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VISUAL PHENOMENA CONNECTED WITH THE YELLOW SPOT.

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I PROPOSE considering a certain number of subjective and entoptic phenomena connected with the yellow spot.

I. *Various appearances in the field of vision due to peculiarities of the yellow spot.*

1. *Loewe's experiment.* If we look at a clear white surface through a solution of chloride of chromium, which is of a celadon green colour, we shall see a purple spot in the centre which varies in size and shape with different persons. On careful examination it will be found to consist of three portions, the centre corresponding to the fovea appears as a bright purple disk, the middle corresponding to the non-vascular portion of the yellow spot appearing as a dark green ring, and lastly Loewi's ring corresponding more or less accurately to the outer feeble yellow portions of the yellow spot which appears as a purple ring surrounding the central portion and possessing a diameter twice or three times as large.

2. *Apparent size of regions of yellow spot in field of vision.* The region corresponding to the yellow spot occupies a considerable area in the field of vision. I find that the visual angle which any portion subtends can be easily measured by projecting the after-image of an object occupying a known visual angle on the sky above a house. A comparison is easily made in both cases with portions of the house. If an observer look straight at the cloudless sky, preferably about three hours before the sun sets, for about ten to twenty seconds, a disk or an ellipse with the long diameter horizontal and which is to me of about nine degrees appears in the sky. Inside this is a central darker portion of about two degrees in each diameter and this surrounds a central

[1] A paper read in the Phys. Section of the Brit. Med. Ass. 1910.

brighter portion which corresponds to the point of direct vision. This is about 40 to 50 minutes in diameter and is circular in form. See Fig. 1.

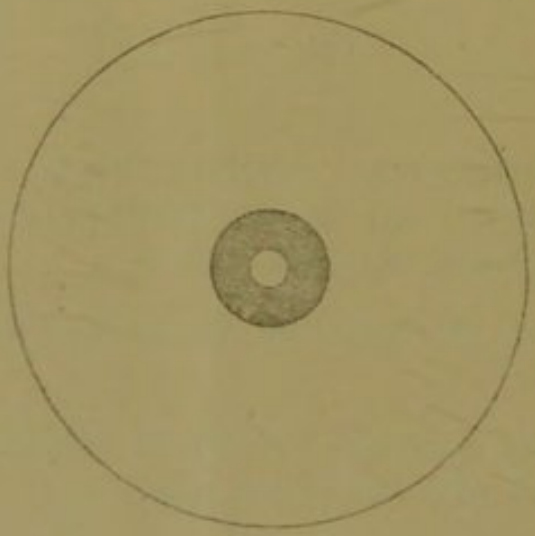

Fig. 1.

Helmholtz[1] gives a disk of the diameter of about 40 to 50 minutes as the apparent size of the fovea in the field of vision, and the diameter of the aureola which corresponds to the non-vascular portion of the yellow spot and is the portion where the yellow is most intense as about two degrees. This is correct for me. The remaining portion which corresponds more or less exactly to the remainder of the yellow spot is Loewi's ring.

3. *Appearance of central region with different intensities of light.* Exner[2] points out that with feeble light the central region is seen as a dark disk surrounded by Loewi's ring and that as the intensity is increased this region becomes brighter and brighter until it becomes more luminous than its surroundings, the fovea being specially noticeable as a bright disk of greater intensity than any other part.

The appearance of Loewi's ring varies with different persons and in different conditions. Loewi saw the ring circular and so do I but Helmholtz saw it rhomboidal. I see all three portions circular in the conditions I have just mentioned and every part is darker than the surrounding sky, the region corresponding to the fovea being the brightest of the three. I have seen after looking at the sky the central portion of the yellow spot appear as a bright yellow spot with a dark centre. It was circular in form and on one occasion lasted for ten minutes before disappearing.

[1] *Physiol. Optik*, p. 567.

[2] *Ctrlb. f. d. Med. Wssnsch.* S. 594. 1868.

When the light is feeble the foveal region is not seen and the central dark portion is larger and Loewi's ring is smaller. The shape is then more often oval, rhomboidal, or irregular. Fig. 2 shows the appearance to my right eye on a dark night with a cloudless sky. The dark centre was surrounded by a lighter portion. Bright lines then came from the periphery and proceeded in an irregular manner to the centre. When these lines reached the centre each broke up in a very similar way to a rocket and left the surrounding portion lighter than before. This continued until the yellow spot region became lighter instead of darker than the ground.

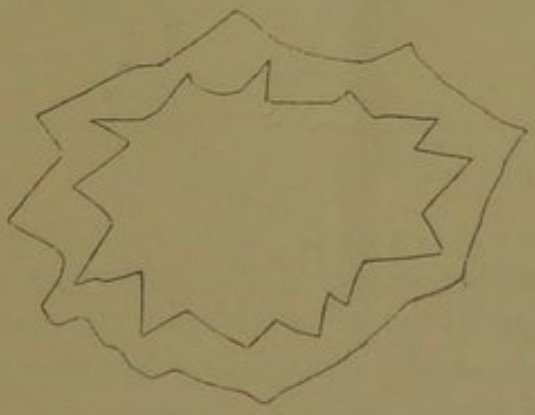

Fig. 2.

I have seen the yellow spot region largest and darkest when on waking in the early morning I have directed my eyes to the white ceiling. The whole of the central portion of the field of vision appeared as a black disk surrounded by luminous circles. These circles then interlaced and encroached on the central black portion which disappeared from without inwards.

There are several ways in which the region of the yellow spot may be seen bright on a dark ground. Helmholtz[1] has seen it on waking in the morning and looking at a dark background after having first exposed the eyes to the light from a large window. A disk of dazzling brightness is seen of the size of the non-vascular areola of the yellow spot.

I find that the region corresponding to the non-vascular portion of the yellow spot can be seen very well as a bright spot on a dark ground in the following way. If one eye be closed and the other directed to the sky through a deep red glass, after ten or twenty seconds the

[1] *Optik Physiol.* S. 569.

central portion will appear purple instead of red. If the eye be now closed and covered with the hand so as to exclude all light, the field of vision appears green with the exception of the centre which is seen as a bright red spot, much brighter than the rest of the field. The green gradually invades this red from without inwards until the whole field of vision is one uniform green and the centre becomes of similar brightness to the parts surrounding it. See Fig. 3.

Fig. 3.

Fig. 4 shows a sector of one of the subjective appearances of the central region as seen by me on awaking in the morning. The centre has a spotted appearance, the circles being larger at the periphery, with gradually increasing black intervals. Outside the macular region the spots of light are further apart and less defined.

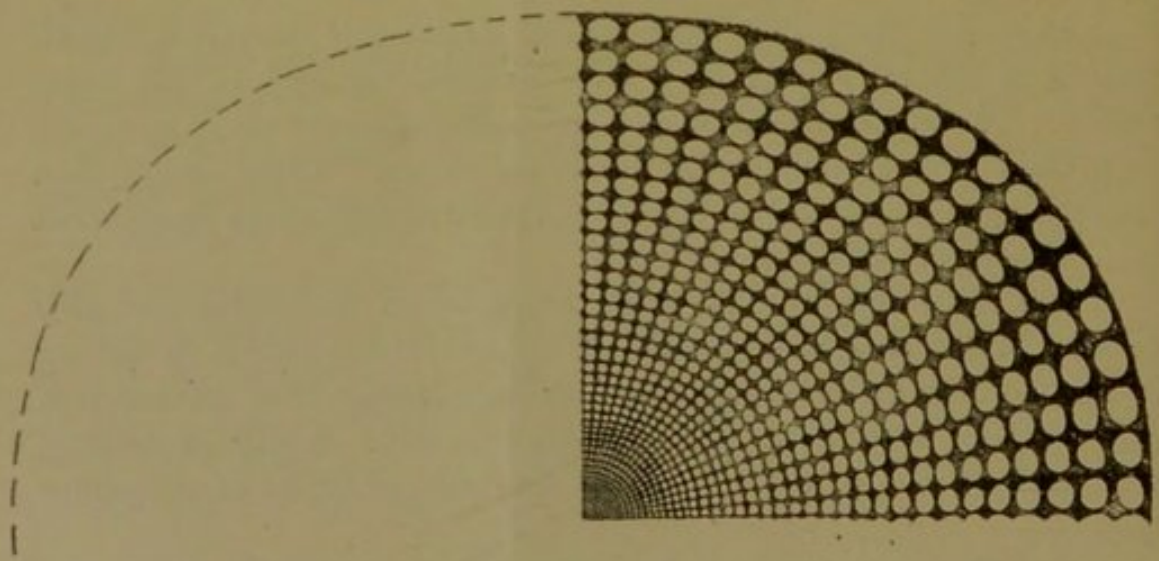

Fig. 4.

The retina after a night's rest is in a most favourable state for entoptic experiments. On awaking in the morning and then directing the eyes to a white ceiling the region corresponding to the yellow spot

is marked out as an oval black patch, and light appears to invade this patch from without inwards. Helmholtz concludes from this that light is perceived an instant later in the central as compared to the peripheral portions of the retina. Helmholtz attributes this observation to Maxwell[1] but as a matter of fact Maxwell said exactly the opposite. He says: "If we look steadily at an object behind a series of bright bars which move in front of it, we shall see a curious bending of the bars as they come up to the place of the yellow spot. The part which comes over the spot seems to start in advance of the rest of the bar, and this would seem to indicate a greater rapidity of sensation at the yellow spot than in the surrounding retina."

I agree with both these contradictory statements.

II. *Entoptic appearance of the yellow spot and the blood vessels of the retina.*

The yellow spot and the blood vessels of the retina may be seen entoptically in several ways. Purkinje described the first three methods[2].

1. *Illumination through sclerotic.* If by means of a lens of short focus a light, as intense as can be endured without discomfort, be concentrated on the sclerotic as far as possible from the cornea whilst the eye is directed towards a dark surface the vessels of the retina will be plainly visible on a yellowish red background. The finest capillaries can be seen and it will be noticed that these are absent in the centre of the field of vision, the vacant space being bordered by the loops of the capillaries. Whilst the portion of the field of vision corresponding to the rest of the retina appears of a uniform illumination, that in the centre where there are no capillaries is brighter and has an appearance similar to that of the fovea under the microscope in which the cones are seen as a series of small round circles, when the retina is viewed from its external side. See centre of Fig. 4. Helmholtz describes the entoptic appearance of this central non-vascular portion as being similar to that of shagreened leather. If the light be moved upwards on the sclerotic whilst the eye is kept fixed the images of the vessels appear to move in the same direction whilst the central non-vascular portion appears to move slightly in the opposite direction. Helmholtz after showing in a very complete manner how the shadows of the arteries

[1] *Report of Brit. Assoc.* II. p. 12. 1856.

[2] *Btr. z. Kenntn. d. Sehens*, S. 89. 1819. *Neue Btr.* S. 115, 117. 1825.

cause the effects which are seen, remarks that the appearance of the central portion is undoubtedly not produced in the same manner. It will be noticed that the vascular tree encroaches on the central portion on the side opposite the light whilst above and below it only touches it; on the side nearest the light there is an interval between the two. All the appearances remain the same whether the light be at the internal or external angle of the eye. The reason of this is that the vascular system is situated anteriorly to the portion of retina which gives rise to the spotted appearance. The portion of retina which gives rise to this appearance exactly corresponds to the non-vascular portion of the retina. When I have repeated this experiment, and I have found the light from an acetylene lamp concentrated on the sclerotic answer admirably, the central portion has first appeared dark but in addition to the vessels concentric bluish-violet coloured waves are seen. These waves appear as bluish-violet coloured circles of light which roll inwards from the outer part of the field of vision. They occupy the whole circumference and appear as steadily diminishing circles. Each succeeding circle reaches further towards the central portion of the field of vision until one touches it. It then appears to break up into a star-shaped figure and becomes much brighter. This is then replaced by the spotted appearance already mentioned.

J. H. Nuel[1] and L. Wolffberg[2] have come to the conclusion from careful measurements that the appearance of the central portion corresponds to the mosaic formed by the cones of the fovea.

2. *Illumination through cornea.* The second method of seeing the blood vessels of the retina is similar to the first only the light is allowed to enter the eye through the cornea. The observer being in a darkened room and the eyes being directed forward a candle is moved backwards and forwards either at the side or above the eye. The fine vessels and capillaries are not seen so well in this method as in the other two. In the central portion several observers have seen a bright disk circular or elliptical in shape, others have been unable to see the whole of the disk. In ordinary circumstances I only see a portion of the disk, it is bordered on its outer side, the side nearest the light, by a dark crescent and external to this is a bright crescent which is much brighter than any portion of the interior of the disk. When the light is moved upwards the bright crescent also appears to move upwards. When I move the light much more quickly and with a circular movement I am able to see

[1] *Arch. de Biol.* T. IV. 1883.
[2] *Arch. für Augenhl.* XVI. 1886.

the whole of the disk. The appearance then often changes to that seen in the first method, this appearance being generally preceded by the pale bluish-violet circles. I often find that the central portion appears dark and not light. I find that the central portion appears dark with red light whilst with green light it appears bright and spotted, the rest of the field also appears brighter.

3. *Illumination through pinhole.* The third method of seeing the retinal vessels consists in viewing a large uniformly illuminated surface, as for instance the sky, through a pin hole aperture which is moved rapidly backwards and forwards in front of the eye. The capillaries are very clearly defined, dark on a light ground. In the centre there is a portion free from vessels and bounded by the convex side of the loops of the capillaries.

4. *Illumination when the retina is specially sensitive.* I find that I can see the retinal vessels very clearly if on opening my eyes in the morning on awaking I immediately direct them to the white ceiling. The larger vessels appear very black and distinct. The central portion of the field of vision appears as an oval black patch and light appears to invade this patch from without inwards. The effect is only momentary.

III. *Currents seen in the field of vision not due to the circulation.*

1. *Currents seen with one eye partially covered.* If one eye be partially covered with an opaque disk whilst both eyes are directed forwards in a not too brightly illuminated room and special attention be paid to the covered eye an appearance of whirling currents will be seen with this eye. See Fig. 5. These currents appear to be directed towards the centre and have a very similar appearance to a whirlpool. On closing both eyes all the portion in which the whirling currents are seen appears as dull purple. These currents cannot be due to vessels because we know that the centre of the retina, corresponding to the point where the greatest movement is seen, is free from vessels. The appearance is also very different from that of the movement of blood in vessels. The experiment succeeds best if the eyes have been previously exposed to a fairly bright light. An opaque disk in a spectacle frame suffices admirably, a certain amount of light being allowed to enter the eye from the periphery.

2. *Currents seen in the light with one or both eyes open.* It is easy to see the currents at almost any time on regarding fixedly a not too

brightly illuminated surface. I find that it is better to use only one eye but they can be seen with both eyes open. The first appearance which is always visible to me is a star-shaped figure corresponding to the region of the fovea. Fig. 6. When seen with one eye this star has eight rays. It is due to the structure of the lens. There appears to be rapid

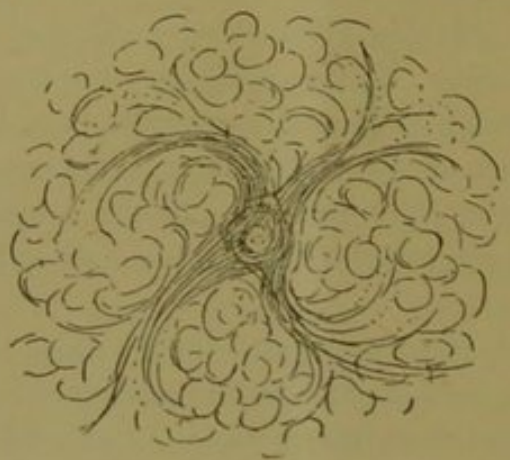

Fig. 5.

Fig. 6.

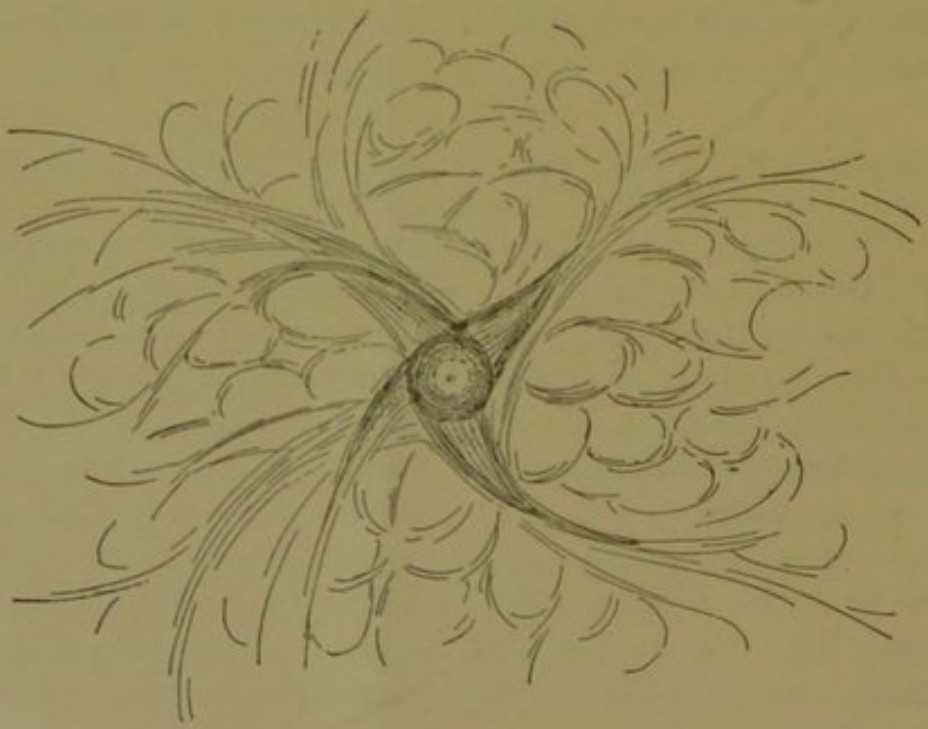

Fig. 7.

circular movement behind this star, that is, the movement appears to be further off in the field of vision, like a top spinning or a catherine wheel, the rays of the star remaining always visible and stationary. The movement is from left to right with the right eye and from right

to left with the left eye. The field of vision then becomes dark and the movement spreads until it covers the whole region corresponding to the yellow spot and the currents in this outer portion form a network with wide meshes. Fig. 7. The currents seem to proceed from four main places of entry, two horizonal and two vertical. The movement is at first slow and then gets more and more rapid, especially in the centre.

3. *Currents seen in the dark.* Currents can be seen in the dark which correspond in their general character to those seen in the light. The whirling in the centre is usually very noticeable. Generally pale bluish-violet circles form in the periphery and these gradually contract and advance on the centre of the field of vision. When the circle reaches the centre it breaks up into a star-shaped figure and becomes much brighter. This is then succeeded by another contracting circle.

4. *Currents seen through yellow-green glass.* I see these currents with yellow-green glass when the eye has become fatigued by looking through the glass, the whole field becomes dark and the whirling currents are seen. The general form remains the same. Fig. 7 should be compared with the drawing given by Exner[1] as the figure seen entoptically with red light. It is evident that he saw the same figure but he does not say anything about movement, this is probably due to the fact that the figure is very fugitive with red light. The position of the currents in the outer part of the field of vision seems to change continually.

5. *Currents seen with intermittent light.* If when regarding a rotating disk composed of black and white sectors we note the time when the fine flicker is most marked and keep the eyes steadily fixed on the disk, the field of vision often becomes dark red and we see a number of interlacing currents forming the figure shown in Fig. 7.

6. *Sudden cessation of currents.* The currents are usually very evanescent, but I have seen them at times continuously for several seconds. Occasionally they will all stop at once and the appearance is like Fig. 8, three cornered spots with rounded ends being seen at the junctions of the currents. These currents whilst preserving the same general form seem to change their path continually. External objects are not visible in the portion of the field of vision in which the currents are seen.

7. *Effect of the currents on an after-image.* The currents carry the visual quality, colour and brightness, of the region from whence they

[1] *Pflüger's Arch.* 1. S. 375—391. 1868.

come into the after-image. They also tend to move the after-image towards the centre, thus if we have two similar after-images, one situated in the centre and the other a short distance from the centre, the one external to the centre may be carried into the centre and combine with the one already there.

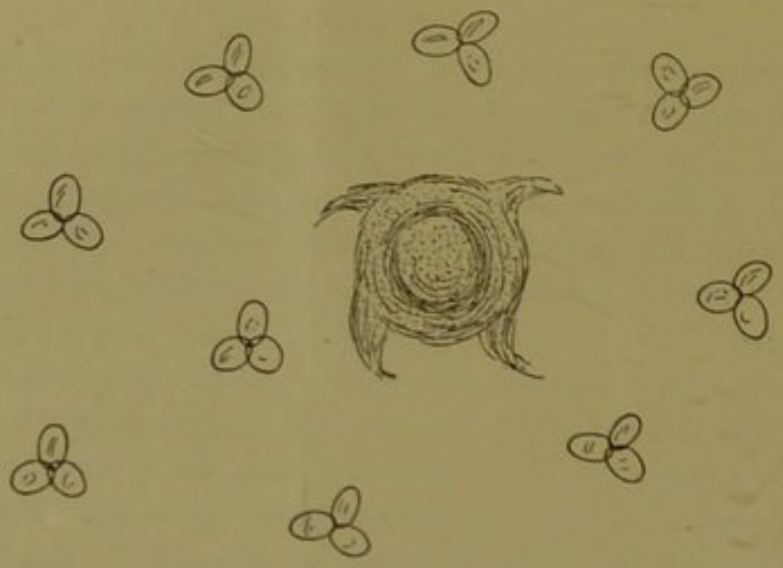

Fig. 8.

The way in which the currents encroach on an after-image may be seen in the following way. One eye being shut and covered up the other is directed to the bright blue sky whilst the open fingers are moved rapidly before it. On shutting the eye and covering both the yellow spot region is marked out as a rose coloured oval. There is a sensation of rapid and whirling movement on the outside of the oval. As the movement encroaches on the rose oval this disappears from without inwards, the last movement to be seen being the whirlpool movement like a top spinning in the centre.

8. *Effect of movement of the eyes on the currents.* The currents especially the broad ones which are found in the outer part of the field of vision are affected by movements of the eyes. It would be thought that a phenomenon so striking and so easily seen as the currents in the retina would have been observed by many, but this is not the case; from the description given by Helmholtz it is evident that he saw them when repeating Vierordt's experiment with intermittent light[1]. He differs from Vierordt in considering that the appearance is due to lymph

[1] *Physiol. Optik*, p. 533.

corpuscles in the blood instead of the circulation in the retinal vessels. After I had written this paper and especially as I had found these currents through predicting their existence I was under the impression that I was the first to state that they were not vascular phenomena, but I find that Ferree[1] has pointed this out in a very conclusive manner. He finds, and I agree with him, that the streams carry with them the visual quality, colour and brightness, of the background from which they come. Ferree considers that eye movement is the chief or sole factor in the formation and direction of these currents, but I see them quite clearly with my eye quite still and the whirling in the centre is not appreciably different when the eye is moved from one point to another. Ferree does not seem to have noticed the special relation of the movement to the yellow spot and the fovea.

IV. *Appearances due to the pigment cells of the retina.*

1. *Visibility through intermittent light.* Charpentier[2] states that if the fingers be slightly separated and then when the other eye is shut the fingers be moved rapidly backwards and forwards whilst the gaze is directed towards the blue sky the field will be covered with dark purple violet hexagonal figures, there being a light interval between each. I agree with Wolffberg that these figures correspond to the hexagonal pigment cells. They cover a much greater area of the field of vision than corresponds to the fovea and have a diameter at least four times as large as that of the circles seen in the region of the fovea.

The following experiment shows almost certainly that the appearances are due to the pigment cells; whilst my right eye was fixed on a gas flame shielded by an opal glass globe I moved from side to side in front of the eye a piece of black cardboard with a vertical slit of an inch long and a quarter of an inch wide. On moving this moderately quickly the whole gas globe appeared pure green instead of yellow and covered with hexagonal figures, each with a brighter circular spot in it. Between these hexagons were little red curved lines in which there appeared to be rapid movement. These red lines were between but did not encircle the hexagons. Increasing the rapidity of the move-

[1] *The Amer. Journ. of Psychol.* p. 484. 1908.

[2] *Compt. Rendus*, XCII. pp. 355—357.

ment of the cardboard did not alter the appearance of the phenomenon. See Fig. 9.

2. *Visibility when the retina is specially sensitive.* I can also often see hexagons of the same size on awaking in the morning but they are light with a dark interval between each.

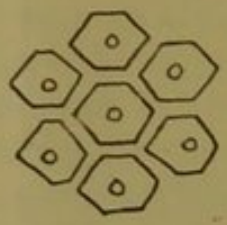

Fig. 9.

Interpretation of the phenomena.

On the theory I have put forward[1] I explain these phenomena in the following way. The currents seen are currents of visual purple flowing into the external fovea. When there is visual purple in the fovea this is the most sensitive part of the whole retina, but when there is none there time must elapse before it can diffuse into the spot.

I have three specimens prepared by C. Devereux Marshall showing the retinas of monkeys from the outer side and the arrangement of the rods and cones. The appearance of the cones of the fovea is exactly the same as the entoptic appearance of this central portion. The cones appeared as circles arranged in lines nearly at right angles to each other with a slight curve towards the centre of the fovea. I found the same with a human fovea only the cones were smaller than in the case of the monkey. On examining the external surface of the retina of a monkey there appeared four slight depressions leading to the larger depression of the external fovea. These depressions correspond to the four main branches seen in the subjective phenomena and would appear to be channels to allow of the easy flow of the visual purple. It occurred to me that if this were the case we should obtain evidence of them in cases where the outflow from the retina was obstructed as by tumour. I find that this is the case, the star-shaped

[1] *Colour Blindness and Colour Perception*, Int. Scient. Series, p. 312.

figure given by Sir Victor Horsley in his paper on tumour of the frontal lobe[1] is almost exactly the same as that seen subjectively.

All the drawings are for my right eye.

The web-like appearance seen subjectively corresponds to the cone distribution of the retina as viewed from its outer side, the portions occupied by rods appearing as dark spaces.

The yellow pigment in the yellow spot on the theory I have given should have a similar function to the yellow screen in photography.

[1] *Brit. Med. Journ.* p. 556. 1910.