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COMMUNICATIONS

ON COLOUR-RINGS, DRUAULT'S TEST, AND LENS-DISTURBANCE

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THIS paper is mainly an epitome of articles on colour-rings by other writers, and is written to draw attention to a useful differential test that has not yet been described in this journal. My own experience of a colour-ring is added because I think the lental changes on which the ring depends were probably promoted by a pressure-experiment on the eye, and that the record may perhaps be useful as a warning.

So long ago as 1898, A. Druault,⁽¹⁾ working under the direction of Tscherning at the Sorbonne, defined the characters of the colouring that depends on the fibres of the lens, and showed a simple means of distinguishing it from the well-known glaucoma-ring. At the Utrecht Congress of 1899⁽²⁾ he carried the matter further, showing the various causes of colour-rings, their size in relation to that of the obstacles that cause them, and the differential test for the lental ring.

Probably because the lental ring is frequently physiological, and, though often discoverable when carefully looked for, is seldom noticed otherwise, Druault's test seems to have attracted little notice for many years. In seven leading text-books of Ophthalmology, English, American, and German, published since

he first wrote, I find no mention of it. Of late it has been practically rediscovered. Morax⁽³⁾ referred to it in his work on glaucoma in 1921. Elliot⁽⁴⁾ thereupon recognized its importance, and at his suggestion experiments on the subject were undertaken by H. H. Emsley, B.Sc.⁽⁵⁾ and E. F. Fincham, of the Northampton Polytechnic Institute, Clerkenwell. Their results are given in a valuable paper in the Transactions of the Optical Society, and, in so far as they cover the same ground, they confirm Druault's in all respects. Elliot⁽⁶⁾ has since discussed the subject fully from the clinical point of view. Later still Druault⁽⁷⁾ has extended his earlier investigation.

The appearance of a ring of rainbow colours round a light is due to *diffraction*—that "slight tendency to bend round corners," exhibited by light-waves "when part of a wave-front is intercepted by one or more opaque obstacles." The explanation must be sought in a treatise on light, e.g. Edser's "Light for Students"⁽⁸⁾ from which I have just quoted; only the more prominent phenomena concern us here. In studying diffraction artificial obstacles—*gratings* of different kinds—are placed before the eye while it views a small bright light, and by comparing the appearances so produced with those which are seen by certain eyes without a grating, the nature of the obstacles existing in the latter is inferred.

A grating in which the obstacles are parallel straight lines all running in one direction, diffracts the light only in a direction perpendicular to the lines; thus lines standing vertically before the eye diffract the light horizontally; and in so doing they break it up into its constituent colours and so produce a narrow spectrum on each side of the central light, on a level with it and at a distance from it, the violet being towards the light, the red away from it. It follows that when the obstacles are bundles of parallel straight lines distributed in all directions like the spokes of a wheel, light is diffracted in all directions, and the innumerable narrow spectra combine to form a colour-ring round the central light and at a distance from it, the colours being placed as just stated. Under certain conditions normal and abnormal, and especially when the pupil is large, the fibres of the lens act in this way.

In such a case let a screen pass slowly before the eye, its edge being vertical (Fig. 1). So long as at least one-half of the pupil remains uncovered, the entering light will fall on fibre-bundles running in all directions, and the colour-ring will remain entire; but when more than half is covered the light will strike no vertical fibres and will no longer be diffracted horizontally; the sides of the ring will, therefore, begin to disappear. When little of the pupil remains free, the light that still enters will fall only on fibres that are nearly horizontal, and will be diffracted only in directions

nearly vertical; hence only small portions of the ring above and below will remain. *The ring disappears in segments.*

Instead of such a screen one may use an opaque strip narrower than the pupil; this, when held in a median position, will allow light to enter at both sides of the pupil; or one may conveniently employ a narrow slit-like aperture, as suggested by Emsley; or a small round aperture may be placed over different parts of the pupil in succession. Different screens have different effects, as shown in various published illustrations, but the principle is the same for all: the fibre-bundles that are hidden from the light diffract no light, and the segments of the ring that depend upon them disappear. A colour-ring that behaves in this way under the

FIG. 1.

Segments of a lental diffraction-ring remaining when more than one-half of the pupil is covered. The arrow shows the direction in which the screen travels. (Reproduced from Druault—1898.)

screen-test certainly depends on the lens-fibres, for it can only depend on linear obstacles arranged radially, and the lens-fibres are the only obstacles of that kind in the media of the eye.

On the other hand a grating that presents numerous rounded particles, e.g. a glass plate strewn with lycopodium spores, produces a colour-ring in a different way. Each particle, by reason of its form, diffracts in all directions; the spectrum due to a single particle is too feeble to be visible, but the joint effect is a brilliant spectral ring. A ring thus produced behaves differently when screened: *it fades gradually as the screen covers more and more of the pupil; it does not disappear in segments; so long as it is visible it is entire*, for any light still entering the pupil meets with obstacles that diffract it in all directions. That is what happens when a glaucoma-ring is tested with a screen.

What are the obstacles that cause the glaucoma-ring? Every fibre, cell, and nucleus in the media of the eye that differs in the least from its surroundings in refractive index or transparency is theoretically a diffracting body; in reality the spectra, if any, so caused are usually so feeble, or so far abolished by over-lapping, as to be invisible. To ascertain what are the bodies that do occasionally induce visible spectra two methods have been adopted. The size of the visible rings has been compared with the calculated size of the rings which would be formed by the various fibres and cells in the media if they became effective as diffracting bodies; and the structural layers of the media have as far as possible been examined separately for evidence of visible diffraction. Something must be said about these methods before the results are stated.

The diameter of a ring may be measured in different ways. One may place the light at a given distance from the eye and measure the ring obtained, or one may vary the distance until a ring of given size is obtained and then measure the distance. In either case the essential magnitudes are the working distance and the diameter of the ring at that distance.

Druault selects the yellow zone for measurement because, though less obvious in colour, it is narrower than the others and its position between the red and green is determined more easily than the outer or inner margin of the whole ring. Elliot's measurements refer to the outer edge of the red. The radius of the ring is measured from the central light by means of a scale or pointer. A metal screen admitting the chief light through a round aperture, and admitting a feebler light through a smaller aperture at a fixed distance from the first, as indicator for the position of the selected zone when the eye stands at the requisite distance, has been employed in laboratory work.

Difficulty in measuring a colour-ring may arise through inability of the eye to define the scale or pointer clearly. In my own case the lental disturbance multiplies the image of the pointer and renders its position on the spectrum uncertain, and the following method answers better:—Two lighted candles are placed at a measured distance from the eye; the distance between them is adjusted until the yellow zones of the two rings appear to blend at the half-way point; the candles are then blown out and the distance between their wicks is measured. This gives the diameter of the yellow zone. The change of colour when the two rings overlap aids in the adjustment, for when the red is intensified one knows that the flames are slightly too far apart; when the green brightens, they are too near; when the pale yellow band between them is at its best, the yellows are blended. The rough instrument shown in Fig. 2 helps considerably in my own case, and should

measurements of colour-rings prove valuable clinically, in connection with the progress of a glaucoma or in any other way, such an instrument furnished with very small electric lamps instead of candles, and marked in degrees and tenths (intervals of 6 minutes) would be found, I think, to work conveniently and quickly.

The size of a colour-ring is best stated in degrees and minutes, for it then holds good for all distances, whereas the linear measurement varies with the distance. But the minutes, however carefully worked out from the linear measurement, must remain doubtful, for an error of 1 mm. in measuring the diameter at 1 metre means an angular error of about 3.5 minutes; an error of

FIG. 2.

When the knob is held to the cheek close below the eye, the candles (Price's night-lights) are 1 metre from the eye. They are movable in the cross-piece, and their distance from each other is measured when the yellow zones blend. To keep their distance from the eye correctly they should move in an arc of a circle instead of in a straight line, but the angles in question are so small that the results would not be appreciably different.

2 mm. at twice that distance means the same, and so on; and larger errors than these are likely to occur. Druault puts the uncertainty at 5 to 10 minutes. It can be lessened by using monochromatic light.

The angular size of a colour-ring is seen at once if one measures with a tangent scale; but it is easily found from a linear measurement. The radius of the ring, divided by the distance between eye and light, is the "tangent" of half the angle required; a table of tangents will show the corresponding number of degrees, and by doubling this we have the angle required. But without help of a table, if working at 1 metre distance, one finds the angle approximately by dividing the diameter of the ring in mm. by 17.5; if working at 2 metres the divisor must be doubled, and so on. The error incurred is much smaller than those that easily

arise in measuring the radius or diameter and is therefore unimportant. (See Figs. 3 and 4.)

For comparison with actual measurements, the size of the diffraction-rings that would be given by the various cellular and fibrous layers of the media, if they gave any, has been calculated from the following facts. The angular dimension of a diffraction-ring is determined primarily by the wave-lengths of light, the

FIG. 3.

FIG. 4.

FIG. 3—*one light*. Let E be the position of the eye, and C that of the candle at 1 metre from the eye; and let $D'D^2$ be the diameter of the colour-ring; then $D'E D^2$ is the angle that we want to measure. On a circle of 1 metre radius 1° measures (approximately) 17.5 mm, hence the number of degrees in an arc of that circle may be found by dividing its length by 17.5. But in the case of a small angle, the straight tangential line $D'D^2$ is so nearly equal to the corresponding arc in length, that it may be substituted for it; thus if we measure the angle by dividing the diameter of the ring by 17.5, the error will be an over-estimate of about 2.5 minutes for an angle of 12° , and of about 1 minute for an angle of 6° .

FIG. 4—*two lights*. Let E be the position of the eye as before, and C^1 and C^2 , each at 1 metre from E, the positions of the candles when the yellow zones blend. Since the working distance is the same as in the previous case, the diameters of the colour-rings $D'D^2$, and the corresponding angles, $D'E D^2$, are equal in the two cases; and since the angle $C^1E C^2$ equals the angle $D'E D^2$ we may measure it instead of the latter. Now if we substitute the chord C^1C^2 for the corresponding arc we get an error as before, but it is opposite in kind and smaller in amount: dividing the chord by 17.5 we get an under-estimate of about 1.5 minutes for an angle of 12° , and of about $1/3$ minute for an angle of 6° .

diameters of the several colour-zones being directly proportional to their wave-lengths, namely greatest for the red, smallest for the violet. It varies inversely with the diameter of the diffracting particles, or with their spacing if linear: the smaller the diameter, or the closer the spacing, the larger the ring. It varies for given obstacles with their position in the eye: the nearer they are to the retina, the smaller is the ring (for formulae and explanatory diagrams, see Druault, 1899 and 1923).

These comparisons, together with Druault's test and certain

direct experiments, have left little doubt as to which are the parts that cause the best-known colour-rings.

The vitreous has been suspected, but apparently without good reason. Koeppe⁽⁹⁾ attributes the glaucoma-ring to a certain arrangement of the stroma. (Druault cites evidence against such an arrangement, and shows that even if it existed and produced a diffraction-ring under pressure, the latter would be very much smaller than the glaucoma-ring. W. Nordenson⁽¹⁰⁾ has attacked the question by experiment. Having trephined the back of an ox-eye and closed the 11 mm. aperture with a conical glass plug, he placed the eye in a suitable support, directed it vertically downwards over an adjustable lamp, and viewed the media under varying pressure and illumination. Under increase of pressure the transparency of the cornea diminished, but that of the vitreous, as judged by the definition of the free iris-edge seen through it from behind, was unaffected. Portions of the vitreous subjected to very high pressure in a glass cell connected with a manometer showed no loss of transparency and no diffraction.

The lens-fibres, removed from their surroundings, have been found to produce partial or complete diffraction rings according to their directions in the parts examined. The arrangement of the fibres differs somewhat in man and animals, and in man at different ages. In the ox, the central area of the lens gives six equidistant segments of a colour-ring, not an entire ring, for the grouping of the fibres is tripartite, nearly as in the human foetus at six months. In the adult human lens the bundles are more nearly radial and, therefore, produce a complete ring, but the central area gives no visible diffraction: a round aperture of 3 mm. or less before the centre of the pupil banishes the ring. Sections of the lens 0.5 mm. in thickness give visible diffraction; thinner sections do so only when the fibres have been defined by staining.

The ring caused by the lens-fibres is seen by the majority of healthy eyes if carefully tested after dilatation of the pupil, and for this purpose cocain is sufficient. It measures 6° to 7° . It is less brilliant than the glaucoma-ring. Because of the peculiar arrangement of the fibre-bundles, it varies in brightness at different parts of the circle, and is somewhat striate in appearance and notched at the edges; for the same reason the axes of the segments that remain when the screen is used are often slightly oblique in relation to the edge of the screen.

The epithelium of the lens when separated from the fibres and stained gave, in certain preparations from the calf, well-marked diffraction rings, but without staining it gave none (Mme. Druault-Toufesco⁽⁷⁾).

The endothelium of the cornea. Following a method previously used by Schiötz⁽¹¹⁾, Druault experimented on human corneae

removed with a ring of sclera and fixed without distortion in a cylindrical box filled with normal saline. Through glass windows in the ends of the box and through the contained cornea immersed in fluid, he viewed the source of light. The intact cornea gave a diffraction-ring of about 4° (yellow zone); when the epithelium was removed by scraping, the ring persisted, but when the endothelium was removed it disappeared. Its size was approximately that which, according to calculation, these cells should give. Druault identifies it with a physiological ring discovered by Tscherning; it was not the glaucoma-ring.

The epithelium of the cornea. Fuchs⁽¹²⁾ discovered long ago that in glaucomatous eyes the anterior-fibre-layers of the cornea become oedematous, and that particles of fluid pass along the nerve-canals in Bowman's membrane and collect beneath and between the epithelial cells lying immediately on it. Schiötz⁽¹¹⁾ shortly afterwards, experimenting on human corneae with the apparatus mentioned above, saw in the absence of pressure a ring of about 4° , apparently the ring which Druault attributes to the endothelium of the cornea; and when the pressure behind the cornea was raised to a certain height, a second ring about twice as large as the first. This larger ring of about 8° , he held to be a diffraction-ring due to the basal cells of the corneal epithelium; measurements of glaucoma-rings tend on the whole to confirm that view.

Laqueur⁽¹³⁾ measured many such rings and recorded 10° to 11° as the usual size for the outer edge of the red zone, which would be about 8° to 9° for the yellow; Druault measured four, and found 8° to 9° (yellow) in all of them; Emsley and Fincham measured two, and found 6° to 7° (yellow) in both; while I am writing my son has measured one at my request and found 7.7° ; Elliot, among a larger number, found greater variation, namely from about 7° to about 12° (outer edge of ring, which appeared to differ in colour in different cases). Other measurements are on record, some of them differing surprisingly, but not having direct access to them, and being uncertain as to the zone measured, I omit them.

The glaucoma-ring, then, is in all probability due to slight oedema at the surface of Bowman's membrane, but whether the cells or the particles of fluid beneath them are the diffracting bodies seems doubtful. To explain a difference in the size of the ring in different persons, and in the same person at different times (Elliot), one may suppose the oedema to extend by degrees from the basal cells to the larger ones nearer to the surface; or one may attribute it to gradual increase in the size of the droplets of fluid, though it is difficult to imagine these latter to remain sufficiently alike in size to give a well-defined diffraction-ring; in either case the ring should diminish in size as the oedema increases, and

enlarge as the attack passes off; observations on that point would be interesting. It is noteworthy, I think, that a colour-ring is not immediately producible by finger-pressure on a healthy eye, though the rise of the chamber-pressure so induced may be much greater than that which accompanies the appearance of a glaucoma-ring. This suggests that an eye threatened with glaucoma is already suffering from slowing of the circulation and incipient oedema of the cornea before the colour-ring appears.

Particles on the surface of the cornea. Blood corpuscles on the cornea give a brilliant diffraction-ring, as may be easily proved by placing a drop of blood on the inner surface of one's lower eyelid; the ring measures nearly 14° . Pus corpuscles have been seen to produce a similar ring immediately after the opening of a small abscess at the edge of the eyelid. Again, leucocytes or fatty particles on the cornea are probably responsible for the rings that sometimes occur with conjunctivitis, and after sleep. Minute air-bubbles produced by the rubbing of mucous between eye and lid are suggested as a possible cause by Elliot; he has found that such bubbles are easily obtained by rubbing a film of white of egg between two glass slides, and that they give diffraction phenomena. All such colour-rings are at once banished by cleansing the surface of the cornea, and are thereby distinguished from those that are due to obstacles below the surface.

Personal experience. Early in 1920, at age 74, I saw one evening an unmistakable rainbow-ring with my *right* eye; I had never seen such a ring before and was not looking for it. The circumstances were unusual. Owing to gas-repairs two candles on a central table were the only lights in the room, and I was tired with gardening and may have had larger pupils than usual. It is likely that the ring would have been seen earlier if looked for under similar conditions. Knowing that the eye had altered in focus of late, I judged the ring to be lental and was satisfied on that point during the next day or two by finding that it was always present when properly looked for, and never associated with discomfort, injection of the eye, or inequality of the pupils. The screen test would have settled the question in a few seconds at the outset, but I have to confess that though Druault's articles had been read when they appeared and were on my shelf, they were forgotten until Elliot's reference to the screen-test recalled them to my mind. Since first seen the ring has always been visible when I choose to look for it.

Characters of the ring. It is best seen with a single small moderately bright light, all surrounding surfaces being in comparative darkness, e.g. a lucifer match at arm's length, a candle at a few feet with a dark curtain at some considerable distance

behind it, or a lamp of medium brightness out of doors at night. It shows, from without inwards, zones of red, faint yellow, green, and sometimes feebly-seen blue, all without sharp limits. It is best measured by the two-light method described above, for when a single light and pointer are used, the image of the latter is blurred to the naked eye, and the size of the ring is altered by the correcting glass. The yellow zone subtends 60° .

The brightness of the ring varies with the size of the pupil, and sometimes in an unexpected way. Thus, I have noticed several times, and at first with surprise, that on going from a well-lighted room into the comparative darkness of a moon-lit garden, the colour-ring round the moon, at first quite brilliant, soon appears to pale; the explanation is that for the first few moments the retina is still adapted for strong light and consequently the pupil dilates to give as much light as possible (the stimulus to contraction is feeble); then, as the retina adapts itself to the feebler light, the stimulus increases and the pupil returns more nearly to its ordinary size; more of the lens is now covered, and the diffraction-ring tends to disappear. Experimental dilatation of the pupil to 6 mm. by cocaine increases the brightness of the ring but does not alter it in any other way. Subsequent contraction to less than the usual size by pilocarpin abolishes the ring entirely for several hours—an effect which might mislead an examiner if the lental origin of a ring had not been already proved by Druault's test. A stenopaic screen with aperture of 2 mm. placed centrally before the pupil banishes the ring entirely.

Under the screen-test the ring disappears in segments in the way already described; Fig. 1 might have been drawn from what my right eye sees except that the segments are not so sharply defined as in the picture, and that the central light is multiplied. Whatever form of screen be used—a straight-edged shutter, a narrow bar, a slit, or a small round aperture—I find it convenient to adapt it to the trial frame; by very small movements of the head one can then vary its relation to the pupil steadily and with great precision.

Under no conditions have I been able to see the slightest sign of a colour-ring with the *left* eye—not even when the pupil was similarly dilated to 6 mm. by cocaine.

Condition of the eyes. Formerly the two eyes were equally good. Each had compound myopic astigmatism of low degree, the maximum error hardly ever reaching—1 D, and diminishing as age advanced; each had V $\frac{5}{4}$ and sometimes $\frac{5}{3}$. Definite inequality was first recorded at age 71 (November, 1916: R.E. —1., V $\frac{5}{4}$; L.E. —0.5 cyl. at 60° , V $\frac{5}{4}$), but may have been present some months earlier. Since that time the *right* has gradually acquired a considerable myopia while the *left* has remained almost unchanged: (February, 1924: R.E. —7. and

—1.5 cyl. at 45° , V 5/7 partly; L.E. : —0.37 and —0.87 cyl. at 55° , V 5/3 partly).

Together with the myopia the *right* eye has acquired a well-marked polyopia for small bright lights. Fig. 5 is an attempt to show the appearance at 1 metre distance, of a 5 mm. aperture in a metal screen placed close in front of a candle-lamp; it was made by affixing white gummed labels to a black card. At greater distances each disc is broken up into many small lights. A bicycle lamp at 20 or 30 yards presents a multitude of tiny lights forming a bright ring round an unbroken dark area. On a dark night an approaching troop of cyclists, themselves invisible but each bearing such a ring, affords a spectacle that is very attractive though not to be desired.

FIG. 5.

Appearance of a circular disc of light 5 mm. in diameter, as seen at 1 metre distance by the *right* eye. The contours of the multiple images in the picture are somewhat too sharp, especially at the lower part of the group. The correcting glass abolishes the polyopia almost completely and gives a fairly good picture of the disc of light.

The *left* eye sees the 5 mm. disc of light perfectly, and when made as myopic as the right by means of a convex lens, it sees it as a circular diffusion-area with no dark centre but uniformly occupied throughout by faintly distinguishable contiguous bright images of the disc. When *both* eyes are open, the single true image of a light is seen within the ring of multiple scattered images, and about at its centre.

Examined by Mr. Wilfrid Allport and my son, the *right* lens shows a centrally placed, deeply seated, hazy patch, not sharply defined and not dense enough to hide the red of the fundus; around this it is clearer and permits a fairly good view of the disc; towards the periphery it is clear except at the lower part of the circle, where there is a denser fan-shaped opacity. The *left* lens shows slight peripheral striae such as are usual at this time of life.

The entoptic picture corresponds. Looking towards the sky through a very small pin-hole, the *right* eye sees a central brown

patch shaped somewhat like the central area in Fig. 5, and a fan-like opacity approaching it from below.

A result of experimental pressure? These changes, of course, may be merely those of ordinary senile cataract with no unusual origin; I suspect, however, that they were promoted if not started by finger-pressure on the eye. In 1917, when studying retinal blood-pressure, I made the well-known experiment of stopping the retinal circulation by finger-pressure on the eye. Using a candle flame as fixation object, and placing the right middle finger on the right lower eyelid, I made pressure on the eye until the visual field, including the image of the candle, was momentarily abolished; I think this was done more than once. (I found, as I had done years earlier, that one cannot in this way obtain a partial or gradual contraction of the field, as some have said, but that it vanishes as a whole, except at the fixation-point where it is more persistent than elsewhere.) No pain occurred, no change was noted afterwards, and I did not think of the experiment again until some months later when a very noticeable development of myopia in this eye set me wondering; I then began to suspect that the experiment was to some extent responsible, though a slight difference between the eyes was already present before the experiment was made.

I know of no evidence to show that experimental pressure on the eye has done damage, but the idea is not a new one. Elliot⁽¹⁴⁾, discussing the work of Bailliart and his followers, dwells on the risk of haemorrhage. I think that in advanced life the risk of damaging the lens is quite as great. Foerster's method of ripening a cataract proved to those of us who tried it that moderate disturbance of a lens that is beginning to degenerate will sometimes greatly quicken the process; and even in a senile lens that still seems functionally perfect the growth of the fibres is slackened, and the bundles at the periphery are tending to separate from each other, and are likely to do so under any deforming pressure. In early life the risk is doubtless smaller, as my own experience seems to show.

In 1878, when first studying certain glaucoma problems⁽¹⁵⁾, I made an apparatus that enabled me to experiment accurately on my own right eye. Pressure was applied through the lower lid by a flat ivory knob 5 mm. in diameter in an upward direction towards the centre of the globe, and on at least one occasion it was loaded up to 100 grammes. That experiment did no harm, but in reporting it I gave a caution:—"It should not be incautiously repeated. I judged the safety . . . by the sensation of my eye, and felt nothing to be called pain even with the great weight of 100 grammes (=3 ounces about); but I did not consider the danger involved in such extreme distortion of the surface near to the lens."

That was in the fourth decade of life; in the eighth, when the risk was greater, I forgot my own warning.

The changes in the lens afford no proof, but at least they are consistent with my suspicion. The chief opacity lies in the lower part of the lens, where the pressure of the finger would be likely to take chief effect. The deeply seated hazy patch indicates disturbance of the posterior cortical layers, and explains the central dark area in the retinal picture (Fig. 5). The multiple images are produced by a surrounding zone which, though comparatively clear, has suffered sectorial disturbance. The myopia of this zone must be due either to a change of density in the nucleus—which is unlikely, for there is no such change in the fellow eye—or to a change of form, possibly promoted by stretching of the suspensory ligament; we know that the attachment of the lens to its surroundings, both behind and at its periphery, weakens as life advances. The complete absence of a colour-ring and the nearly complete absence of refractive change in the *left* eye, in spite of peripheral striae, suggest an additional factor for these changes in the *right*.

At this time of life, the other eye being excellent, these changes are of small importance; to me, so far, their interest has been far greater than their inconvenience; moreover the suspicion I have spoken of is not unwelcome for it betters the prospect for the other eye; but one can imagine cases in which a similar sequence might give rise to grave concern. It is for this reason that I have put my experience on record.

I am much indebted to Mr. Lawford, Professor Schiötz, Col. Elliot, and Dr. W. Nordenson for enabling me to read certain articles referred to in this paper, and to Dr. Barlow of the Birmingham University for examining it with regard to questions of physics.

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