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ON

ALBUMINURIC RETINITIS.

BY

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ON ALBUMINURIC RETINITIS.

THAT dimness of sight in many cases accompanies disease of the kidneys, has long been recognised, but until comparatively recently the defect in sight was invariably attributed to uræmic poisoning of the nervous system. Now, although this is occasionally the case, as a rule it is due to organic alterations in the retina. The symptoms in the two classes of cases are, as was pointed out by Von Graefe, quite distinct. Where the dimness of sight is due to uræmia, the amaurosis occurs suddenly, reaching its height in several hours—in some cases even in a few minutes—and the blindness is not unfrequently complete. Resolution occurs equally rapidly. In the other form the sight may also become pretty rapidly impaired at the commencement, but thereafter progresses more gradually, and after increasing for several days remains stationary for a longer period. Very seldom does absolute blindness ensue. Resolution, too, when it does occur, proceeds very slowly.

It is to this latter form alone that I intend to direct attention. Dr Türk has the credit of having first pointed out that fatty degeneration of the retina may occur in Bright's disease, he having found this condition on microscopical examination of the eyes of a man who had died of that malady. This was in 1850, before the invention of the ophthalmoscope. Dr Heymann, of Dresden, in 1856 was, as far as I can ascertain, the first to describe the ophthalmoscopic appearances of a peculiar variety of inflammation of the retina, followed by, or accompanied with, fatty degeneration of that structure, and associated with Bright's disease.[1] He narrated three cases, in one of which a fatal result occurred. He subjected the eyes to a careful microscopical examination, and found the retina studded at points with large fat corpuscles and what he supposed to be ganglion-cells in a state of fatty degeneration. Liebreich next, in 1859, more particularly described the appearances characteristic of albuminuric retinitis, referring especially to the envelopment of the optic papilla by a circle of swollen degenerated retina

[1] Archiv. für Ophthalmologie, Band IV. abth. ii. p. 41.

of a bright white colour (as if by a mound), and the peculiar arrangement of groups of brilliant white spots at the macula lutea, in the form of lines radiating from the centre of the macula.[1]

Numerous cases have since been recorded by Nagel, Von Graefe, Schweigger, Hulke, Galezowski, Hart, Hutchinson, etc., in all of which similar appearances were observed. As regards the exact tissue of the retina in which the degeneration occurs, a considerable diversity of opinion has prevailed, but most have observed the change primarily to affect the outer and inner layer of granules, while Nagel and Schweigger also found the connective tissue of the retina, the fibres of Müller, similarly affected.[2]

In addition, a thickened sclerosed condition of the optic nerve-fibres was noticed by some observers.

The form of Bright's disease in which this condition most frequently occurs is the contracting or cirrhotic, but it has occasionally been observed in the amyloid variety. It has also been described as accompanying the albuminuria of pregnancy, and at least one case of this description has come under my own observation.

Traube ascribes the retinitis to hypertrophy of the left ventricle, and in almost all cases, though not invariably, this condition has been found present. But it is surely rash to conclude that this is the exciting cause of the retinal inflammation, as hypertrophy of the left ventricle occurs in very many diseases in which retinitis has not been observed as a concomitant affection, and is invariably present in advanced stages of Bright's disease. Is it not likely that in the delicate structures of the retina, nutritive changes scarcely observable in other parts may lead to serious impairment of function, and that this may explain the phenomena in question? This view is, it appears to me, confirmed by the facts that derangements of other nervous functions are not unfrequently observed in the course of chronic Bright's disease, and in one case fatty degeneration of some of the ganglion-cells and of the parenchyma of the corpora striata was detected. This would serve to indicate that a similar diseased condition occurred in other parts of the nervous system. That the impairment of vision in albuminuria usually depends on retinitis is proved by Von Graefe's statistics, for he shows that of thirty-two cases of impaired vision with albuminuria, which he carefully examined, retinitis was present in thirty, while in the remaining two there were well-marked uræmic symptoms.

It is a striking fact that in a large proportion of cases where the retina becomes affected, uræmia soon thereafter occurs, while in other instances retinitis becomes developed shortly after the manifestation of uræmic symptoms. Landouzy has expressed the conviction that albuminuric retinitis is very often an initial symptom of Bright's disease, which view is negatived by Von Graefe, who refers to the condition of the kidney which is found associated with

[1] Archiv. für Ophthalmologie, Band V. abth. ii. p. 265.
[2] Ibid., Band VI. abth. i. p. 191; and ibid., Band VI. abth. ii. p. 294.

retinal affections, as indicating a long pre-existent state of disease, and explains the fact that impaired vision is occasionally the first symptom that obliges the patient to apply for relief, by the consideration that the symptoms of kidney-disease are, in such cases, of a very insidious nature, and escape the notice of the patient, but on careful examination into the history of the case can generally be found to have existed.

Von Graefe has in three patients observed the white degenerated spots in the retina completely to disappear with recovery of function, which he believes may be explained by the view that the connective tissue is the chief seat of the fatty degeneration. Almost complete resolution has also been observed by Liebreich. The peculiar arrangement of the degenerated spots at the macula lutea has been ascribed by Schweigger to the anatomical arrangement of the fibres of Müller, which at the macula are placed obliquely, and radiate from the central point, and which are, according to many microscopists, first affected with the degeneration.

The following cases, which have occurred in my practice during the past year, have induced me to bring this affection under your notice as a subject of some importance and of considerable interest, although I have little to add to what has already been recorded.

I. Mary Ormiston, æt. 17, consulted me, on the recommendation of Dr Matthews Duncan, on the 17th January 1870, respecting dimness of vision. Her mother informed me that when she was about two years of age, for about two months she had daily fits of a convulsive nature. The fits lasted about ten minutes or a quarter of an hour, and were attributed to teething. After a single administration of chloroform by Sir James Simpson, who was called to see the case, the fits never returned, but for six or eight months after there was complete loss of power in both legs, which, however, eventually entirely disappeared. When about four or five years of age she had a severe attack of jaundice. With these exceptions she enjoyed good health till about two years ago, when she became afflicted with distressing headaches, the pain being usually most severe in the right supraorbital region. The headaches recurred at irregular intervals till the last two months, during which time they have recurred regularly once a week. The pain commences in the afternoon, gradually increases in severity till two or three o'clock in the morning, when the symptoms again gradually subside. These attacks are accompanied by severe sickness and vomiting. The bowels are generally regular, and her appetite and general health in the intervals between the attacks very good. She has never menstruated, but her mother was nineteen and a sister eighteen before they menstruated. No œdema of ankles or eyelids was ever observed. For some months she has complained of thirst, and passes a large quantity of urine. She is often obliged to get up at night for the purpose. Her mother has noticed that the urine was frothy. Her skin is usually dry. She was of spare habit, but has recently become stouter. The family history was exceptionally good. Inquiry regarding the origin and progress of her eye-symptoms disclosed that she had always been short-sighted, but had otherwise good vision, till about three weeks ago, when she noticed that her sight was dim and misty, and that on attempting to read a journal a black cloud appeared between her and the print. Both eyes were equally affected. For a long time previous to this occurrence her eyes got readily fatigued while reading. Her sight has since then become gradually more impaired. Her father was very short-sighted, but her mother's sight is good.

The patient was a moderately stout, dark-complexioned, healthy-looking girl; to all outward appearance free from disease. On examining the eyes, the media were found clear and the pupils active, but the sight much impaired. With each eye she was only able to read No. CC. of Snellen's types at 15 feet distance ($V = \frac{15}{200}$). Neither convex nor concave glasses materially improved her sight. On ophthalmoscopic examination, both eyes were found to be affected with retinitis, which presented all the characters of the albuminuric variety. The disease appeared to be a little further advanced in the right than in the left eye. In both the morbid process was almost entirely limited to the neighbourhood of the optic disc and macula lutea and the intervening retina. The optic papilla was of a grayish colour, and could scarcely be distinguished from the infiltrated retina which immediately surrounded it. At the macula lutea, and for some distance around it, the retina was of a gray colour from diffuse exudation into its substance; while, corresponding to the punctum centrale, there was a small round pearly white spot, and arranged in lines radiating outwards from it like the spokes of a wheel there were numerous other small white glistening spots. This was most marked in the right eye. Some similar but larger white patches were found between the macula lutea and optic disc. At several points, small extravasations of blood were observed. The retinal vessels were here and there obscured, but at other points lay superficial to the exudation. The results obtained by the ophthalmoscope at once directed attention to the kidneys. The urine was found to be pale, of low specific gravity (1012), and very highly albuminous. It deposited no tube-casts or other sediment. She was ordered bromide of potassium (gr. xii. thrice daily), and to continue a mixture containing iron and arsenic which had been previously prescribed by Dr Matthews Duncan.

I again examined the patient carefully on the 23d March. The sight in the right eye had become still more dim, so that she could only count fingers with it at the distance of four feet. The sight in the left eye was the same as at first examination. There was now slight convergent strabismus of the right eye. Fatty degeneration of the retina is in both eyes much more marked, and in the right white patches are now visible in some peripheral portions of the retina, while the spots formerly observed have increased in size and coalesced, so as to form one large white patch enveloping the optic papilla, and extending thence to beyond the macula lutea. In the left eye the diseased condition is more circumscribed to the neighbourhood of the macula lutea, where the degenerated points are arranged in lines radiating from the punctum centrale. Her general symptoms have increased in severity. She is still very thirsty, drinking large quantities of water day and night. The headaches occur periodically as before, but do not entirely disappear during the intervals. There is still complete absence of anasarca, and she passes a large quantity of urine. The appetite continues good, and she has not materially lost flesh, but she is very easily fatigued.

Shortly after this she discontinued her visits to me, and I heard nothing more of her till her mother called at the Eye Dispensary and informed me that she had been advised to send her daughter to the country, with the assurance that change of air would effect a complete cure; that, accordingly, she had sent her to Prestonpans, where she was seized a few days later with convulsive fits of which she died.

I wrote to Dr Oliver, under whose care she was, who kindly informed me that he had been called to visit her during a fit of epileptiform character, that she had a succession of similar fits, and that from the first attack she was never conscious. No post-mortem examination was made.

I cannot doubt that in this girl's case we had an example of contracting kidney. The insidious progress made it difficult to obtain a satisfactory history of the renal symptoms, and it was only on observing the state of the retina that attention was directed to the condition of the kidneys.

II. John Patterson, æt. 49, shoemaker, consulted me on account of dimness of vision on 17th May 1870. He states that he enjoyed very good health, "never lying a day in his life," till eleven weeks ago, when, after a severe rigor, he was attacked the following evening with very severe vomiting, attended with distracting pains in the head and back of neck, and sometimes in the loins. The vomiting lasted to a greater or less degree for four weeks. The matters vomited varied much, being sometimes bilious. Once vomiting lasted from 2 A.M. till 9 P.M., even a drink of water not staying on the stomach. Was frequently very drowsy, and would fall asleep even while sitting on a chair. He has never had any œdema of the ankles or eyelids. For the last twelve months he has had to make water more frequently than formerly, especially during the night, and he passes a larger amount than he used to do. He suffers much from thirst, and has to get up at least six times during the night to get a drink of water.

His sight was not markedly affected till about a fortnight after the commencement of his sickness, when his vision suddenly failed him one morning, everything appearing veiled by a thick mist, while the previous evening his sight had been quite clear, and he was able to read as usual. He also saw black motes floating in the mist, and a few weeks later bright spectra appeared before him. The mistiness has continued to the present time, but has somewhat diminished in degree, so that now he sees better than he has done since the original attack. The stooping posture gives rise to a feeling of heaviness and pain in the head, and increases the dimness of vision. About three or four months ago he had double vision for a few minutes, but it has not recurred.

The patient was rather anæmic, but otherwise appeared healthy. The pupils were of natural size and mobile, and the media were clear. With the left eye No. CC. of Snellen's types can be read at 15 feet; with the right eye, assisted by a weak convex lens (+ 28), No. XL., at same distance. Opthalmoscopic examination reveals the presence of albuminuric retinitis. In the left eye the macula lutea was the seat of extensive fatty degeneration, and the retina between it and the optic papilla clouded with exudation. At several points small extravasations of blood had occurred into the retina. The optic nerve was also infiltrated with exudation, and two small blood extravasations were visible in the optic papilla. The right eye was similarly affected, but the disease was less advanced, and the blood extravasations more numerous. The urine was pale and highly albuminous. The patient was ordered iodide of potassium in gr. v. doses, and counter-irritation by means of the biniodide of mercury ointment applied to the temples. I recommended the patient to enter the Infirmary, under Dr Stewart's care, but he merely attended as an out-patient till 21st October, when he was brought in suffering from uræmic symptoms, and died comatose on 23d October. On post-mortem examination the kidneys presented, characteristically, the appearances of the contracting form of Bright's disease. This man had no suspicion of any serious affection beyond impairment of vision when he applied to me for advice, and the ophthalmoscopic appearances led to the detection of the renal malady.

III. Mr F. consulted me, upon the recommendation of Dr Warburton Begbie, on the 15th September last, on account of chemosis of his left eye, and dimness of sight in both. The chemosis was so great that it was only when the orbicularis was brought into strong action that the eyelids were completely closed. The left eye appeared to be somewhat protruded, and the conjunctiva was considerably injected. Vision was very defective in this eye, and even with the right he could only decipher No. XL. of Snellen's types at 15 feet distance. On ophthalmoscopic examination the appearances of albuminuric retinitis was most characteristically presented. The disease was more advanced in the left than the right eye. Upon then inquiring into the history of his case, I learned that disease of the kidneys had been previously detected. For the following data I am indebted to Dr Begbie. For nearly two years Mr F. had been subject to periodic attacks of acute pain in the right occiput, most severe at night, and accompanied by sickness and vomiting. During these attacks vision was always much impaired. He has lately had occasional discharges of blood from the urethra, and his sputa have been tinged with blood. He has never noticed any swelling of his ankles. He has recently passed larger quantities of urine than he formerly used to do. The urine is albuminous even when no blood is present. Numerous remedies have been employed in his case, but most improvement attended the internal administration of arsenic and iron.

This is another well-marked example; and, in connexion with it, I would draw attention to the periodic headache and vomiting which were associated with the progress of the disease. When such symptoms occur in a case of chronic Bright's disease, retinitis is rarely found to be absent.

IV. On the 18th of January last I examined, at Dr Grainger Stewart's request, the eyes of Archibald March, a man aged 40, of anæmic complexion, and affected with chronic Bright's disease. His case has been recorded in Dr Stewart's work on "Bright's Disease" as a typical case of waxy degeneration. I found his vision much impaired, especially in the left eye. On ophthalmoscopic examination I detected the presence of retinitis in both eyes, with commencing degenerative changes, and several points of blood extravasation. This patient gradually sank, and died comatose from uræmia on the 3d February. On post-mortem examination waxy degeneration of kidneys, liver, and spleen was found.

This is an instance of retinitis accompanying amyloid degeneration of the kidney, which is of comparatively rare occurrence.[1]

V. James Stein, æt. 28, stone-mason, came to the Eye Dispensary on the 9th of February, complaining of defective sight. The ophthalmoscopic appearances were characteristic of albuminuric retinitis, there being exudation into the optic papilla and surrounding retina, extending to the macula lutea—numerous points of blood extravasation, and glistening white patches of fatty degeneration. On inquiring into the history of his ailment, I learned that he had occasionally during the last two years suffered from œdema of the ankles; and that, on one occasion, he had swelling of the face and eyelids and body generally. He now makes water very frequently, and passes a large amount in the twenty-four hours, and has lost flesh. His sight began to fail a week ago, when everything seemed dim and misty, and he had the appearance of bright spectra before the eyes. This attack was accompanied by severe pain in the head. I sent this patient to the Royal Infirmary, where he remained under the care of Dr Grainger Stewart, exhibited severe uræmic symptoms, from which, however, he rallied, and

[1] Similar cases have been recorded by Traube and Beckmann.

was able to leave the Infirmary and return home, where he died from a recurrence of the uræmia a few weeks later.

I hope that these cases may suffice to direct the attention of the members of this Society to a combination of diseases which has hitherto attracted less notice than, in my opinion, it deserves. Treatment, unfortunately, does as little for the retinal affection as for the disease with which it is associated. At the same time recovery has taken place,—we are therefore not entitled wholly to despair.

I have summarised, as follows, the chief points of interest to which I have referred:—

1. That dimness of vision is a frequent concomitant of chronic Bright's disease; and that, while in a few cases the defective sight may be attributable to uræmic poisoning of the nervous system, in the great majority of cases it is due to inflammation of the retina, attended with fatty degeneration.

2. That this disease of the retina presents such distinctive ophthalmoscopic appearances as enable it to be at once with certainty recognised.

3. That this retinal affection is found most frequently to accompany the contracting form of Bright's disease, but occasionally, also, the amyloid variety.

4. That not unfrequently, from the insidious progress of the disease, the affection of vision is the first symptom that obliges the patient to apply for advice, and that thus the ophthalmoscope may lead to the detection of previously overlooked kidney disease; and,

5. That, in a few cases, the diseased condition of the retina has been resolved, with restoration of function.

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AIDS TO

OPHTHALMIC DIAGNOSIS.

BY

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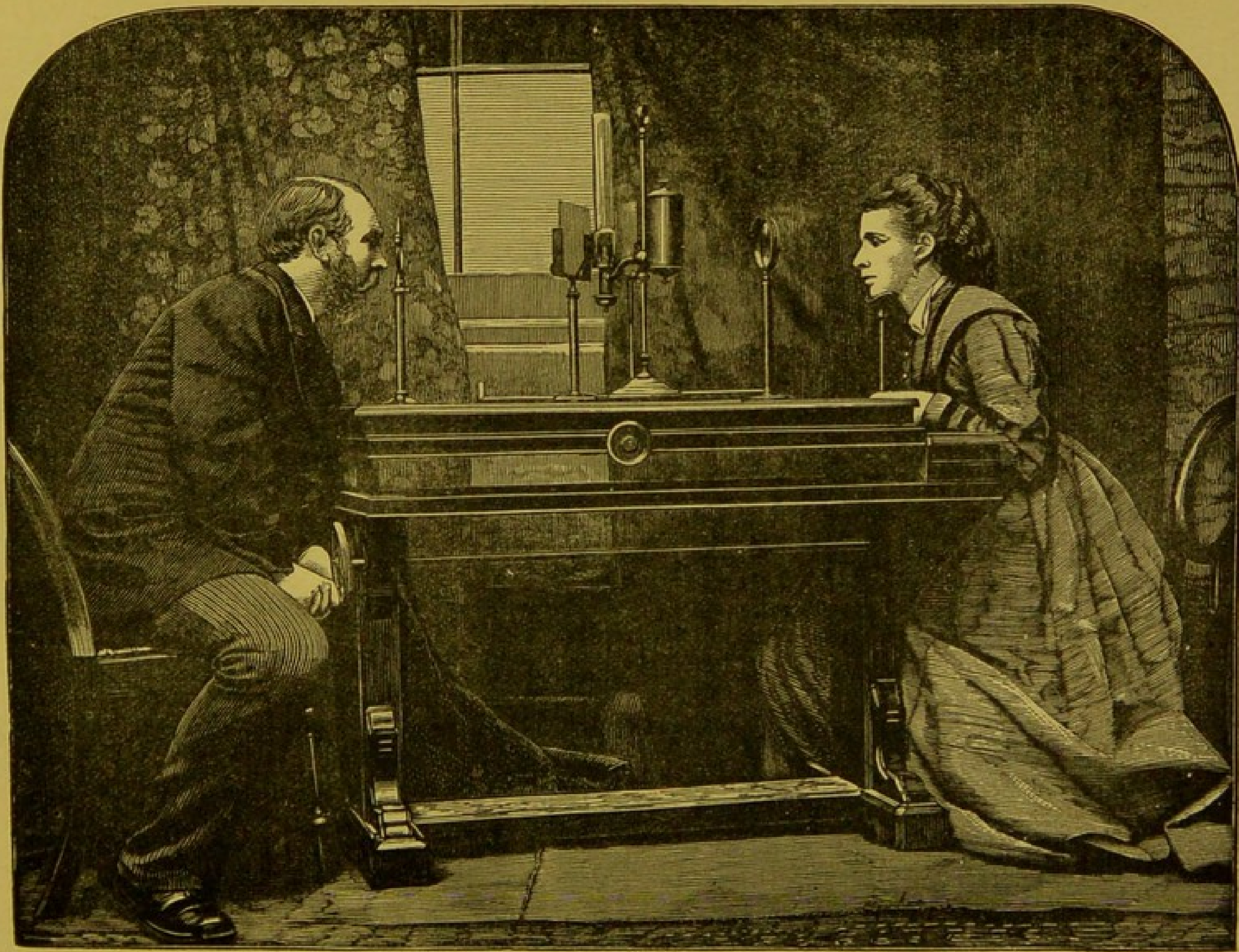
INTRODUCTION.

The following pages contain a brief account of several instruments which I have devised to facilitate the examination of patients in ophthalmic practice. It is chiefly in special hospitals, where a large number of patients present themselves, that their utility and importance will be recognised.

I have now had them in operation for some time, at the Newcastle Infirmary for Diseases of the Eye; I find they work well, and with a view to serving others, I venture to bring them before the notice of the profession.

Newcastle-upon-Tyne.

July, 1874.



THE DEMONSTRATING OPHTHALMOSCOPE AND TABLE.

THE DEMONSTRATING

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The importance of rapidity in the examination of cases in hospital ophthalmic practice frequently precludes the use of some of the most beautiful and valuable apparatus of modern invention. Thus the demonstrating ophthalmoscope of Burke, from the great care and nicety required in its adaptation, and consequently the constant necessity for re-adjustment in each case under examination, is not convenient for shewing large numbers of cases in rapid succession: and to shew differences, both physiological and pathological, to students, it is necessary that they should be able to contrast a number of cases as rapidly as possible. The same objections apply to the modified form of demonstrating ophthalmoscope, in which a lens is substituted for the second mirror; and it is with a view to remedy this defect that I have had the table constructed, of which Plate I. is a photographic representation.

The table, which is about 3 feet 9 inches in length by 1 foot 8½ inches in width, and 2 feet 4½ inches high, is supported at each end by a broad, substantial leg. These legs, which are sections of a parallelogram, are hollowed out, and contain the boxes to which the top of the table is fixed. These boxes are connected with a rack and pinion movement, which is controlled by the wheel seen in the hand of the examiner, and by means of this arrangement, the table can be made to rise and fall in a vertical direction. The whole of the upper part of the table, however, does not move, a small segment upon which the chin-rest is placed being detached from the moveable portion, and firmly fixed to the leg which supports it. The table, further, has two tops—one (the lower) a false one, is, in reality, only a framework to give attachment to the boxes for the vertical movement. The other—the true one—is connected to the false one by means of a long screw, the end of which terminates in a small circular wheel or handle, visible on the right hand side of the table. When this handle is set in motion, it causes the true to glide over the false top in a horizontal direction, either right or left as desired.

The movements executed by this table resemble, in many respects, those of the stage of a microscope; there is, however, this exception, that whilst the movements of the stage of the microscope are all made in one plane, the movements of the table, by varying its height, can be made in any plane within the range of its vertical movement.

The advantages of this table are manifestly very great, for, whereas with an ordinary table, for the examination of each separate person, a fresh adjustment of the mirror lens and lamp is necessary, by means of this table we are enabled immediately to adjust the whole of the apparatus to the necessary height for any patient, and can, further, without moving the patient or instrument, throw the light into the right or left eye, as we may desire.

Mr. Foveaux, the able manager of Messrs. Weiss & Co., has recently, by means of a very simple contrivance, added to the object lens, given the examiner so far a control over its movements, that it may be gradually raised and depressed. The extent to which any such movement can be employed, without also necessitating a change in the position of the mirror, is so extremely limited, that I have found the apparatus practically useless. It is an essential condition of using the demonstrating opthalmoscope, that the axis of the mirror lens and patient's eye should coincide, and any deviation, however slight, from this condition interferes with the exact production of the image. I make these observations because some enquirers have asked me whether this power of control over the object lens would not do away with the necessity for the demonstrating table, and I wish to show that, putting aside the question of lateral movements, which is one of the chief features in the table, the vertical movement of the lens alone is but an inefficient substitute for the vertical movement of the whole apparatus. I would now say a word about the mirror in general use. Burke's instrument having been the origin of the present form of demonstrating ophthalmoscope, a paraboloid or concave mirror, is the form which is always supplied. Although the resulting image is exceedingly beautiful and well defined, the field of vision is too limited. This depends upon the parallel direction of the rays which emanate from this form of mirror when the lamp is placed in its principal focus; and with an undilated pupil, all that can be seen is the disc, with, at most, a very narrow portion of surrounding retina. What I now usually employ is a plane mirror, about $3\frac{1}{2}$ inches in diameter, with a circular aperture of about $\frac{1}{8}$ inch in diameter. The illumination is from an ordinary argand burner, placed about 12 inches in front, and a little to the side of the mirror; the rays of light emanating from it are consequently divergent, and continue divergent on reflexion.

The advantages of divergent rays in examination by the inverted image have long been recognized, and we find that by their use the field of view is very materially increased in size, the illumination, too, appears much brighter, and slight lateral displacements of the eye are not so apt to shew the image so much out of view as when parallel or convergent rays are used.

I have tried various experiments with a view to ascertain to what extent the central aperture of the mirror could be enlarged without materially interfering with the illumination of the fundus. One mirror I employ, has an aperture $\frac{3}{4}$ inch in diameter; its use is attended with certain advantages; for instance, it enables the examiner to place his head at a considerable distance from the mirror, and thus keep both eyes open. The examination is consequently made with less inconvenience and fatigue. It enables the operator too, by slight movements of the head, to displace reflexion and broken lights, to correct slight movements of the eye of the examined person, and offers a larger area for the action of magnifying lenses placed behind the mirror.

The frontispiece is a drawing of the demonstrating ophthalmoscope table, which I exhibited at the Annual Meeting of the British Medical Association, in London, in 1873. The way in which it facilitates ophthalmoscopic demonstrations was the subject of general remark when contrasted with the ordinary method. It is impossible to carry out the latter successfully without the use of one, and sometimes even two assistants, and then the use of atropine is almost indispensable.

continued on account of the facility and rapidity with which it is carried out, but it can scarcely be very accurate; it cannot be registered, and must leave but a doubtful impression on the Surgeon's mind: hence it is of great importance that some instrument should be obtained, the use of which will not take up more time than the old method, and whose results can be accurately registered.

The instrument which I have devised, and which is figured in the text, will enable the operator to map out the field of vision with as great, if not greater rapidity, than with the old method, which I have described above; its measurements are taken with the greatest accuracy, and if necessary the limits of the field of vision can be immediately transferred to a chart, and kept for future reference. It not only fulfils the purposes of a perimeter, in an ordinary sense, but it will also test the field of vision for colours transmitted or spectral, and by a very simple addition it can be made to indicate the presence of astigmatism, and shew the meridian in which it exists. Some other indications it can fulfil, I shall speak of bye and bye, as they will be more readily understood when the instrument has been fully described.

The perimeter is an instrument of light metal (zinc or copper) hammered out with great accuracy, its diameter being 24″. The concavity of the instrument is painted a dead white, and this surface is divided by fine black lines into degrees of latitude and longitude. The meridians of longitude commence at the pole and run towards the margin or equator of the perimeter, every two contiguous lines including a space of 15°. The parallels of latitude encircle the pole—the first being placed at 10° from it, and each successive one having an interval of 10°. The pole itself is occupied by a circular opening about $\frac{3}{4}$″ in diameter, the purposes of which will be further explained, as will also some other markings on the surface of the perimeter.

In order to measure the field of vision it is necessary, whatever instrument be employed, to have a fixed point, and a moveable point. The latter must be some small object which can be made to move in different parts of the field of vision, and whose image will consequently travel over those portions of the retina which are not occupied by the fixed point. In the instrument I am now describing, these indications are fulfilled in the following manner:—A gas lamp (Argand burner) is so adjusted upon an upright moveable stand placed behind the perimeter, that some of its rays pass through the hole in the pole of the hemisphere. These rays are made to fall upon a small mirror which (as seen in the engraving) is attached by a rod to the chin-rest. The mirror being ground to a focus of a little less than 12″, will form, when placed at this distance from the central aperture, a clear and bright reflected image of it upon the surface of the perimeter. To enable this disc of reflected light to be thrown in any direction required, the mirror is attached to its connecting rod or support by a ball and socket joint.

To use the perimeter for testing the field of vision, we proceed in the following manner:—The chin-rest is placed opposite the concavity of the hemisphere, its height being so adjusted that when the patient's chin is placed upon it, the eye to be examined is opposite the aperture at the back of the perimeter. The reflecting mirror is now adjusted, and made to occupy a position slightly below and to the outside of the eye to be examined, the other eye being covered by a shade. By a little management, the beam of light which passes through the aperture in the perimeter is made to fall not directly upon the examined eye, which it would dazzle, but somewhat obliquely upon the mirror which reflects it.

When a patient is placed in the position above indicated, his eye directed upon the central aperture, an image of the perimeter is projected upon his retina, which is, so to speak, artificially mapped out into exactly the same divisions as are present on the instrument—the central aperture lying exactly at the yellow spot, the peripheral parts of the instrument occupying the peripheral parts of the retina. In this way the concavity of the retina becomes an exact counterpart (of course inverted) of the concavity of the instrument. Now it is evident that if a disc of light is made to travel over the surface of the perimeter, its image will also travel over the surface of the retina, in an opposite direction. Should this travelling spot of light pass over a portion of the retina whose sensibility is lost or impaired, it will immediately disappear, and by referring to the position the disc then occupies on the surface of the perimeter, we know the corresponding position of its image in the fundus of the eye. In the same manner, by directing the disc of light along the various meridians of longitude, and noting the place at which it disappears, we are able to form an accurate chart of the limits of the field of vision.

Let us illustrate this. A patient is placed in position, with his right eye opposite the perimeter, and fixed upon the central aperture. We know that the image of the central aperture now occupies the exact position of the yellow spot, and we wish to examine the blind spot or optic nerve entrance in this eye. We know that its situation, anatomically, is slightly to the inner (nasal side) of the yellow spot, we therefore gradually move the travelling disc outwards, and when it arrives at a position about 15° to the outer side of the central aperture, it will disappear.

If we wish to ascertain the exact limits of the field of vision, we cause the disc to travel along the various meridians of longitude, and mark the exact position in which it passes out of sight. To record cases under examination, charts of the perimeter are prepared on several different scales.

As it is advisable, in some cases, to measure with precision the size and limits of the optic nerve entrance, or blind spot, the surface of the perimeter, in the region which this portion of the fundus occupies, has been more carefully divided into spaces of one degree.

Attached to the back of the perimeter will be found two sets of diaphragms, these are represented in Fig. II. One, the smaller, contains apertures of various sizes, which thus enables us to regulate at will the diameter of the hole at the back of the perimeter. The other contains discs of variously coloured glass, representing the prismatic colours; it contains, besides, a disc, the diameter of which is traversed by a fine slit; this disc is made to revolve upon its own axis, and is used in testing for astigmatism.

The use of these parts will now be explained. In many cases, where the sensibility of the retina is much impaired, a small aperture and consequently a small disc of light will not be convenient for measuring the field, hence the larger apertures. The smallest is for taking exact measurements of the blind spot, the area of which can be more readily defined by the disappearance and re-appearance of a fine point of brilliant light, and here I may state that the intensity of the light can always be regulated by the amount of gas burnt.

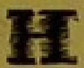
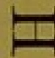
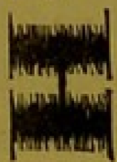
To test the field of vision for colours, we proceed in exactly the same way as under ordinary circumstances, the disc of the colour required being interposed between the flame and the aperture in the perimeter.

The processes above described enable us to test what is termed the quantitatve field of vision, or that portion in which a person distinguishes roughly a spot of light. To measure the qualitative field of vision a stencil letter is inserted in an inverted position in the aperture of the perimeter, when the mirror immediately forms a bright erect image of it on the surface of the perimeter. The operator now ascertains at what distance from the fixed point this reflected letter is recognised; he tries this in all the various directions, and makes a chart in the ordinary way. This forms a very severe but useful qualitative test, and the shape of the test object can be varied *ad infinitum*.

I now come to speak of the manner in which this instrument can be used to determine the presence of astigmatism, which it does not by any new method, but by being easily adapted to some of the simplest methods of diagnosis.

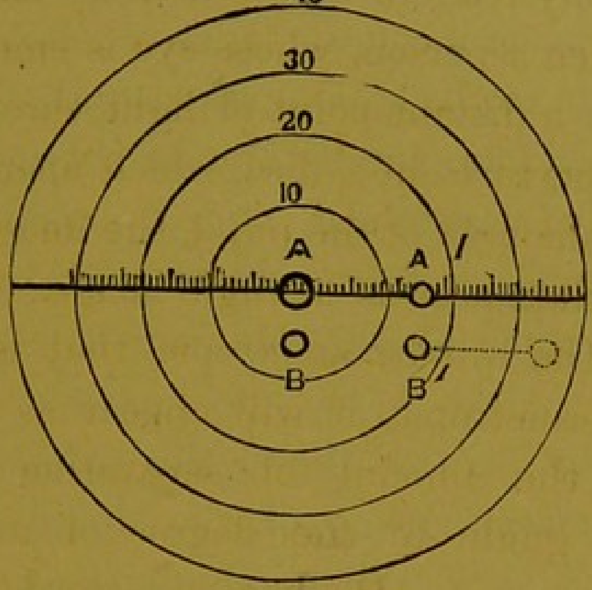
In the larger diaphragm, which is adjusted at the back of the perimeter, is a circular metallic disc which has a slit traversing its diameter about $\frac{1}{10}''$ in width. This slit, when occupying the aperture in the perimeter and illuminated from behind, will appear to the observer in front of the instrument as a bright stroke of light; by means of a small handle attached to the disc in which the slit is made, it can be rotated upon its own axis, and thus the slit can assume any desired meridian. Thus, we have at our command a bright luminous stroke, which stroke can be readily made to occupy any meridian, and whose position we can register by reference to the markings on the interior of the perimeter. Now, as astigmatic persons, according to the meridian of astigmatism, do not see clearly strokes or lines which occupy certain directions, it will be obvious that if we have a stroke or line which is moveable in every direction, we have a means of ascertaining in what meridian vision is defective. The clearness with which a stroke is seen depends upon the clearness with which its outline is seen, and this must depend upon the accuracy with which the different meridians of the cornea are adapted. A vertical stroke | may be said to be made up of a number of small horizontal ones ⁝, and if the horizontal meridian is at fault it will not be distinctly seen, but will appear  A horizontal stroke, on the contrary, ______ may be said to be made up of a number of closely packed vertical strokes ...., and if the vertical meridian is at fault, a horizontal line will not be clearly defined, but will appear  .

A person, then, with a normal eye will see the luminous slit well defined, in whatever position it is rotated, but an astigmatic person will not do so, if he is astigmatic in the vertical direction, when the line comes to occupy a horizontal position its definition will be interfered with, and *vice versa* when he is astigmatic in ths horizontal direction, the line will not be clearly defined in the vertical position. Thus, by rotating the slit opposite an eye whose accommodation is suspended, we shall be able to ascertain, by the clearness of its outline, the presence and meridian of astigmatism; the kind and degree must be subsequently determined by suitable cylindrical glasses.

In the same way a stencil letter, for instance the letter H, whose size shall correspond to No. XX. of Snellen's type, may be inserted at the back of the perimeter. This being gradually rotated, the positions are noted in which the letter is recognised or not, and the presence of astigmatism ascertained. Thus, if the letter H is clearly defined when in the vertical position, we infer that the horizontal meridian is normal, and that rays passing through it are brought to a focus. If it is seen blurred  or is not even recognisable in that position, we infer that the rays passing through the horizontal meridians are not brought to a focus, and that astigmatism exists in that plane. Again, supposing that the letter H is recognisable when in the vertical position, but when gradually rotated till it assumes this position,  is then not recognisable, or appears thus , we infer that the horizontal meridian brings rays to a focus upon the retina, but that the vertical meridian is astigmatic. If for ascertaining the presence of astigmatism, an ordinary point of light is desired, and this method is, I believe, the one in general use, one of the small apertures in the inner diaphragm can be used for the purpose.

I must here point out how the perimeter can be used in ascertaining the refraction of the eye, according to the highly ingenious method of Dr. Thompson, of Philadelphia.

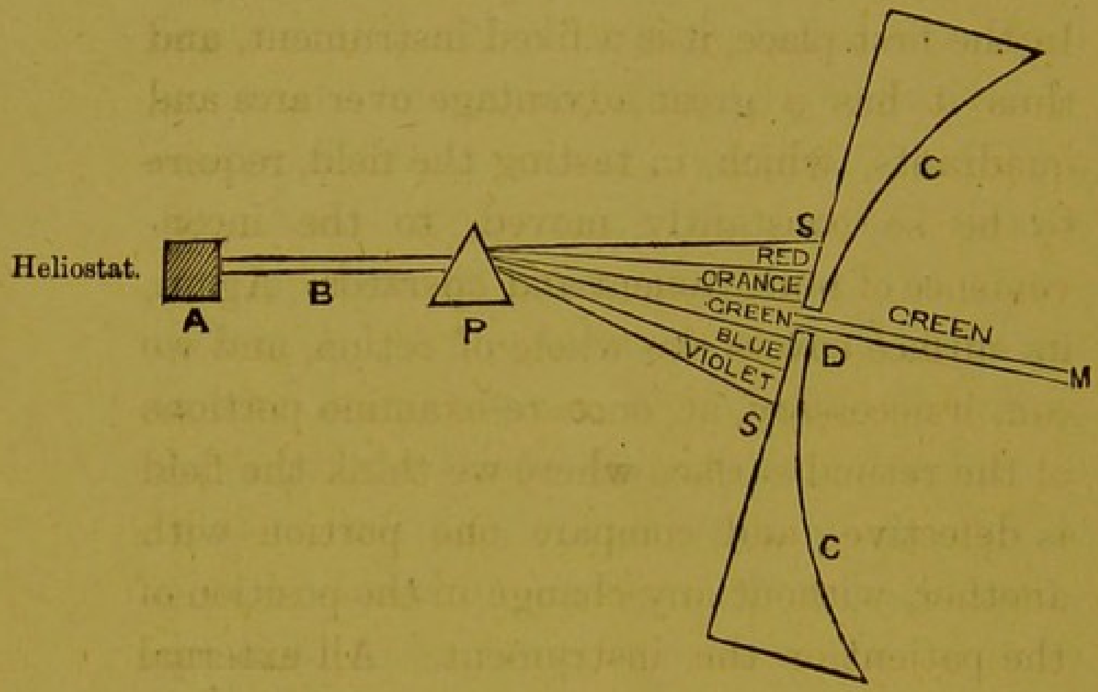
As all my readers are aware, he has shewn that when a person, whose eye is emmetropic, looks at a distant point of light through two small apertures in a disc, which apertures lie within the area of the pupil, the image of that light will appear as a single image; but that, should the eye be ametropic, that is myopic or hypermetropic, it will appear as a double image, the amount of separation being a certain guide to the degree of myopia or hypermetropia. He has, in accordance with his theory, drawn up a table which shews the amount of separation in the images occuring in certain degrees of myopia and hypermetropia, and I should strongly recommend all who are interested in this subject to refer to the original paper; here I shall only point out how the perimeter may be made subservient to the measurement of the angle of separation. The patient is placed at the necessary distance from the perimeter, one of the smaller apertures occupying the back of the perimeter is brilliantly illuminated from behind.



Supposing the patient is myopic, when the two small apertures in the disc which is held before the eye are in the horizontal meridian, the light A will appear double, the second image appearing at A^1, and the distance between A and A^1 will be guide to the degree of myopia. But the distance between A and A^1 must be accurately measured, and the patient being 17 feet from the perimeter, any guess at the separation of the images would be too imperfect for determining the degree of M. To measure them more exactly, the travelling disc of light which is used for measuring the field of vision is thrown immediately below A at B, it will necessarily, like A^1 be seen double, the second image appearing at B^1. It is now, however, set in motion towards the right, and the patient is told to indicate when B comes under A[1]; reference is then made to the scale marked upon the horizontal meridian, the separation between A A[1] accurately ascertained, and by reference to Dr. Thompson's table, the degree of myopia corresponding to this amount of separation noted.

It is obvious that the method which applies to the measurement of the double images produced, as described above, may also be applied to the measurement of the angle of diplopia in cases of paralysis of the ocular muscles, only, in this case, the patient must be brought sufficiently close to the instrument that the angle of displacement may be within its range. I have often, in cases of paralysis of the third nerve, been able to measure the degree of diplopia, and have observed that one of the first symptoms of improvement has been the diminution of this angle. By the use of a prism, artificial degrees of diplopia may be produced, and the various strength of the ocular muscles in overcoming these ascertained.

With regard to testing the field of coloured vision, in the method above described, I know it will be urged by some that the purity of colours transmitted through glass is not sufficiently great to be perfectly accurate. Theoretically this, no doubt, is so, but, practically, I have not found much difference in the range of field when the pure colours of the spectrum have been used, as compared with those obtained by coloured glass. Upon this subject I may say something more by and by, but my object here is to point out how the pure spectrum colours may be used for physiological or experimental purposes. A beam of light, about one inch in diameter, is allowed to enter a darkened room, through an aperture in a shutter. By means of a heliostat, it is reflected in a horizontal line corresponding with the height of the aperture in the pole of the perimeter. A prism, held vertically, is now placed in the course of the beam of light, when immediately a spectrum will be formed, the colours of which will be arranged in vertical bands, whose thickness will depend upon the distance of the spectrum from the prism. The perimeter is now placed in such a position, that the spectrum falls upon the aperture at its back, and, by shifting it laterally, the colour of each beam can be separated from the rest, and allowed to fall upon the reflecting mirror. This is best understood by referring to the diagram, which represents a horizontal section through the perimeter and prism.



A Heliostat. B ray of light.
P prism. SS spectrum. D aperture in CC perimeter.
M mirror. The green ray of the spectrum is passing through.

In our own smoky town, the appearance of the sun is such a precarious event, during the winter months, as to have prevented me from making many observations, as to the area of colour vision. Generally speaking, blue has the largest range, then come in order, but with a decreasing field of vision, red, yellow, green, orange. At some future time, I hope to be able to give more full particulars on the subject.

Having now described the construction and uses of the photo-perimeter, I shall point out what I consider to be its special advantages. In the first place, it is a fixed instrument, and thus it has a great advantage over arcs and quadrants, which, in testing the field, require to be so constantly moved, to the inconvenience of both patient and operator. Again, its surface covers the whole of retina, and we can, if necessary, at once re-examine portions of the retinal surface where we think the field is defective, and compare one portion with another, without any change in the position of the patient or the instrument. All external objects are excluded from the eye, and there is nothing to attract the patient's observation but the fixation point. One of the chief improvements appertains to the use of a disc of light as the measuring point. Here, no hand or piece of mechanism is brought before the patient's eye, whilst the measuring point is mapping the field—further, the brilliancy, size, and colour of this disc are easily regulated, and letters, or other forms of different sizes, can be used when such a proceeding is thought advisable.

It would be difficult to have an instrument in which so many advantages were combined, and not expect to meet with some disadvantage; and there is one which has been frequently urged against the photo-perimeter. It is, that the eye of the patient is not readily watched by the observer. Now, if this were absolutely true, it would be an objection of some weight as regards the examination of uneducated and stupid persons; and with such a class, almost any accurate form of perimetrical examination is a matter of difficulty, but in reality, in my method of examination, a good profile, even of the eye, is always obtainable, and with a little experience and practice, we soon learn to ascertain whether it is properly fixed. Again, the rapidity with which the travelling disc of light can be directed to any point will always enable us to ascertain, by reference to the blind spot, whether the fixation is correct or not.

From what I have previously said in describing the photo-perimeter, it will have been gathered that, in a complete examination of the field of vision, there are three things which must be ascertained. 1st. The field of *qualitative vision*, or the surface of the retina in which light is recognised. 2nd. The field of *quantitative vision*, or the surface of the retina in which, though vision is imperfect, the form of objects is still recognised. And 3rd. The area of the blind spot, or optic nerve entrance.

Time and space forbid my entering into a full enquiry upon the variations of size and shape these different areas may assume under certain physiological and pathological conditions. My object will be to point out the results I have obtained by the use of the instrument in the comparatively short period during which I have employed it.

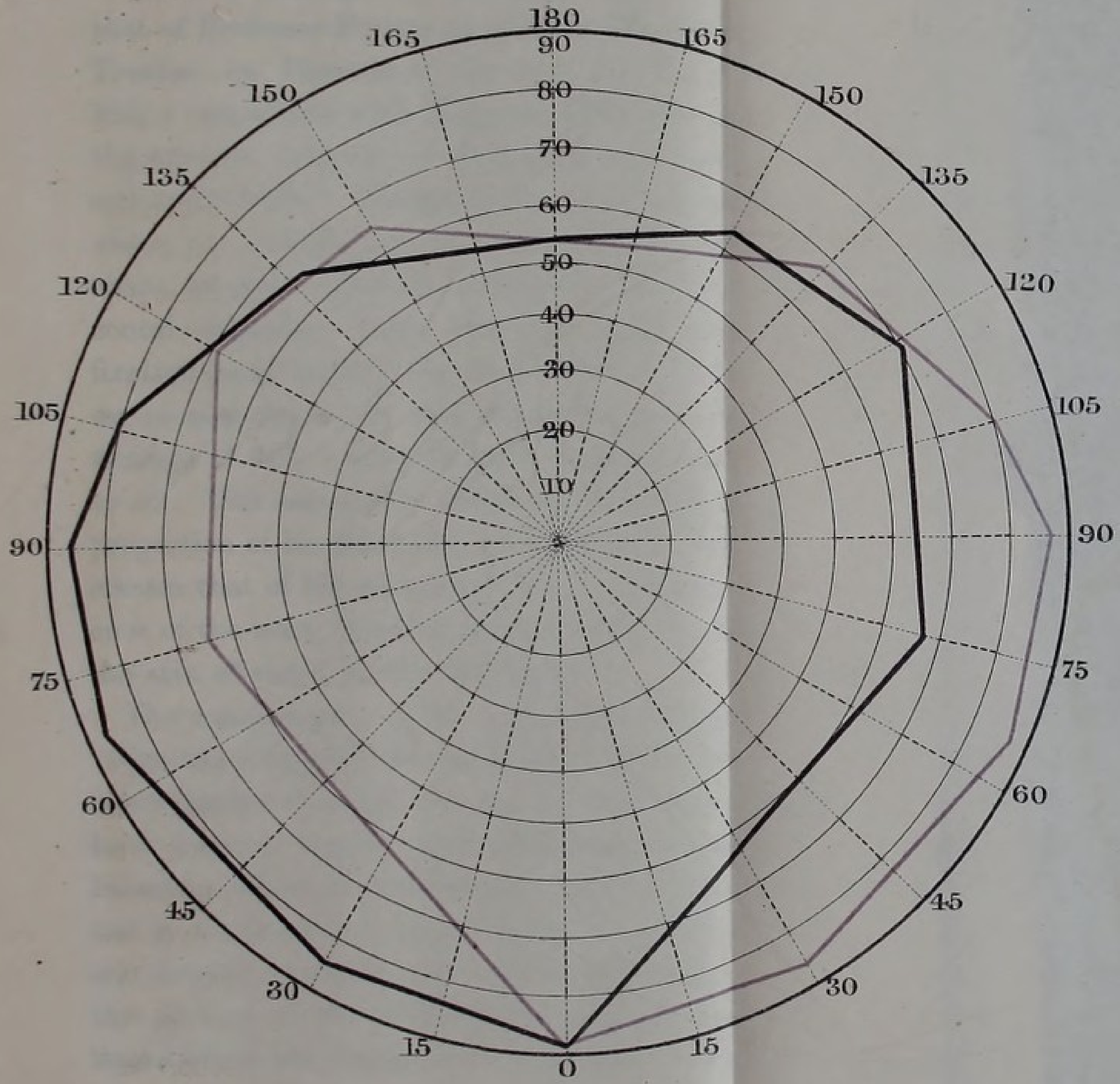
The measurements hitherto given of the normal field of vision have been very conflicting. Thus, between the figures of two such able observers as Forster and Helmholtz, we find startling differences. In the horizontal meridian, the average diameter as given by the former observer, measures only 150°. By the latter, 160°. In the vertical diameter, 120° is the figure given by both observers.

The measurements I have found to coincide with health are given in the annexed diagram of the field of vision. It has been drawn from the measurement of a considerable number of young healthy persons with pupils which act readily, and are of medium size—for, I need scarcely say, that the size of the pupil must have some effect upon the area of the visual field, as will also peculiarities in the form of the orbit, prominence of the nose, etc.

The form of the field of vision is very peculiar; it is that of an ellipse, one extremity of which is larger than the other. The axis of the ellipse occupies an oblique direction across the vertical axis of the eye. It is this oblique diameter which I find to be the largest in the whole area of the field of vision, and in my schematic field it measures 160°, whilst the horizontal and vertical measurements generally correspond, each measuring on an average 150°.

In the diagram opposite, we have a figured chart of the right and left fields of vision, one outlined in black, the other in violet. These figures are superimposed, so that the two yellow spots correspond as happens when our two eyes are directed upon an object, and, combined, form a chart of the binocular field of vision. From this we get a fair idea of the relative proportions of the eye in which objects overlap each other, and we see singly. The central portion representing the area of binocular vision, the external portions the area of monocular vision. We shall find that the greatest diameter of binocular vision lies in the vertical direction, and

PERIMETER CHART.



measures about 150°, the horizontal diameter being about 120°.

When I contrast my binocular chart with that of Professor Forster as given in Wecker's Treatise on Diseases of the Eye, vol. II., p. 428, I am struck with the great difference in the relative proportions of the binocular and monocular fields. The larger area of binocular vision, as compared to the monocular in my chart, depends upon the increase in my horizontal diameter, when measured from the fixation point towards the nasal limit. Thus my measurements in this direction give an average of 60°, whilst Forster's only amount to 50°. This necessarily decreases the relative proportion of his binocular area, whilst it increases that of his monocular one. Prominence of the nose, however, is very apt to limit the area of vision on the nasal side.

The measurement of the qualitative field of vision has always been a stumbling block in the investigation of ocular disease, because there have been no regular and fixed data established by which comparisons can be instituted, and in comparatively recent works on opthalmic surgery, students are directed to map out this portion of the field by ascertaining the limits where two fingers are recognised. The facility with which the bright images of letters can, by means of the photo-perimeter, be directed into various portions of the field, have led me to employ them for the mensuration of the qualitative field; and I think that, for various reasons, their employment is the best test we can use, as it enables us to bring peripheral vision within the range of the same expressions as we use for direct vision.

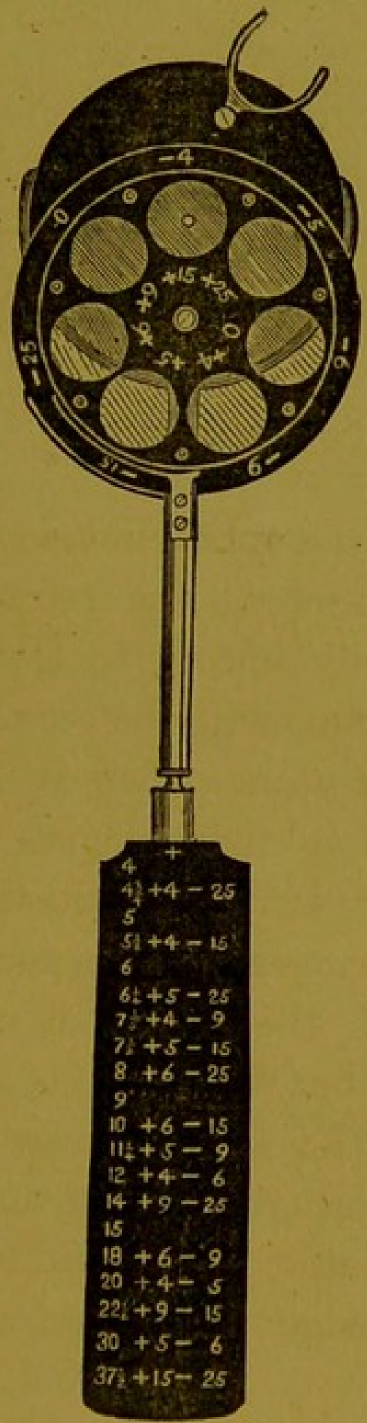
I shall content myself with pointing out roughly certain general features connected with this method of testing vision, and shewing how it may be amplified and worked with an instrument more perfectly constructed than the one I at present use.

According to the investigations I have been enabled to make, I find that in normal eyes the acuteness of vision decreases in a regular ratio from the fixation point towards the periphery. At 5° $V = \frac{1}{10}$, at 10° $= \frac{1}{20}$, at 15° $\frac{1}{30}$, at 20° $\frac{1}{40}$; and thus I express numerically the acuteness of peripheral vision in the qualitative field. I do not mean to say that the figures I have just given would be an accurate test in every case, for I have been much astonished at the difference of acuteness in the peripheral fields of many persons of normal refraction and sight, and it would require a large number of examinations to form a reliable standard. In the meantime, I think the figures here given are not far from the normal; the aperture in my perimeter will not, however, admit of sufficiently large letters for testing the more distant portions of the retina in this way.

A REFRACTION OPHTHALMOSCOPE.

The value of the ophthalmoscope as an optometer, or measurer of the refraction of the eye, though fully known to Helmholtz, was not brought prominently before the profession till more recent years, when it has assumed at the hands of ophthalmologists the attention to which it is deservedly entitled. To make use of the instrument as a means for viewing the fundus of the eye is a comparatively easy matter; but to use it to ascertain the refraction of the eye is a matter of some difficulty, requiring much care and experience, a keen appreciation of the definition of objects, and a knowledge of the refraction of one's own eye.

The whole question to be determined in calculating the refraction of a given eye, is the direction of the rays leaving the fundus



-4
-5
0
+15 +25
-25
+
4
4½ +4 − 25
5
5½ +4 − 15
6
6½ +5 − 25
7⅕ +4 − 9
7½ +5 − 15
8 +6 − 25
9
10 +6 − 15
11¼ +5 − 9
12 +4 − 6
14 +9 − 25
15
18 +6 − 9
20 +4 − 5
22½ +9 − 15
30 +5 − 6
37½ +15 − 25

of that eye. This can easily be obtained, if we know the refraction of the examiner's eye, and the distance between the two if the rays, the accommodation being suspended, (and to make a careful examination this should always be done) emanate from the principal focus of the dioptric system, that is to say, the retina is situated at this point, they will leave the eye parallel, and the eye will be emmetropic ; for, in reversing the order of things, parallel rays would fall upon the retina at the principal focus of the dioptric system. If the rays from the fundus emanate in a divergent direction, we know that the fundus must be situated in front of the principal focus (hypermetropia.) If the rays emerge in a convergent direction, we know that the fundus must be situated behind the principal focus (myopia). The extent to which these rays diverge or converge, will be an index of the degree of hypermetropia or myopia, and it is with the opthalmoscope that this measure is made. Now, for a person who is emmetropic and can suspend his accommodation, this calculation is very simple, for his eye will then be in a condition to unite parallel rays upon his retina as the principal focus of his dioptric system, and if such an eye is placed in a position as to receive light emanating from an eye similarly circumstanced, a clear view of the fundus will be immediately obtained, and the examining person will know that the examined person is emmetropic. Should the person under examination be myopic, that is, giving off convergent rays, the examiner, who is only adapted for parallel rays, will not be able to see his fundus until a concave lens shall have so overcome their convergence as to make them parallel. Should the person be hypermetropic, these rays will emanate divergent, and the examiner will not be able to see the fundus until these rays have been rendered, by a convergent lens, parallel.

Now, could the examined and examining eye be brought so close together as to touch, it is evident that in the case of myopia and hypermetropia, the respective lenses which would paralyze the rays, and enable the emmetropic examining eye to see the fundus of the emmetropic eye it would be in each case a measure of the degree of emmetropia, hypermetropia, or myopia ; but in practice this cannot be done, consequently the distance between the two eyes will alter slightly the calculation. Let us imagine, for instance, that the rays from the fundus of an hypermetropic eye issue from the cornea of that eye with such an amount of divergence as would necessitate, theoretically, the point from which these rays diverge, being situate at 6″ behind the nodal point of that eye, a convex lens of 6″ focus, or, as it is usually expressed, $\frac{1}{6}$, being placed immediately in front of the cornea such an eye would render these rays parallel; but to the examining eye, situated at two inches beyond the cornea of the examined eye, these rays will seem to diverge from a point 8 inches from it. Consequently, the examiner, who is emmetropic, would require a $+ \frac{1}{8}$ to see the fundus of a person who has hypermetropia of $\frac{1}{6}$, and from this we may deduce the rule that the degree of hypermetropia is always greater than the glass, which, in the erect image, neutralizes it. In myopia, we shall find that this rule is just the opposite. Supposing a myopia of $\frac{1}{6}$ exists, the rays leaving the cornea of such an eye will converge towards a point 6″ in front of that cornea, and a $\frac{1}{6}$ placed immediately in front of that cornea would render such rays parallel. But to an examining eye, situated at 2″ from the myopic eye, the rays will appear to be converging to a point 4″ behind such an eye, and consequently $\frac{1}{4}$ will be required to parallellize the rays, and render the fundus under examination visible. Hence, the concave glass, which, in the erect image is required to enable an emmetropic eye to see distinctly the fundus of a myopic one, is always stronger than the glass which, as spectacles, would neutralize the myopia.

We have been supposing in these cases that the examiner is emmetropic, and has the power of suspending his accommodation. But these two conditions unfortunately are rarely found combined. Hence, when an examination of the refraction of an eye is being made, many factors are brought into the calculation. It is with a view of reducing some of these that I had the present ophthalmoscope constructed. It consists of an ordinary concave mirror of 30″ focus, behind which are placed two discs which revolve upon each other; each disc contains 6 lenses and a small blank aperture, and they are so adjusted, that the lenses can be brought successively behind the aperture of the mirror, each lens separately, or two lenses combined. The lenses in the inner disc consist of $-\frac{1}{4}$ $\frac{1}{5}$ $\frac{1}{6}$ $\frac{1}{9}$ $\frac{1}{15}$ $\frac{1}{25}$; those in the outer disc consist of $+\frac{1}{4}$ $\frac{1}{5}$ $\frac{1}{6}$ $\frac{1}{9}$ $\frac{1}{15}$ $\frac{1}{25}$. Now, it is evident that when any of these two lenses are used in combination, the resulting lens will be the balance of the stronger over weaker. Thus, for instance — $\frac{1}{4}$ combined with + $\frac{1}{5}$ − $\frac{1}{20}$. By thus combining lenses of different characters, we can obtain from a small number of lenses a large number of varying powers. The principal powers, and the combinations necessary to produce them, are engraved upon the handle of the ophthalmoscope which is constructed of ivory, and is made broad on purpose to receive them, on the front the − combinations, on the back the + combinations. Now, for a person who is emmetropic, and can suspend his accommodation, in using this ophthalmoscope, the only calculation necessary to be made, is that which the distance between the examined and the examining eye necessitates. Thus, in myopia, if *a* represents the glass which enables such a person to see the fundus, and *b* represents the distance between the two eyes, *M* will equal $\frac{1}{a+b}$. In hypermetropia, H will equal $\frac{1}{a-b}$. If the examiner were ametropic, or could not suspend his accommodation, the value of this combination would be proportionally altered to him. Hence, I have added a small clip which holds what I term the rectifying lens, or lens which renders the observer emmetropic, its power will necessarily vary for different observers, and all those who wish to practise this branch of ophthalmoscopy should have it carefully and repeatedly verified by a competent person. My own vision is emmetropic, but in examining in the erect image, I have not the power of suspending all my accommodation. The amount which I cannot suspend requires a $-\frac{1}{20}$ to overcome; hence my rectifying lens is $-\frac{1}{20}$, and when examining the fundus with this rectifying lens, in front of the combined lenses, their values will be exactly that which is inscribed on the handle. The rectifying lens for a myopic person must be the sum of his myopia and the accommodating power he cannot suspend. For a hypermetropic person, the rectifying lens must represent the value of the hypermetropia, which remains after the accommodating power has been taken into account.

It will be found that the various combinations of these two discs will put us in possession of altogether 40 different powers, and in order that these may be seen at a glance, together with the combinations which produce them, I have constructed the following table :—

	— 4	— 5	— 6	— 9	— 15	— 25
+ 4	neut	+ 20	+ 12	+ $7\frac{1}{5}$	+ $5\frac{5}{11}$	+ $4\frac{16}{21}$
+ 5	— 20	neut	+ 30	+ $11\frac{1}{4}$	+ $7\frac{1}{2}$	+ $6\frac{1}{4}$
+ 6	— 12	— 30	neut	+ 18	+ 10	+ $7\frac{17}{19}$
+ 9	— $7\frac{1}{5}$	— $11\frac{1}{4}$	— 18	neut	+ $22\frac{1}{2}$	+ $14\frac{1}{16}$
+ 15	— $5\frac{5}{11}$	— $7\frac{1}{2}$	— 10	— $22\frac{1}{2}$	neut	+ $37\frac{1}{2}$
+ 25	— $4\frac{16}{21}$	— $6\frac{1}{4}$	— $7\frac{17}{19}$	— $14\frac{1}{16}$	— $37\frac{1}{2}$	neut

The column at the top is that of the minus disc, the column at the left is that of the + disc. The power which will result from a combination of any two glasses will be found at the angle of position of a line drawn from each.

It will be seen that many of the combinations do not produce whole numbers. This is not a matter of great importance, as, practically, we can only make an approximate estimate of the refraction in this way.

The numbers, both positive and negative, we are able to produce by the various com-

binations of the two discs, are as follow :—
4, $4\frac{3}{4}$*, 5, $5\frac{1}{2}$*, 6, $6\frac{1}{4}$, $7\frac{1}{5}$, $7\frac{1}{2}$, 8,* 9, 10, $11\frac{1}{4}$, 12, 14*, 15, 18, 20, $22\frac{1}{2}$, 30, $37\frac{1}{2}$. These numbers form a useful sequence, leaving no large gap between them, and are quite sufficient for all practical purposes.

One of the mechanical advantages of this ophthalmoscope is that the mirror is removable, and that the lenses, when employed by themselves are sufficiently large as to be readily used as trial glasses. We can thus, on the spot, and with the same instrument, verify our ophthalmoscopic diagnosis. This will be found occasionally very useful, as a set of trial lenses is very inconvenient to carry about.

*** The numbers marked by an asterisk are not perfectly correct, but are sufficiently so for practical purposes. The number $4\frac{3}{4}$ is really $4\frac{3}{4} + \frac{1}{84}$. The 8 is $8 - \frac{2}{19}$, the $5\frac{1}{2}$ is $5\frac{1}{2} - \frac{1}{22}$, and the 14 is $14 + \frac{1}{18}$.

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