When I was asked to read a paper on Scotometry, I began to ask myself what were the limits of the subject, and how it differed from perimetry. In scotometry one is concerned with scotomata, that is, more or less blind areas surrounded by more or less healthy, seeing, retina. The term is applied, I believe, by common consent, to the investigations of those areas near the fixation point, within 30° to 40° of it.

It differs from perimetry in no respect other than that it involves a more detailed investigation.

Two types of scotoma are recognized—absolute, when an area of the retina is quite inappreciative of all light, and relative, when, although it can appreciate brightly illuminated white objects, it is inappreciative of certain colours or grey, or even, on occasion, of white objects if the illumination be sufficiently reduced.

In determining the size of a scotoma, various points have to be considered. These are:

1. Illumination.
2. Colour of the object.
3. Colour of the background.
4. Size of the object.
5. Rate of movement of the object.
6. Distance of the object.
7. Scale and size of the chart.
8. Method of making the observations.

1. The intensity and colour of the illumination are important. One desires to find out if any part of the retina is even only partially insensitive to light. If quite a small object be very brilliantly illuminated it may be quite possible for it to be seen over an area in which a much larger, but poorly illuminated, object may be invisible. The light should not therefore be too intense. Direct bright sunlight should be avoided. Indirect sunlight and daylight vary in intensity from day to day, and in colour from season to season.

Thus a scotoma might be found to vary from time to time with varying intensity and colour of light when in reality, it is of unaltering size if examined under strictly comparable conditions.

No standard of artificial illumination has yet been agreed upon,

but the light from a single carbon filament lamp, such as is used in ophthalmoscopic examinations, half a metre from the object is found to be fairly satisfactory as long as the lamp is new.

The great disadvantage of all forms of carbon filament lamp, however, is that they alter rapidly both in colour and intensity after only a few hundred hours of burning.

Recently two lamps standardized as to colour have appeared on the market. I refer to the Sheringham Daylight Lamp and the Chance Daylight Glass. They both employ gas-filled (so-called “half-watt”) lamps, and by correcting this light each produces what is substantially daylight. The difficulty in employing either will be in keeping the light intensity sufficiently low. One probably does not require more than 20 to 30 candle-power, and it may possibly be necessary until smaller gas-filled lamps are made, to place the lamps at some considerable distance from the object or to employ small white surfaces to reflect only a portion of the light.

2. The colour of the object is important. Green is less easily seen than red, and red than blue, and blue than white.

Green may appear to change colour into yellow or grey, and thereby demonstrate, even when using a comparatively large object, a change in retinal sensitteness which, had white been employed, could only be discovered by using quite a small object and then only if in a dull light, and possibly not even then. When using a red object, the intelligent patient may observe that the intensity of the colour itself may vary in different parts of the field, even though the object itself does not become invisible.

3. Background. There should be a marked contrast between the colour of the object and the background. This may conveniently be black or grey. It should not reflect any light.

Some surgeons use a white background and a black object. This method works admirably for plotting out the blind spot, but difficulties arise as soon as attempts are made to determine the size of a relative scotoma. A green object, invisible on a black background, becomes a black object on the white background. Further, the handle on which the object is mounted, unless exquisitely white, is very obvious against the background and may throw a shadow. Complications arise in dealing with a relative scotoma, in that the retina may become partially fatigued and the result obtained may not be comparable with that found when a black background is used.

4. The size of the object should be measured in terms of the angle that it subtends and not by the length of its edge, otherwise a comparison of the results obtained by different observers working at different distances is difficult.

Some observers state that half a degree should be the smallest size used. If one only uses this large size and does not also go
over the field with a coloured object, one will almost certainly fail to find a small scotoma. The object in an Elliot scotometer subtends about an eighth of a degree and is certainly not too small.

5. Rate of movement of the object. This is a matter of utmost importance—of a great deal more importance than is usually accorded to it. If the surgeon is anxious to discover areas that are possibly only slightly less sensitive to light, the patient must be given time to consider and make up his mind as to whether the object does change in appearance or colour.

If, when employing similarly coloured objects subtending the same angle, different results are obtained when working at different distances, as for example with a Bjerrum screen at two metres and a perimeter at 33 cm., the principal, if not the only, reason for the discrepancy is the difference in the speed with which the object is moved in the two cases. It will be noticed that most surgeons move the object when working with a Bjerrum screen at two metres not more than 4 to 8 cm. a second, that is, about 1 cm. per second along the perimeter arm. In order to obtain comparable results when working with a perimeter, it is essential that the image of the object should pass across the retina at substantially the same speed. This means that the object should be moved at not more than one-sixth of the speed; that is, about 1 cm. per second along the perimeter arm. In order to attain this, the handle of the ordinary McHardy perimeter requires to be turned at about the same rate as the second hand of a watch. It will be admitted that it is rare for this precaution to be taken, and that usually when attempts are made to plot out a scotoma with a perimeter, the process is a less leisurely one than when a Bjerrum screen is employed.

No standards of speed have been established. But they should be. The statement that no scotoma is present should always be qualified by giving the size and colour of the object employed and the approximate speed at which it was moved.

6. The distance at which the observations are best made is a most controversial topic. Some aver that the nearer the object is to the patient's eye the better. Others consider that it is only by working at two metres or more that really accurate observations are made.

Subject to the conditions under which the observations are made being comparable, it is quite unimportant at what distance the object is from the patient, always excepting that it should not be too near. It is probable that if it be nearer than 33 cm., it is disadvantageous. The object is of necessity small and it is obvious that the patient should have a clear sharp image of it on his retina. He should therefore wear glasses to correct any refractive error he may have, with a suitable addition if he be presbyopic. Many of these patients are presbyopic and their reading glasses will not enable them to
read at a distance nearer than 33 cm. It is difficult to get a patient to keep a trial frame and lens in place while taking out a scotoma, and therefore difficult to correct for an object nearer than his reading distance. For these reasons it is undesirable to work nearer than 33 cm.

Not infrequently it will happen that one requires to take out the scotoma of a patient with a central scotoma. Then he will be instructed to place the tip of his index finger on the fixation spot and to look where the tip of his finger is (not to look at the tip of his finger, or he will look at it eccentrically and the result obtained will be valueless). Under these circumstances the central fixation point must be within reach and therefore should not be more than half a metre away at the most.

All the earliest work was done at two metres or so. I believe that the original findings were only possible when working at such a distance because observations were made in daylight with white objects and that it was only by working at this great range and with minute objects that the intensity of the stimulus was sufficiently reduced to enable the small changes of sensitiveness of the retina to be discovered.

With suitable appliances and appropriate conditions, quite as accurate observations may be made at the usual perimeter distance of a third of a metre.

7. The scale and the size of the scotometer chart are purely matters of convenience. It is desirable that one degree of arc should be represented by at least as much as two, probably 3 millimetres. If a smaller scale than this be used variations in the size of the blind spot, for example, may not easily be noticed. The chart should be big enough to include the fixation point and a part of the 30° circle.

8. Methods. There are many methods. A good method should
1. Be easy to employ,
2. Give accurate results,
3. Enable a permanent record to be made easily,
4. And above all, enable the observer to watch the patient, if necessary, the whole time to see if he is keeping his eye fixed on the target. Most patients will allow their eye to wander unless they are carefully watched.

When using Bjerrum's screen, one works two metres or so from the patient. One must watch where one is moving the object. One cannot therefore pay that attention to the patient that is usually necessary. Pins may be put into the screen to mark out the limits of the scotoma, and the position of these may be plotted out on to a suitable chart afterwards. The method is extremely accurate, but far from rapid. It requires the services of two persons,
Scotometry

one to move the object and one to watch the patient. It is not self recording.

A considerable improvement has recently been introduced, and consists in attaching the object to one limb of a pantograph. This is used to reduce the size of the scotoma suitably, and by means of a pricker, a permanent record is made on a chart that is mounted near the edge of the screen. The observer can now face the patient and watch his movements but from a distance of two metres it is difficult to be sure that he is keeping his eye fixed on the target.

Elliot's scotometer is designed to be used at the distance of one metre. With it eventual plotting out of the scotoma is more rapid than in the case of a Bjerrum screen in that a numerical value is obtained for the position of the margins of the scotoma. It is more easily used if one has an assistant to copy down the numbers so found. By standing at one side one may obtain a tolerably good view of the patient's eye to see if he is keeping his attention fixed.

Accurate results may be obtained by using an ordinary perimeter. There are two objections to this method.

The first is that the small object is usually mounted on a large object holder. It is difficult then to determine whether the patient sees the object or the holder. If a suitable object holder be employed the only objection to taking the field on the perimeter is the fact that the reduction is too great. In the McHardy of the usual type the 180° is represented on the chart by 100mm, which means that the whole of the scotometer chart, that is up to the 30° circle, would only be the size of a penny, which is obviously far too small.

A perimeter fitted with a two-scale reduction device would be excellent but the charts must be made of such form that it would be impossible to use the wrong one. Some of the original recording perimeters had such a two-scale reduction device but they went out of use because the difference between the two scales was insufficiently great to avoid the possibility of mistakes, and one was at times in doubt as to whether the low or high gear had been employed more particularly, since for the sake of simplicity, they only employed one chart for both purposes.

If the difference in the scales be great, say as much as 6 to 1, this confusion could not occur.

With such a perimeter when the scotometer gear was being used the driving mechanism would also be altered so that the speed of the object would appropriately slow.

When using a perimeter it is easy to watch the patient.

More recently other forms of instrument have come into use. They are simpler and therefore less expensive than a perimeter. During the war, Dr. Gordon Holmes used a screen of the Bjerrum type but worked nearer the patient. He employed an object holder
which had a pin protruding backwards. With this a prick is made through the cloth on to a piece of paper placed immediately underneath. By this means one has a full sized record. Mr. Bishop Harman employs a grey screen at a third of a metre. Under this he has a piece of carbon paper and a chart. He uses a rigid object holder with a style-like process passing backwards. He marks the limits of the scotoma by pressing the holder backwards thereby obtaining a permanent carbon record.

In neither of these methods can one see the exact limits of the scotoma until one lifts off the screen. It not infrequently happens that when one is working out the limits of a crescentic or irregular scotoma, one wants to know if one has left any part of the margin incompletely defined. For this reason the perimeter type of scotometer would be particularly useful.

For this reason I designed a new form of scotometer. It has no advantage over a good perimeter, except that it is cheaper. One can watch the patient, one can observe where one has determined the limits and where one has not, and any piece of paper is suitable for making the record on. It is not necessary to employ a particular form of chart.

9. When one is considering the size of the blind spot and comparing it with the normal, it is essential to remember that the refractive error will have a profound influence. In high myopia, for instance, the angle between the limits of the blind spot and the centre of the pupil will be a much smaller one than in the case of a high hypermetrope. In fact the disc of the latter throws a scotoma about twice the diameter of the former. This will account, I think, for the remarks of one observer at the Oxford Congress last year, who found that the size of the disc plus the myopic crescent was not much, if any, larger than the normal scotoma for the emmetropic disc.

Some extremely important observations may be made with a scotometer. It occasionally happens that a patient with a high degree of hypermetropia may possibly be the subject of increased intracranial pressure. The question then arises, is the swelling of the disc physiological or pathological. If the size of the disc when determined with a dull green is only slightly larger than with a brilliant white, the condition is probably physiological. If the scotoma for green be considerably larger, then the nutrition of the retina around the disc is disturbed, and the condition is probably pathological. The scotoma for colour is usually slightly larger than that for white.

In obscure nervous diseases with slight disturbance of visual acuity but no change visible in the retina, and no central scotoma, the blind spot may be enlarged for red or green.

In certain cases of toxic amblyopia and in cases of retrobulbar
PHOTOGRAPHS OF FUNDUS TAKEN WITH PROF. SALOMONSON'S APPARATUS.

Normal fundus.

Choked disk in cerebral tumour.

Choked disk in syphilitic meningitis.

Atrophy of the papilla n. optic in sclerosis multiplex.
neuritis, scotomata for red and green or for green only may be found. At times the green is seen the whole time but is stated to change colour, turning to yellow.

Occasionally a paracentral scotoma may be found. Rarely, in cases of pituitary tumour, a small central scotoma strictly limited by the mid line, usually bi-temporal, may be present.

But of course the purpose for which scotometry is of such importance is the determining of the increase of the blind spot in cases of suspected glaucoma.

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**A NEW PHOTOGRAPHIC AND A NEW DEMONSTRATION OPHTHALMOSCOPE**

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In both these instruments, Gullstrand's principle of the "simplified indirect reflexionless ophthalmoscopy" has been applied (v. Tigerstedt, *Handbuch der physiologischen Methodik*, Vol. III, i; *Sinnesphysiologie*, Vol. III, p. 88, 1814). We shall first consider the photographic instrument.

Fig. 1 shows the general arrangement of the illuminating and the reproducing optical systems. The ophthalmoscope A lens forms a part of both systems. It is one of Zeiss's aspheric aplanatic lenses. The image of the retina formed by this lens in its back focus a, b, is in the photographic instrument reproduced on the same scale by means of a photographic lens B. The illuminating agent is a small arc lamp K running on some 6 amperes. A condenser C forms an enlarged image of the crater on a diaphragm D of 8 millimetres diameter. A rectangular prism E placed immediately below it deflects the illuminating rays in the direction of the ophthalmoscope lens, the surface of which is reproduced in the plane of the condenser by a lens, resting on the diaphragm, where also the photographic shutter has been placed. The already-mentioned reflecting prism partly covers the front surface of the photographic lens, so as to leave a free surface of a little more than half the diameter of the last one. If the pupil of the eye be placed at such a distance from the ophthalmoscope lens that this reproduces the aperture of the photographic lens, and, of course, also the illuminated diaphragm in the pupil of the eye, we have fulfilled the condition postulated by Gullstrand for the elimination

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*Based upon a demonstration given before the Section of Ophthalmology, Roy. Soc. Med., on January 14, 1921.*