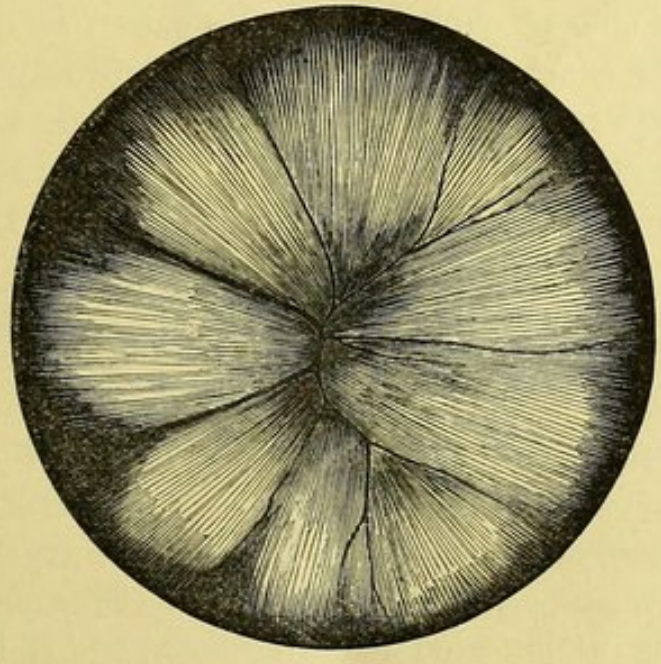
* The parts concerned in the operations of the eye; 1849, p. 72.

† *Loc. cit.*, p. 68.

seems highly probable that its seat is, primarily and essentially, rather in the edges of those planes than in the fibres themselves."* From this extract it will be seen how near, twenty-five years ago, Mr. Bowman approached what I now maintain to be the fact. My own experience corroborates that of Mr. Bowman with respect to non-occurrence of trilinear opacity in the adult lens. I must, however, observe that in one or two instances in old persons, where the nucleus of the lens had become opaque and amber-coloured, I have noticed a gaping of the rays apparently from shrinking of the cortical layers, and that this gaping assumed the trilinear form, the rays of which had the same direction as those of the fœtal lens.†

The most remarkable case I have ever met with is one, an enlarged representation of which is given in the Figure 3. Such a condition as is there shown is, I believe, unique. By

FIG. 3.



* *Loc. cit.*, pp. 72 and 73.

† Since the above was written, my attention has been called by Mr. Buller to a well-marked trilinear opacity in the adult lens. But in this case the streaks had the appearance of an inverted Y, and could not therefore have been due to an opacity extending along the edges of the planes of the trilinear figure of the fœtal lens, unless we imagine the lens to have been inverted.

an examination of this figure, it will be seen that the most superficial fibres of the anterior portion of the lens are opaque, while the rays of the normal stella and the periphery of the lens are quite transparent. The clear lines which are evidently identical with the normal rays, consist of primary, secondary, and even tertiary rays. It will be seen that the secondary ray from the horizontal line to the right of the figure is not yet complete, and only extends a short distance along the anterior surface of the lens. By transmitted light, all the parts shaded black in the engraving allowed the red reflex of the fundus to be seen through them. The opacity was, as I have said, very superficial, for when the pupil was fully dilated with atropine, as represented in the figure, the lens behind the opacity could be seen to be quite transparent. With this eye the patient could read No. 2 Snellen and $V = \frac{20}{200}$. The only history I could obtain from the patient, who was a woman aged 42, was that the sight of this eye had become dim after a blow which she received twenty-two years ago. I can offer no explanation as to nature of the cataract, or as to its exact seat, but wish only to relate the facts. The opacity was not capsular or sub-capsular, for then the stellation would have been invisible. I have frequently met with instances in which one or two sectors were affected, and Ruete* has also figured such cases ; but, as far as I know, no case at all resembling the one now figured has been recorded.

I shall now refer to a phase of this subject which is better known, namely, the subjective examination of the rays, their functions, and their influence on vision. If we throw homocentric light into the eye, we may observe an entoptic figure of the radiating lines of the crystalline lens, as was first pointed out by Listing.† This observer also described an umbilicated radiating body, which he regarded as being due to the separation in the fœtal state of this part of the capsule from the inner surface of the cornea ;

* Bildliche Darstellung Krankheiten des Menschlichen Auges, Leipsig, 1854.

† *Loc. cit.*, p. 17.

but concerning this, Donders says, "In examining the entoptic phenomena I found that multiple images, lines radiating from points of light, and the entoptic image of Listing, pass imperceptibly into one another, and therefore have one and the same origin; but respecting the proper cause in the structure of the lens, I could form no satisfactory idea, and even now I have not been sufficiently successful in my attempts to make known the result."* Whether this umbilicated body is a constant element, or whether, indeed, it be not the result of an erroneous observation, I do not pretend to know; but it must not be forgotten that many of Listing's observations were made on persons who were not acquainted with the subject of ophthalmology or of physiological optics, and that, therefore, they may not have correctly interpreted their subjective sensations. Nor can I offer any other explanation of the case which is mentioned by Listing, in which there were no radiating lines seen entoptically. From what we know of the anatomy of the lens, it seems highly probable that their alleged absence was the result of the negative fallacy of non-observation. Professor Donders has, however, informed me that some time ago he also had a case in which no radiating entoptic lines were seen. And two years ago, Mauthner recorded a case in which a star was seen as a point of light, and in which the vision at this distance was acute, that is, no rays were observed. Beyond the explanation I have given of such cases I can form no opinion, for it is difficult to conceive a condition of the crystalline lens which will allow of normal acuteness of vision, but in which the rays of the stella, at least, the primary rays do not exist; because the trilinear rays seem to be essentially associated with the formation of the lens, while the multilinear ones are as closely connected with its development and growth.

Many of the phenomena of irregular astigmatism have their origin in the rays of the stella. Monophthalmic polyopia, for instance, has been shown to be the same condition as that which gives rise to the rays of a bright star or

* *Loc. cit.*, p. 550.

point of light at a distance for which the eye is not accommodated. We know, also, that by passing a small point of light into the eye, we may observe the rays proceeding from a point of light to pass into the well known radiating entoptic image. The monophthalmic polyopia, rays of stars, and radiating lines of light in the entoptic images are, therefore, all dependent on the same peculiarity in the structure of the lens, namely, the existence of the stella. Donders has, moreover, pointed out the fact that the sectors of the lens which are divided off by the rays of the stella form distinct images of a point of light, for by moving a small aperture before the pupil, he has observed that when the aperture is opposite a sector, a single image is formed; but when it is moved to the boundary between two sectors, two faint images appear, of which, on further displacement, the one first seen disappears. On rapidly moving the small aperture before the pupil, the little images of light jump as it were from one sector to another.*

We may also determine subjectively the influence of the rays of the stella in vision by regarding a large number of fine concentric and equidistant circles, such, for instance, as those figured in Helmholtz plates.† In that figure the inner circle is about the fiftieth of an inch in diameter, and the outer one about 2 inches in diameter, the intervals between the peripheries of the intervening circles being about the fiftieth of an inch. If the eye be made myopic by placing before it a convex glass of, say, 6 inches focal length, and the figure placed at about 5 inches in front of the eye, all the fine circles will be seen clearly defined, that is, if the eye of the observer be otherwise emmetropic. At about $5\frac{2}{10}$ inches the small inner circle becomes obscured on one side, and at about the fifth of an inch further, a second small circle appears at the obscured side. Further still, the circle becomes crenated by the multiplication of images, passing through many sectors. At about 6 inches the circles will no longer be clearly seen throughout their whole circumference, but become divided into sectors, which at $6\frac{1}{10}$ inches are dis-

* *Loc. cit.*, p. 546.

† Fig. 4, plate ii.

tinctly separated. At this distance a large number, from 10 to 15 sectors, consisting of irregularly shaped cones of well-defined portions of the circumferences of the circles may be observed, with intervals of a greyish neutral tint, in which the lines of the circles cannot be made out, so that gaps appear at intervals across the peripheries of the circles. Towards the periphery of the figure secondary and tertiary divisions may be detected in the radiating cones of clear lines, corresponding, I believe, to the divisions of the stellar rays. With my eyes, which are astigmatic to about $\frac{1}{100}$, I can at the greatest distance of distinct vision see clearly the rays in and adjoining the vertical and horizontal meridians, while those in the oblique meridians are less distinct, but may nevertheless be made out. Towards the centre of the figure the obscured intervals are not so well marked, and the circles are broken up into crenated and polygonal figures. It must be noted that if the observer's eye be astigmatic, the anomaly must be corrected, in order to make out the phenomena, which I have here attempted to describe, as seen by myself.

It will be seen that my remarks have applied exclusively to the examination of the living crystalline lens. The opportunities of making a microscopical examination of the commencing cortical opacities are so rare, that it has never fallen to my lot to meet with a cataractous lens after death which was not already advanced far beyond the stage to which my remarks on the formation of cortical opacities apply. I have also confined myself to the consideration of cortical striæ, and do not pretend to offer any explanation of the causes which determine some of the other varieties of cataract, such as the dotted, the zonular, or the nuclear, all of which are probably due to entirely different conditions from those which give rise to the radiated cortical striæ, and many of which are caused by formative changes of various kind, and by the proliferation of the nuclei of the lens fibres.

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