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PRINCIPLES OF RETINOSCOPY

presented on the basis of the
theory of projection

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RETINOSCOPY is the achievement of the latter part of the 19th century, the century of physics, and almost all the significant theoretical work had been published by about 1906. Among the few more recent authorities who have contributed to the problem, Marquez and Polliot are to be mentioned. Tribute has to be paid to Borschke (1904) whose name is almost entirely forgotten. He was the first to point out that the basis of retinoscopy is the same as that of any projection, a line taken up recently by Polliot.

Landolt's presentation, which is best known, is based on two assumptions that during examination the observer sees the patient's pupil, and the image of the retinoscopic light-source on the patient's retina. The construction therefore is based on these two elements, and illustrations of this kind are used in many text-books. Another explanation frequently used in text-books is based on the relation between the retinoscopic visual field, and the projection of the immediate source of light upon the plane of the punctum remotum. It may be difficult for a student with a limited

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knowledge of physics to understand these explanations although they are correct from a physical point of view. The problem can be presented in a way which may be more easily understood.

The following presentation is based on the theory of projection. For the sake of completeness elementary considerations had to be included.

A *simple optical system* is composed of three elements: Light-source, aperture, and screen. (Fig. 1). The source emits light-rays in all directions, and illuminates the screen. An aperture is a hole made in an opaque sheet, or body. If we place the aperture between light and screen, only the light passing through the aperture can reach the screen. If the source is far from the aperture, the light-patch on the screen resembles the form of the aperture; if it be round, the light-patch will also be round, if it be square,

FIG. 1.

L light-source. A aperture. S screen.

the light-patch will be square. The light-patch is surrounded by shadow, which is the shadow of the opaque rim of the aperture. If we move the source of light upward, the light-patch on the screen will move down. The light passing through the aperture is called a light-pencil or beam, and the size of the aperture exerts an influence on the light-pencil by limiting its size. If the light-source is far from the aperture, the illuminated area on the screen is small, and as the source comes nearer, the light-patch gets larger. Eventually if it is situated in the aperture the whole of the screen is lit up.

Effect of mirrors and lenses:—If now we place mirrors or lenses in the way of the light; the mirrors alter the direction, and the lenses alter the vergence of the light. Besides these effects, the lenses and mirrors themselves have the effect of an aperture also. The edge of the mirror or lens limits the reflected or refracted light-pencil (aperture effect). The optical surfaces give an image not only of the light-source, but also of the apertures and the screen (Fig. 2). (When a driver looks into the side mirror of his

motor-car and sees in it the driver of the car behind him, the latter can see the driver of the first car in the same mirror).

Conjugate focus:—If a convex lens is introduced into this simple system the divergent rays, falling on to the lens, will be refracted and transformed into a convergent light-pencil. The convergence

FIG. 2.

Mirror (M) gives an image of the light-source (L'), of the aperture (A') and screen (S').

FIG. 3.

of the refracted light-pencil can be shown by moving the screen to and fro. If the screen is placed at the apex of this convergent light-pencil, an inverted image of the light-source is formed. The degree of vergence of the refracted light-pencil depends on two factors:—1. The distance of the source from the lens, and 2, the dioptric power of the lens. The position of the image is, therefore, determined by the refractive power of the lens, and its distance from the source. For a certain lens, and source at a

certain distance, only one image-distance exists. They thus have three interdependent numerical values, and image and source are called conjugate foci.

If the screen is moved towards the lens the image becomes blurred, but it is still similar to the source. If now the screen is moved still nearer to the lens, the image becomes more and more blurred, and eventually it becomes a circular light-patch with blurred edges. When the screen is brought close to the lens, the outline of the circular area grows more and more distinct again, until it corresponds in size and definition with the edge of the lens. The image has now become that of the aperture. The lens thus has a double function. (1) It alters the vergence of the light-pencil and (2) it exerts an aperture function. Source image, and aperture image are two extremes, and they represent two extreme positions of the screen. In the first case the screen is at the image plane (L'), i.e., at the maximum concentration of the light-pencil, and in the second case the screen is on the lens (D), and here the light-pencil is spread out to its maximum. In intermediate positions, the shape of the light-patch will be influenced by that of the aperture, and also by that of the source, or its image. If the screen is relatively nearer to the image-plane, the light-patch will have a similarity to the shape of the image, and if the screen is relatively nearer to the aperture, the light-patch will show similarity to the shape of the aperture.

Aperture test of vergency:—The conjugate focus of the source has been so far determined by means of its image. There exists, however, another method, and that is, by the use of an aperture, and may be called the aperture test of vergence by means of shadow movement. If an aperture is placed in the way of the light-pencil between lens and screen, the conjugate focus can be determined by means of the shadow, cast by the aperture on the

FIG. 4.

Aperture in different positions (1, 2, 3) in relation to the image-plane L' , L—light-source, L' —image of light source, S—screen.

screen. If the aperture is at position 3 (Fig. 4) when the light-patch is moved upward, the aperture rim cuts off the upper part of the light-pencil thus causing an "against" shadow. The shadow comes against the direction of the movement of the light-patch. But in position 1, when the light-patch moves upward, the aperture rim cuts off that part of the light-pencil which goes to the lower part of the light patch, thus the shadow will be "with," it follows the light-patch, both move in the same direction. If the aperture is placed at position 2, that is at the crossing point, or point of reversal, or conjugate focus of the light-pencil, no shadow-light movement will ensue, the light will suddenly appear or disappear.

The movement of the shadow on the screen depends thus on the relative positions of the source (or its image), the aperture, and the screen (Fig. 5).

(1) In $L' A S$ the shadow shows "against" movement. L' immediate source of light; A aperture; S screen.

(2) In $A L' S$ the shadow shows "with" movement.

(3) In $L' S$, that is when the light-source is in the aperture plane, the change from dark to light is sudden, there is no shadow movement at all. This is the so called point of reversal and represents

FIG. 5.

L' , immediate source of light, A aperture, S screen.

the conjugate focus of the source and plays an important part in retinoscopy.

Retinoscopic mirrors:—In retinoscopy the light is projected into the patient's eye by means of mirrors. The explanation usually given is, that with the plane mirror, Fig. 6, the image of the light-source (immediate source of light) L' , is behind the mirror, whereas with the concave mirror it is in front of the mirror. Thus

FIG. 6.

Plane mirror is turned toward left (from A to B), the image L' will move toward right from $L'A$ to $L'B$.

if we turn the mirror from right to left in case of a plane mirror the image will move from left to right ("against"), while with concave mirror (Fig. 7), it moves from right to left ("with"). But the thing is not as simple as that. If a concave mirror is

FIG. 7.

Concave mirror turned toward left (from A to B) image of light-source will move toward left (from $L'A$ to $L'B$).

used with a convergence power of *e.g.*, 4 D. and the lamp is at about 1 metre, the image of the lamp is formed about 30—35cm. from the mirror. Now, if the curvature of the mirror is reduced, the image of the source will move further away from the mirror, that is, the convergence of the reflected rays

is reduced (Fig. 8). And when the curvature is such, that the source is in its focus, the rays will have a vergency of zero, that is a beam of parallel rays will emerge (Fig. 8, F), and if the convergence power of the mirror is still further reduced the reflected rays will become divergent (Fig. 8, G).

In retinoscopy the observed shadow-light movement depends not on whether plane or concave mirror is used, nor whether the immediate source of light is in front of or behind the mirror, but upon

FIG. 8.

The original source of light is assumed to be at the fixed distance (approx. 1m. from the mirror). Mirrors of different curvature reflect light-pencils of different vergence.

the position of the immediate source of light relative to the patient's eye, and this is the governing factor. If it is between the mirror and the patient's eye, the shadow movement will be that of a concave mirror, "with" in myopia, and "against" in hypermetropia (Fig. 8 A, B). If, however, the image of the source is behind the patient's eye, the shadow movement will be that of the plane mirror, "against" in myopia, and "with" in hypermetropia (Fig. 8. D—G). In the case, *e.g.*, of a concave mirror with such a convergence power that the image will be formed about 2 metres from the mirror, *i.e.*, one metre behind the patient's eye, then although this image will move in the same direction as the mirror, yet the observed retinoscopic shadow-light movement will be that of a plane mirror. The third possibility is that the immediate source of light falls in the pupil (Fig. 8, C), in this case

no shadow-light movement will be observed at all, whatever refraction the patient's eye may have. The explanation is similar to that which applies to Fig. 5, case (3) $\frac{A}{L}$, S. This point is a point of reversal, and Marquez called it "the first neutral point," but before him it was already known that with a concave mirror which reflects a convergent light-pencil, the apex of which falls on the patient's pupil no shadow movement can be observed. (Van den Bergh, 1894), and in 1904 Borschke invented his "Achsenskiaskop" which made practical use of this "phenomenon." He suggested a cylindrical mirror, one axis of which was plane, while the other axis had a curvature of 0.75 D. With this mirror the shadow movements are apparent in the plane axis only, while in the 0.75 D. direction no shadow-light movement is seen. This instrument is said to be useful in cases of astigmatism.

Thus, there are three distinct groups of retinoscopy mirrors. In the first group are concave mirrors which project a source-image at a distance up to one metre, *i.e.*, the image is between the patient's pupil and the mirror. These behave in retinoscopy like concave mirrors. The second group: (a) concave mirrors which project the source-image behind the patient's pupil, (long focus concave mirrors), and (b) plane mirrors. Both (a) and (b) behave like plane mirrors in retinoscopy. And finally the third group are mirrors with a convergence power of one metre, the source-image is projected into the patient's pupil. These give no retinoscopic shadow at all. We find here the parallel of the familiar retinoscopic classification of the three groups of eyes: (1) myopia greater than one D., (2) myopia of less than one D., emmetropia, and hypermetropia, and (3) myopia of 1 D. which marks the point of reversal.

Aim of retinoscopy, determination of the vergence of the emitted light-pencil:—As it was shown previously, if the distances of the two conjugate foci are known, the refractive power of the lens can be calculated. In retinoscopy the problem is different, because the question is: the position of the retina relative to the refractive system of the eye, whether the retina is in focus or not, or expressed in other terms, what is the vergence of the light-pencil emerging from the patient's eye when the eye is at rest. The emerging light-pencil may be convergent in myopia, it may be parallel in emmetropia, and finally it may be divergent in hypermetropia.

Model experiment to retinoscopy: An experiment in which the conditions are made as simple as possible is the following. A small tubular box is fitted with a 40 D. convex lens at one end, and the other end of the box is made of tracing paper. Some

arrangement is made to move the lens nearer and farther away from the tracing paper. Here we have a model eye, the lens being its refractive system, while the tracing paper is its retina. Now, if a narrow beam of light falls on the tracing paper, for instance from the slit-lamp, there is an illuminated area on the retina of the model (Fig. 9), and by adjusting the distance between lens and tracing paper the model can be made myopic, hypermetropic or emmetropic (or by a clip-on cylindrical lens, astigmatic). If the model is set for hypermetropia, and the observer looks into it from

FIG. 9.

one metre distance and the light is moved, the apparent movement will be "with." The model gives in this simple arrangement all the elements of retinoscopy: *source* (the light-patch on the retinal portion of the model), *refractive system* which determines the vergence of the emitted light-pencil, and the *observer's eye* which contains two essential elements, the *pupil* which is the aperture, and the *observer's retina* which is the screen. The apex of the convergent beam (point of reversal) is the image of the light-patch on the model's retina, and here again there are the same elements, and the same possibilities. It may be (as in Fig. 5) light-aperture-screen ($L' A S$), or aperture-light-screen ($A L' S$), and light in the aperture ($L' A S$) which is the point of reversal. If the observer is at one metre distance from the model, and the emerging light-pencil has a vergence greater, or less than that distance, by inserting concave lenses the vergence can be reduced, and by convex lenses it can be increased, *i.e.*, by means of spectacle lenses the apex of the length-pencil can be moved. In this experiment—as in practical retinoscopy—the observer's pupil, and retina are essential.

In *clinical retinoscopy* the conditions are somewhat complicated as there are two systems. The first system creates a light-patch which is caused to move on the patient's retina. This is done by reflecting the light of a lamp into the patient's eye by means of a mirror. In this system the elements are: *immediate source of light* which is the image of the lamp formed by the retinoscopic mirror, *apertures*: the edge of the mirror and the pupil of the patient, and the *screen* on which the light-patch is formed, which is the retina of the patient. The task of this first system is fulfilled when this light-patch has been projected on to the retina of the patient. From now on this light-patch on the patient's retina acts as a light-source which emits light in the opposite direction to the first system. The second system consists of the following elements. *Source*: patient's retina, *apertures*: patient's pupil, and observer's pupil, or hole of retinoscopic mirror, further the *refractive media* of the patient's eye which determine the vergence of the emitted light-pencil, and lastly the *screen* which is the observer's retina. The vergence of the emitted light-pencil is determined by the point of reversal; and the apex of the emitted light-pencil is moved, by means of spectacle lenses. Here again we have the same three possibilities, the apex of the emitted light-pencil may be in front of the mirror hole (myopia of more than 1 D.), or it may be behind the mirror hole (myopia of less than 1 D. emmetropia, and hypermetropia), or it may be in the mirror hole (myopia of 1 D.), which is the point of reversal.

This presentation takes into consideration *only* the emergent light-pencil, and by it the retinoscopic phenomena are explained in the space *in front* of the eye. This is justified as the law of the conjugate foci is valid not only for source and image, but also for the whole light-pencil, and the emerging light-pencil is conjugate with that inside the eye. By determining the one, the other is computed. There are only two points of elementary physics with which the student has to be familiar: (1) image formation through lenses, (2) the aperture test of vergence by means of which it is possible to determine the point of reversal of a light-pencil.

The material hitherto presented is sufficient for understanding the principles of retinoscopy. There are, however, some details which have practical importance, and these need further consideration.

1. *Retinoscopic field* is the area on the patient's retina which is covered by the light-pencil corresponding to the mirror-hole or observer's pupil. In this presentation the retinoscopic field can be dispensed with and the mirror-hole itself substituted for it.

2. *The speed of the reflex-movement.* In fixed distance retinoscopy the factors governing the real movement of the immediate source of light, such as the distance of the retinoscopic lamp from

the observer, and the distance between patient and observer can be regarded as constant, and only the refraction of the patient's eye has to be taken into account.

The emerging light-pencil is in hypermetropia divergent, in myopia convergent, but beyond the point of reversal it will become divergent again. With the increase of the refractive error the convergence of the myopic, and the divergence of the hypermetropic emitted light-pencil increases. The observer is thus placed in the light-pencil itself (Fig. 10), and the area of the cross-section of the light-pencil at the plane of the retinoscopic mirror will increase with the refractive error. Every movement of the

FIG. 10.

The observer's eye (O) is situated in the light-pencil emitted from the patient's eye (P).

mirror will move the whole light-pencil, and if this cross-section is large, *e.g.*, in higher refractive errors, it will take some time for all the rays to pass the mirror hole, and it will be perceived as slow. When spectacle lenses are placed before the eye, and the refractive error is reduced the cross-section of the light-pencil at the plane of the retinoscopic mirror becomes smaller and smaller. Here a very small movement of the mirror will be sufficient for the light-pencil to pass over the mirror-hole, and it will be perceived as fast. Eventually the point of reversal is reached, the apex of the light-pencil is at the plane of the retinoscopic mirror, and the slightest movement will produce a sudden change in the illumination from light to dark.

Borschke made a practical suggestion for estimating the refraction by the area of the reflection of his square mirror. This will be described later in "retinoscopy in astigmatism."

(3). *Brightness of the pupillary light* depends upon the brightness of the retinal light-patch, and upon the refraction of the examined eye: The factors determining these are: (a) brightness

of the light-source, (b) distances, (c) apertures and (d) losses in transmission.

(a) *Brightness of the light-source*, not the candle power alone but also its relation to the area of the incandescent element has to be considered. This will determine the brightness of the light-patch projected on to the patient's retina. If the intrinsic brightness of the incandescent element be increased, the intensity of the light-patch will increase. For instance of two bulbs with the same candle power, the one in which the area of the incandescent element is smaller and therefore its intrinsic brightness greater, will give a brighter light-patch.

Some examples of intrinsic brightness are:—*Intrinsic brightness*, = candle power per square inch.

Paraffin flame enclosed in glass chimney	10
Incandescent oil with mantle	340
Ordinary tungsten filament in vacuum	960
Tungsten filament in Argon 65 Watt	7,500
Tungsten arc "Pointolite"	12,000—16,000
Crater of ordinary carbon arc	110,000
Sun at noon, British Isles, summer sun at zenith...	1,000,000

The claims put forward in favour of the use of the pointolite lamp are supported by these figures.

In retinoscopy the light-patch on the patient's retina is the source. If all other factors remain unchanged, the intrinsic brightness of the light-patch will be at maximum when its area is smallest, that is when it is a sharp image of the source.

(b) *Distances*:—the general rule, that the brightness of the light-patch decreases as the square of the distance holds true in retinoscopy. With a plane mirror the rule is simple, the nearer the source is to the mirror, the better the light-output. With a concave mirror, however, the position is different, as it has a combined action of reflecting and bending the light, *i.e.*, it alters the direction as well as the vergence of the reflected light-pencil.

(c) The *apertures* are: edge of the mirror, patient's pupil, mirror hole (or examiner's pupil).

Mirrors: assuming that the light-source and distances (of the patient and of the light-source from the mirror) remain unaltered, some comparison can be made between plane and concave mirrors.

Plane mirrors limit the size of the reflected light-pencil. The diagram (Fig. 11) shows that the light reaching the pupil is proportional to the area of the cross-section of this light-pencil in the pupillary plane in relation to the area of the pupil. The utilized portion of this light-pencil is not influenced by the mirror, and, as the

FIG. 11.

The plane-mirror (M) reflects a light-pencil which has diameter CD at the pupillary plane (large circle), and only a fraction of this (small circle) enters the pupil. The utilised portion of the light-pencil is relatively small.

diagram shows, the light received by the pupil is determined by the size of the pupil and the distance from the source.

Concave mirrors:—besides reflecting the light they bend the light-rays and the reflected light-pencil becomes convergent. Here again the utilized portion of the light-pencil depends on the relation

FIG. 12.

Concave mirrors of different focal length. The utilized portion of the light-pencil (which enters the pupil) is better in 2 and 3 than in 1.

between the area of its cross-section at the pupillary plane, and that of the pupil; but the area of the cross-section of the light-pencil depends upon the focal length of the mirror.

Fig: 12 shows concave mirrors with different focal lengths. The utilized portion of the light-pencil will be better in 2 and 3 than in 1.

With concave mirrors their size is important as the diameter determines the collecting angle (Fig. 13).

Thus, in concave mirrors the brightness of the pupil, if all other conditions remain unchanged, depends upon the curvature *and* size of the mirror. For instance if a 4 D. mirror is used and the lamp is at 1 m., the source-image will be at 33 cm. from the mirror, i.e., 67 cm. from the patient's eye, and if a 3 D. mirror is used, the source-image is formed at 50 cm. The position of this image determines the light reaching the patient's pupil, and the ratio

FIG. 13.

Concave mirror M_1 will give a brighter image of the original source of light than M_2 as its size is larger.

of the utilized portion of the light-pencil to the total cross-section at the pupillary plane will be greater if the source-image falls nearer to the patient's eye. The curvature should be such that the source-image will not fall into the patient's pupil when the observer moves a little forwards or backwards. Otherwise the first neutral point (Marquez) would lead to errors in the examination.

There is no doubt that a suitable concave mirror gives better illumination than a plane one, and in high refractive errors, when it is almost impossible to see any reflex movement with a plane mirror, it is easily seen with a suitable concave mirror.

The rôle of the size of the patient's pupil and the mirror-hole :— The brightness of the pupillary light will increase with the diameter of the pupil. But the increase of the size of the pupil is accompanied by an increase of the size of the confusion circles, when the retinal image of the light-source is a blurred image (and usually this is the case in retinoscopy). This will lead to an

increase of the area of the light-patch, and consequently its intrinsic brightness (candle-power per square inch) becomes reduced, and thus a reduction of the brightness of the pupillary light ensues. An increase of the size of the mirror-hole—though it may increase the light reaching the observer's eye—affects the sharpness of the point of reversal.

(d) *Losses in transmission*:—due to imperfect reflecting surface of the mirror, to absorption of light by the ocular media (normal or abnormal structures), spectacle lenses, etc., to absorption of light by the retina, and its pigment layer, will reduce the brightness of the pupillary light.

The retinoscopic lamp, the mirror, and the apertures determine how much light enters the eye, but to appreciate fully the elements of the brightness of the pupillary light, the examined eye has to be regarded as a projection apparatus, which projects a beam of light towards the observer. Here there are two elements: 1, the proper focusing of the optical system of the apparatus (refraction of the eye), and 2, the brightness of the source (light-patch on retina). In a projection apparatus, the brightness of the emitted light will depend upon whether the source is in focus or not. If the source is in focus, the illumination is optimal. If it is out of focus, the emitted light will be spread out over a larger area, and consequently the brightness of the emitted light diminishes. On the other hand the source itself plays an important part, for if there are two identical projection apparatuses, both having a bulb of the same candle power, but the one has an incandescent element with a surface area one-tenth that of the other, a ten times greater intrinsic brightness will result, and therefore the beam projected will be ten times as powerful.

In retinoscopy both these elements operate. In high refractive errors the source of light, *i.e.*, the patient's retina, is out of focus, and the emitted light-pencil is con- or di-vergent and therefore the light-energy of the retinal light-patch is spread out over a larger area and consequently its intensity reduced.

The second element is the intrinsic brightness of the retinal light-patch. In refractive errors the retinal image of the source is a blurred image which may occupy a considerable area. But as the quantity of light emitted by the retinoscopic lamp remains unchanged the intrinsic brightness of the retinal light-patch will be reduced in proportion to the increase of its area. In retinoscopy the size of the retinal light-patch varies continually with each new spectacle lens put before the patient's eye.

If the brightness of the retinal light-patch were kept constant, the pupillary light would diminish in refractive errors because of the con- or di-vergence of the emitted light-pencil. On the other

hand if the vergence of the emitted light-pencil were kept constant and the brightness of the retinal light-patch varied, the pupillary light would vary proportionately. The poor pupillary light in higher refractive errors may be attributed to the combined effect of these two factors, the reduction of the intrinsic brightness of the retinal light-patch, and the vergence of the emitted light-pencil. They vary during retinoscopy in a way which shows a certain parallelism. With the correction of the refractive error both are improved, but their optima never meet. If the source were in the mirror-hole the maximum brightness of the light-patch and the maximum concentration of the light-pencil would coincide at the point of reversal.

4. *The shadow in retinoscopy*:—According to Landolt the shadow is the edge of the retinal light-patch. It may be recalled that the light-patch is the combined effect of the source and of the aperture (patient's pupil). The shadow is caused by the patient's iris. A clinical experience which supports this is that the retinoscopy of albinotic eyes is difficult, and the explanation may be the absence of pigmentation of the albinotic iris which thus provides a poor shadow.

There seems to be a difference of opinion as regards what should be observed during examination, the movement of shadow, or of the little central bright spot, which as Williamson-Noble pointed out is particularly noticeable using a Pointolite lamp. In any case the observation is based on contrast. The central bright spot can be obtained with any light-source of small area. The small opening of the Lister ophthalmoscopic bulb is quite satisfactory, and it is marked if a concave cylindrical mirror is used for retinoscopy. This central bright spot makes it easy to keep the attention of the examiner at the central part of the pupil.

The *mirror-hole* causes a shadow in the light-pencil when the hole is drilled, and a dimming of the centre only if the silvering has been removed. At the point of reversal mirror and patient's retina are conjugate foci, and the image of the mirror-hole may be the cause of the so-called central grey disc which can be seen at the point of reversal. In a mirror with no hole, as for instance in using a transparent mirror, such as Imre's reflector glasses, the central grey disc is not noticeable.

5. *Factors influencing the point of reversal*:—Hitherto the definition of the point of reversal has been the position in which the image of the source (*i.e.*, that of the retinal light-patch) is situated at the plane of the aperture (mirror-hole or observer's pupil) and is characterized by the sudden appearance or disappearance of the pupillary light, without the examiner being able to see any movement of light or shadow. By moving the mirror the light-patch on the patient's retina is caused to move, and yet the

observer cannot see it. The questions of the point of reversal are : (a) Why is it that there is a sudden change of shadow and light at the point of reversal, and (b) What happens during retinoscopy in the examiner's eye? (c) What are the factors influencing the point of reversal.

(a) As is known, the refracted light-pencil has a maximum concentration at the image plane, *i.e.*, the image elements are condensed to the smallest possible area; while before or behind the image plane the image-elements are spread out to form confusion circles. If the aperture lies before or behind the image plane, where the confusion circles have reached a certain size, it is possible for them—by moving the *source-image* to move into the aperture gradually, *i.e.*, it may be that one part of a confusion circle is inside the aperture, while the rest of it is yet outside the aperture, on its opaque rim (Fig. 14). In such a case a gradual

FIG. 14.

FIG. 15.

increase or decrease of the light-patch on the screen will result, and there will be a noticeable shadow-light movement (Fig. 15).

When the aperture is getting nearer to the image plane, the confusion circles become smaller and smaller, and at the image plane their area is condensed to a maximum, they are so small that when they pass the aperture rim at all, they pass it entirely. At the point of reversal there are two possibilities only: the image element falls either at the opaque rim of the aperture, and in that case no light passes the aperture, and the screen remains in darkness, or the image element falls into the aperture when the screen is suddenly lit up.

The absence of movement may be explained by the following: The image elements, after passing the aperture, travel on until they reach the screen, as confusion circles. The size of the confusion circles will increase with the distance of the screen from the image plane; they overlap each other, and eventually the confusion circles reach a size when they fill the light-pencil. In that stage all the confusion circles fall necessarily on the same area, and no movement of light or shadow will be observed.

(b) What happens in the eye of the observer during retinoscopy?

In high refractive error it is possible for the observer to see fundus details which is a real image in high myopia, or a virtual one in high hypermetropia. In these cases the emitted light-pencil can be brought to an image by the observer's eye. But as the refractive error is gradually reduced by the trial lenses, and the image of the retina, *i.e.*, the apex of the emitted light-pencil gets closer to the observer's eye, the fundus details become more and more blurred, and only the movement of the light-patch (the reflex-movement) is discernible. The observer's retina receives large confusion circles only. Eventually, at the point of reversal, when the image of the patient's retina is formed at the plane of the retinoscopic mirror (or on the observer's iris) the confusion circles occupy the whole of the illuminated area of the observer's retina. Now as the size of this light-pencil is determined by the size of the patient's pupil the phenomena of the point of reversal are the functions of a system with two apertures, the patient's pupil and the mirror-hole (or observer's pupil).

This is only another expression of the point of reversal, and fits well into the conception hitherto described. These conditions can be demonstrated by means of a simple experiment. A small light-source (L) is placed before the first aperture (A^1), close to the aperture there is a +15 D lens. A second aperture is put at the image-plane (A^2). Both apertures should have a diameter of about 10—15 mm. (a hole in a card). A screen is placed behind the second aperture. The arrangement is shown in Fig. 16.

FIG. 16.

L A₁ D corresponds to the patient's eye. A₂ S to the observer's eye in retinoscopy.

The size of the light-patch on the screen will increase with the distance of the screen from the second aperture. But as the distance between the observer's retina and pupil is constant, the factor of distance of the screen from the second aperture (observer's pupil), can be regarded as constant. The size of the light-patch on the screen depends thus upon the size of the first aperture only. If the first aperture is replaced by a smaller or larger one, the size of the light-patch will alter accordingly. If a convex lens (*e.g.*, +14 D) is put close behind the second aperture, no change in the size of the light-patch ensues. In this experiment the light-source may be regarded as the patient's retina, the first aperture as the patient's pupil, the lens (D) as the patient's refractive system; the second aperture and the screen as the observer's pupil (or mirror-hole) and retina. This experiment shows that at the point of reversal the illuminated light-patch on the observer's retina is determined by the size of the patient's pupil. In position 2, *i.e.*, the point of reversal a sudden change of light and shadow can be observed. By moving the second aperture from this point in either direction (1 and 3), and by moving the light it can be demonstrated that the shadow moves *with* in position 1 and *against* in position 3.

(c) *Factors influencing the point of reversal. Limitations of retinoscopy.*

The rôle of the mirror-hole is this. The smaller it is the sharper will be the point of reversal. But the size of the mirror-hole, or examiner's pupil is only one of the factors influencing the point of reversal.

There is, even in the case of sharp focus a high degree of aberration, and consequently large confusion circles arise. The decentration of the cornea, the spherical aberration of the refractive media, the size of the retinal light-patch (which acts in retinoscopy as a light-source) exclude a "point" of reversal because the sur-

face of the conjugate image is not a plane one, but is formed in depth. In astigmatism the question of the point of reversal is even more complicated, as the two foci cannot be regarded as lines, but are formed in space.

Although these factors set a limitation to the accuracy of the results; retinoscopy—if intelligently used—is a reliable and simple method of determining the refraction, and it satisfies all practical requirements.

Summary

The nature of the light-pencil emitted by the patient's eye during retinoscopy is best understood on the basis of the projection theory.

Retinoscopy is an aperture-test by means of which the point of reversal is determined of a myopic eye, or of an eye made myopic by trial lenses.

The elements of the illumination and of the returning observation systems of retinoscopy are analysed.

Factors.—(1) Retinoscopic field can be substituted by the mirror-hole.

(2) Speed of reflex-movement is explained by the area of the cross-section of the emitted light-pencil at the plane of the retinoscopic mirror.

(3) In the brightness of the pupillary light the factors are: (a) brightness of the source, (b) distances, (c) apertures, and (d) losses in transmission, and the vergence of the emitted light-pencil.

(4) The retinoscopic reflex seen in the pupil is influenced by the size of the original source of light, and the mirror used.

(5) Factors influencing the point of reversal.

(a) Explanation of the sudden change of light and shadow at the point of reversal.

(b) The observer's retina receives during retinoscopy image elements of the patient's fundus or confusion circles of it, depending upon the vergence of the emitted light-pencil. The size of the confusion circles is maximum at the point of reversal.

(c) The factors influencing the point of reversal set a limit to the accuracy of retinoscopy.

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CASE OF NEUROFIBROMA OF THE CHOROID*

BY

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NEUROFIBROMA of the choroid is an extremely rare disease; so that any instance of it deserves reporting; recently a case has reached Moorfields, which, in many respects, is unique among the few on record.

Case History.—M. C., a girl aged 3½ years, had been noticed for the previous 4 months to have an increasing prominence of the left eye, being well in every other respect. She was then shown to her doctor, who referred her directly to Moorfields, and the following signs were evident:—The right eye was normal. The left eye was moderately proptosed, with some limitation of all movements, especially on looking upwards. There was no other abnormality save on ophthalmoscopic examination, which revealed a globular mass almost filling the supero-temporal quadrant, whiter than the adjacent choroid, but with distinct choroidal blood-vessels on its surface, and normal retinal blood-vessels directly overlying it; there was no pigmentary proliferation. The mass was sharply demarcated, almost reaching the optic disc; at the lower border was a trace of fluid detachment; elsewhere the fundus was normal.

The appearance was thus similar to that of a choroidal sarcoma with extra-ocular extension, but the age of the patient prevented this diagnosis.

X-ray and general examination showed no evidence of metastases or other abnormalities.

On May 14, 1943, Mr. Doyne performed an exploration of the

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* Shown at the Section of Ophthalmology, Royal Society of Medicine, November 12, 1943.