and the carbonate of lithia are well adapted. It is to be borne in mind that should it be rendered alkaline the phosphates are ever ready to take advantage of a small hemp-seed or pin-head particle of gravel, and upon it, as a nucleus, to initiate a rapidly-growing stone. The object of keeping the urine neutral is to keep the lithic acid in a soluble condition until after its removal from the body. It is also most important to keep the action of the skin healthy, as it has been ascertained that the quantity of lithic acid in the urine is augmented when the cutaneous transpiration is interfered with. Warm clothing, the wearing of flannel or chamois leather next the skin, occasional diaphoretics, and the use of the vapour bath, are means of warding off the excessive formation and deposition of lithic acid concretions which will be worthy of attention after the removal of a calculus of this description. At the same time it will be necessary to endeavour to restore the proper tone of the organs of digestion, and to combat any peculiar form of dyspepsia which may be present, since the lithic acid diathesis is so much due to defective primary assimilation.

ART. III.—*On the Theory and Principles of the Ophthalmoscope.*

By HENRY WILSON, F.R.C.S.I.; L.K.&Q.C.P.I.; Assistant Surgeon to St. Mark's Ophthalmic Hospital; Member of the Royal Irish Academy, &c., &c.

(Continued from Vol. XLII., page 360.)

IN the production of the *erect* image we employ the ophthalmoscope mirror alone, and make use of the refracting media of the eye itself as a lens; in this examination the observed as well as the observer's eye must be accommodated for distance, and be very close to each other—about two inches; the emergent rays being parallel, will be united on the examiner's retina, and form there an inverted image of the observed fundus; this image, which is magnified by the dioptric apparatus of the observed eye itself, and apparently situate behind the eye, will, however, be mentally perceived as upright. Another mode of producing the erect image consists in the employment of a concave lens, as shown in the

accompanying illustration. If $a b$, Fig. 5, be two points in the illumined fundus of A, pencils of rays will emerge parallel to the axial lines $a L$, $b L$ to form at the anterior focal distance of A an image of $a b$. The concave lens L, however, being now inter-

Fig. 5.

posed, these rays are diverged to d and f , and they appear to proceed from the prolongations of these lines—from $a' b'$, at which place an enlarged *upright image* of $a b$ will apparently be situated. The direct examination is principally of value in cases where it is desirable to obtain a more accurate observation of the minute details, such as individual vessels or nerve fibres, or in the determination of anomalies of refraction, such as myopia or hypermetropia. It is, however, attended with more difficulties than the indirect method of examination; it necessitates, also, a very close approximation of patient and examiner, which may, for various reasons, be undesirable or objectionable; the enlargement is very considerable, and therefore only a small portion of the fundus can be seen at a time; moreover, the concave mirrors of the ordinary ophthalmoscope do not suffice for this examination. I would, therefore, recommend beginners first to employ the indirect method of examination; and as soon as they may have become familiar with this method, and the reversed image, they may proceed to the direct examination.

As might naturally be expected, there is a great variety in the form and construction of ophthalmoscopes; but no matter how they may apparently differ in outward shape and appearance, they are, one and all calculated to fulfil the same purpose—to illumine the background of the eye by dispersed light, and to allow of the parts so illumined being clearly seen at a convenient position and of a suitable size. The essential part of the ophthalmoscope is the perforated mirror; this may be either of glass, backed with a layer of amalgam, or of metal; the metal specula are preferable to the glass ones, inasmuch as they are less liable to injury, but

chiefly on account of the central aperture through which the observer looks; in the glass mirrors this orifice is more or less in the shape of a tube or canal, from the internal surface and edges of which there is very likely to be most disturbing and annoying reflection of light, which would obviously interfere with the reflected light from the fundus; in the metal mirrors, on the contrary, the walls of the central perforation are extremely thin and the margins sharp, and there can be, therefore, very little, if any, reflection from this part. The illumination afforded by glass mirrors is, moreover, in my opinion, too intense (provided the examiner's eye be normal); the details can be discerned more satisfactorily by a somewhat subdued illumination; hence I am in the habit, when using a glass mirror, of breathing on its surface, or otherwise damping its reflection. When I was in Berlin, some years ago, Liebreich, who has since then removed to Paris, employed a metallic mirror which he had dulled by means of sand-paper. All mirrors have necessarily an opening, and are usually attached to a suitable handle or frame.

Ophthalmoscopes may be divided into two great classes—in one the mirror is concave, and its focus calculated from its surface definite and fixed; such instruments are termed *homocentric*. In the other class the mirror is either plane or convex, and in combination with a double convex lens; in these the focus may be altered, is negative, and situate behind the surface of the mirror; such instruments are denominated *heterocentric*.

An enumeration and explanation of the several individual instruments constructed would be of little practical value. I will, therefore, merely adduce a few of the more important ones, commencing with the *homocentric*.

The simplest, most convenient, and, at the same time, most practical of all instruments is Liebreich's small or hand ophthalmoscope, and is the one I usually employ. It consists, as shown (the actual size) in Fig. 6, of a concave metallic mirror $1\frac{1}{4}$ " in diameter, and of 8" focal length,^a which is fixed into a metallic frame, to which the handle is attached. The central aperture is a shallow, funnel-shaped opening, the base $\frac{3}{8}$ " wide in the metallic frame, the apex nearly $\frac{1}{8}$ " wide in the mirror itself; the sight-hole thus enlarging gradually from before backwards, and the parts adjoining it, and indeed the whole back and sides of the instrument being

^a The inch is, for brevity, expressed by ("), the foot by ('), and the line by (").

thoroughly and effectually blackened there can be no reflection from these parts and no interference with the rays coming to the observer's eye. The handle, about $3\frac{1}{2}$ " long, is screwed into the frame, to which is also attached a clip with a jointed movable arm;

Fig. 6.

the clip serves to hold a small convex or concave ocular lens, which can thus be brought immediately behind the opening in the mirror, and consequently in front of the examiner's eye. The instrument is fitted into a case $5\frac{1}{4}$ " by $2\frac{1}{4}$ ", and little more than $\frac{1}{4}$ " thick; two large double convex object lenses, generally of $1\frac{1}{2}$ " and $2\frac{1}{2}$ " focus; four small concave ocular lenses, of 6 ", 8 ", 10 ", and 12 " inch focus, and one small convex ocular lens of 10 " focus are likewise fitted into the case. In my own case I have substituted for the $2\frac{1}{2}$ " convex lens one of $3\frac{1}{2}$ " as I find in the general run of cases the enlargement produced by the latter much more satisfactory. One of the uses of the small ocular lenses is to neutralize any error of refraction or accommodation which may exist in the examiner; another use is to effect the examination in the erect image; the convex ocular may also be employed to magnify the reversed image. The large lens, whether convex or concave, which is held before the examined eye in order to produce the image, is styled the *object lens*, to distinguish it from the small one placed in the clip behind the mirror, which is called

the *ocular lens*, and the reflecting surface of the ophthalmoscope is regarded as the front of the instrument. Dr. N. C. Macnamara, professor of ophthalmic medicine and surgery in Calcutta, has lately published a most admirable and trustworthy work on ophthalmoscopy under the title *Lectures on Diseases of the Eye*; but in his description of Liebreich's instrument he states that "attached to the mirror is a clamp by which one of the *object-glasses*, to be found in the instrument case, may be fixed *in front* of the sight hole." This sentence, which to a beginner would be so confusing, shows the necessity for a strict adherence to a uniform nomenclature.

Messrs. Weiss manufacture an ophthalmoscope consisting simply of a concave mirror set in a circular frame, the principal recommendation of which is its portability, as it may, together with a convex lens, be carried in the waistcoat pocket or in a pocket instrument case.

The best of the *fixed ophthalmoscopes* belong to this division; such instruments are so constructed that when adjusted they and the patient's eye shall retain a definite, fixed, relative position, so that once the image is projected a number of persons may in succession, examine it without any trouble or difficulty on their part. Here, likewise, Liebreich's ophthalmoscope is undoubtedly the best. The accompanying diagram, Fig. 7, (about one-third the actual size), shows its construction. A and B are two tubes moving one within the other by means of a rack and pinion, I, and having their interior well blackened. At the end of the tube A a concave perforated mirror, M, is swung on trunnions, *t t*—and a portion of the walls of the tube cut away so as to allow the rays from a laterally placed lamp to fall on the mirror; the tube B carries the convex object lens L, of 2" focus, swung, like the mirror, on trunnions: this tube is provided with a stout encircling collar, having at one side a projecting clamp, capable of being widened or narrowed by means of the screw H; an upright rod, R, is affixed to the corner of a table by means of a strong clamp, D, and the instrument is then affixed to this rod by means of the perforated projection, and slides up and down on the rod, and may be fixed at any wished-for height by the screw H; on this rod slides also a stout horizontal jointed arm, C, having at its extremity an oval padded cup, which acts as chin-rest; this, of course, is put on the supporting rod beneath the ophthalmoscope. A horizontal bar, F, slides in a box projecting from the upper part of the collar: at the extremity of

this bar is a padded disk, which serves as a head-rest; a small jointed movable arm, K, carries a polished metal ball, for directing the patient's eye to any given position, and a shade, projecting laterally from each extremity of the instrument, at *s* and B, screens the observed and observer's eye from the lamp; there is also a clip behind

Fig. 7.

the mirror, M, for holding a convex lens, three of which are contained in the case. When in use the patient's chin rests in the cup, C, and his forehead against the pad, F; the instrument should usually be about two inches from the eye. the focal distance of the lens L, and a lamp placed towards the side, from which rays may fall on M, and so directed then through L into the eye; it will be seen that the anterior extremity remains stationary, while the tube A, carrying the mirror, is movable. The formation and position of the image is the same as that already described and illustrated by Fig. 4. When obtained, the image of the fundus is very clear

and beautiful, and may be readily seen by any number of persons in succession. A camera lucida for drawing purposes may be attached, and also a microscope; its inventor has also constructed an ingenious addition to the instrument, by means of which the fundus of the living eye may be photographed. Professor Follin, whose learned and well-written *Leçons sur l'Exploration de l'Œil* I can confidently recommend to those who are familiar with the French language, has also constructed a fixed ophthalmoscope; but in its optical arrangement, and even in its mechanical construction it appears to differ but slightly from the one just described. I have found the manipulation of Liebreich's instrument rather difficult, and its adjustment often tedious and troublesome, the light being one of the principal sources of trouble; I had a lamp made some years ago which I attached to the upright rod, and which I found to answer much better than the lamp placed beside the instrument; the instrument, too, is liable to shake or tremble from the nature of its support. These and other circumstances led Messrs. Smith and Beck, the eminent opticians and microscope manufacturers, of 31, Cornhill, London, to construct a modification of Liebreich's large ophthalmoscope. This instrument^a is shown in use in Fig. 8.^b It consists, like its prototype, of two tubes, one carrying the lens, the other the mirror. These tubes are, however, fixed permanently on an upright stem capable of being raised or lowered by a rack and pinion; to this stem is attached a horizontal arm which carries the lamp. No matter how the instrument may be moved, up or down or from side to side, the flame of the lamp and the mirror will always be on the same level, and always retain their relative positions; the instrument is mounted on a broad board, having three small rollers fixed in its inferior surface, so that it can be freely moved about on a table or any smooth surface; by means of a half-rule joint, secured by a pin close to the base, the board is capable of being turned up against the stem, and the lamp, being brought round to the mirror end, the instrument may be fitted into a small space. As seen in the engraving, a chin-rest supports and steadies the patient's head at any convenient height; a small shade screens the light from the patient's eye, and a small ivory ball at the end of a sliding tube, with a ball and socket joint at its base, serves for fixing the patient's eye at any wished-for position.

^a Already figured, and described by Dr. Wright in the Number of this Journal for August, 1865.

^b From a photograph by Allen, 12, Westland-row.

I now employ this in preference to Liebreich's original ophthalmoscope, as it is much more easily and quickly adjusted, and affords an equally good image; even an inexperienced person may, by its

Fig. 8.

aid, see the fundus of an ordinary eye without any difficulty. I have been able also on several occasions to demonstrate satisfactorily the fundus of my own eye to others by means of this instrument. Another useful tubular ophthalmoscope, although not nearly so efficient or practical as the two just described, is that constructed by my friend Dr. Gałeczowski of Paris. This instrument is not exactly a fixed one, but holds an intermediate place; the ocular end of the tube projects beyond the object lens, and is so shaped and padded as to fit over the margin of the patient's orbit, and so to exclude all light except that transmitted by the ophthalmoscope mirrors; the instrument can be shortened or lengthened in the same manner as a telescope.

The principal advantage of fixed instruments is, that by their means the fundus can be satisfactorily demonstrated in a short time to a large number of observers. Fixed ophthalmoscopes are, however, at all times cumbersome and do not afford a satisfactory view of the peripheral portions of the fundus; hence they are, and probably will always remain, merely ancillary to the hand ophthalmoscopes.

Ophthalmoscopes in which the mirror is either plane or convex,

and in combination with a double convex lens, are termed *hetero-centric*, and were first devised by Coccius.

The convex lens, which must be of shorter focal length than the negative focus of the convex mirror, is interposed between the flame and the mirror. These ophthalmoscopes are based on the principle of Brücke's experiment, already alluded to (Fig. 2)—*i.e.*, of the eye under observation being accommodated for a different distance than that from which the light actually emanates. Coccius' ophthalmoscope consists of a plane perforated mirror fixed to a handle, attached to which is a jointed arm carrying an upright clip with a convex lens in it: there is a smaller clip on the mirror frame for an ocular lens. Figure 9 may be supposed to be an illustration of this instrument. The rays of light passing through the convex lens fall on the mirror convergently and are reflected by the latter converging into the eye, and form on its fundus a circle of dispersed light. The eye regards the bright surface of the mirror, but in consequence of the action of the convex lens the image of the flame seen in the mirror does not correspond with an actual flame in the position of the reflector, but with one placed a certain distance behind the mirror.

Zehender's ophthalmoscope, shown, the actual size, in Fig. 9,

Fig. 9.

differs from Coccius' only in the mirror, which is convex; in appearance, therefore, these two ophthalmoscopes are at first sight identical.

The lens is $1\frac{1}{2}$ " focus, and the convex mirror has a curvature of 6" radius. This is a most valuable instrument, and preferable to Coccius'; it affords a larger and better field of illumination than any other ophthalmoscope, and is especially of use in the direct examination. Its manipulation is, however, not very simple, and hence partly it is not such a favourite as Liebreich's hand ophthalmoscope. The light must be at the patient's side, and the lens inclined at such an angle that the rays shall traverse it, and fall on the mirror, from which they are reflected into the eye.

Two other forms of heterocentric ophthalmoscopes deserve mention, but more for their ingenuity than for their practical utility. Ulrich employed two prisms presenting in section the forms of right-angled triangles, with equal containing sides, and fixed them together in such a manner that the hypotenuse of one should be at right angles with that of the other; rays of light falling on the first prism reach its hypotenuse, and are there totally reflected and thus projected into the eye, the fundus of which they illumine; emerging from the eye they strike the hypotenuse of the second prism, and are reflected by it at right angles into the observer's eye.

Another form of ophthalmoscope is that of Hasner, and consists of a convex or concave lens, having one surface silvered, with the exception of a small space in the centre, which acts as a sight-hole. The chief object aimed at in these is the combination in *one* of the reflector and the lens; a **biconvex** silvered lens acts as a concave mirror—a biconcave silvered lens as a spherical mirror.

The construction of the instruments I have mentioned, and the large variety of kindred ophthalmoscopes, is such that the observer can become cognizant with *one* of his eyes only; hence the errors and deceptions which arise from monocular vision are at all times likely to occur. To rectify this defect Dr. Giraud-Teulon constructed an ophthalmoscope, by means of which binocular vision was secured, and an image of the fundus obtained, in which the parts are seen as they actually exist—in relief, or depressed, or plane. This *binocular ophthalmoscope* is constructed on the principle previously applied in microscopes by Mr. Wenham, and by Nachet, the optician, of Paris—that of employing prisms or rhombs for the purpose of deflecting the rays in part or in whole. Giraud-Teulon employed a glass concave mirror, with a large oval opening in its silvering, and placed behind it two rhombs of crown glass, each representing a double prism of 45° , and capable of effecting total reflection from their inclined surfaces; these rhombs were

placed horizontally behind the mirror, with their apices meeting behind the orifice. The accompanying diagram will serve to explain the nature and principles of this instrument. M represents the concave mirror and L the convex lens, by means of which the reversed aerial image I is formed as with the ordinary ophthalmoscopes; if we take any point in this image we find rays proceeding from it divergently; thus, a pencil of rays is represented in Fig. 10 passing through the orifice *o* in the mirror. Here it meets the

Fig. 10.

rhombs R and R', and divides right and left; the ray on the left side is reflected at *b* to *c*, where it is again reflected to P, and emerges from the rhomb; in the same manner the ray on the right side undergoes total double reflection. If an observer now place his eyes in the line of emergence of these rays at E and E', he will see two images, *f* and *g*; by placing two prisms, P, P', however, with their bases turned outwards behind the rhombs, the emergent rays are deflected outwards and receive the direction E I, E' I; the two images are fused into one, and thus both eyes participate in the visual act. As is evident, the width between these emergent rays must correspond to the distance between the examiner's eyes, for otherwise one eye would be excluded from seeing the image, and the instrument would be simply a monocular one. Nachet subsequently

remedied this defect by dividing the right-hand rhomb into two, and making the outer half of it movable, so that the instrument as now made can be adapted to the distance between the eyes of various observers. The rhombs are enclosed in a metal case, in which are spaces for the prisms, four of which are supplied, of various angles; there is an aperture at one side of the frame, into which a handle may be screwed; I frequently use the instrument, however, without the handle, holding it between finger and thumb. The mirror is attached by a universal joint, so that the instrument can be used with the flame either above or to the side of the patient.

My friend Mr. Zachariah Laurence, ophthalmic surgeon to St. Bartholomew's Hospital, Chatham, and the Ophthalmic Hospital, Southwark, has devised a very ingenious modification of this ophthalmoscope; it consists of two reflecting prisms, E, E, placed

Fig. 11.

behind the opening in the mirror, K, and two others, F, F, termed oculars, at some distance to the outside; these latter "shift upon an horizontal metallic plate, A B, and can be adjusted to any required inclination by means of a screw G G, carrying the nuts I I, which work in the slots, H H."

"The optical action of the instrument is represented in Fig. 12. O A and O B are the extreme outer rays of a pencil, proceeding from a point (O) of the inverted image formed by the ordinary object lens; the ray O B is reflected by the prism B to the prism D, and hence to the observer's right eye placed behind D. Similarly, the ray O A is reflected to the observer's left eye. He then sees *two* images of the fundus oculi. By inclining the ocular prisms (D and C) inwards by the mechanism described above, the two images are fused into *one*."^a I am indebted to Mr. Laurence for the loan of these two cuts.

^a Laurence and Moon's Handy-Book of Ophthalmic Surgery.

The framework and adjusting mechanism is, however, fragile and delicate, and easily injured by careless handling; it is said, however, to prevent the squinting which may occur in the examination

Fig. 12.

with the French instrument, and to produce a clearer image; and its weight is only half that of the other. I cannot speak with confidence on the relative merits of the two, as my experience of Laurence's has been somewhat limited. I have, however, found its manipulation and adjustment difficult, and prefer Nachet's improvement of Giraud-Teulon's ophthalmoscope as a more practical instrument for every-day use; many, however, prefer Mr. Laurence's to Giraud-Teulon's binocular instrument. The manipulation of the French instrument is so easy, and the image afforded by it so beautiful, that I am now beginning to employ this binocular ophthalmoscope in preference even to Liebreich's hand ophthalmoscope. These ophthalmoscopes are most useful in the examination of cases in which an inequality of surface may be suspected; thus, in glaucoma they afford a beautiful and clear image of the cup-like depression of the optic nerve and of the vessels on the sides and in the bottom of the depression.

As is evident, the image of the fundus can be examined only by one individual at a time. Mr. Z. Laurence, has here also brought his great knowledge of the science to bear on the subject, and in 1863 proposed a method whereby the original aerial image may, while

being regarded by the observer, be reflected so as to become visible to a *second* person at the same time; he interposed at right angles between the ordinary reversed image and the ophthalmoscope mirror a plate of glass, with plane parallel surfaces like that used in Helmholtz's first ophthalmoscope; by means of this plate a duplicate image is formed, which may be seen by a second person placed in a certain given position. Giraud-Teulon has suggested an addition whereby even a *third* person may participate in the examination; this is the employment of a plane perforated mirror to reflect the light on to the ophthalmoscope mirror; a lamp is placed near the ophthalmoscope, and is furnished with a chimney, blackened on three-fourths of its circumference; through the remaining clear portion the light proceeds, and falls on the plane perforated mirror, and is reflected by it on to the concave ophthalmoscope mirror, from whence it proceeds to illumine the fundus; the original observer sees the image in the usual way through the ophthalmoscope mirror opening; the second observer sees the reflected image by means of Laurence's plate of glass; and the third places his eye behind the opening in the plane reflecting mirror, and obtains an image from the concave mirror; this third observer is, in fact, almost in the position of a conjugate focus.

Shortly after the establishment of the science and art of ophthalmoscopy Coccius proposed and eventually carried into practice a plan of examination whereby the eye can inspect its own fundus. This consisted in placing close in front of the eye a perforated plane mirror, with its reflecting surface towards the eye, and behind this a flame; the rays passing through the aperture are focussed on the retina; and after emerging from the eye again are made to strike on the mirror close to the perforation, where an image of the illumined portion can be seen; by this means the optic nerve entrance may be seen by the macula lutea of the same eye. Various ingenious *autophthalmoscopes* were subsequently devised; one of the best, though large and complicated, was that of Dr. Heymann, of Dresden. Dr. Giraud-Teulon also constructed one, the principles of which may be learned from the accompanying diagram, copied from the more elaborate figure in his *Précis de la Réfraction et de l'Accommodation de l'Œil*, &c., contained in the supplement to the admirable French translation and annotation of Mackenzie. In this figure the eye A is examining its fellow B; F is the flame, and M a concave perforated mirror, held obliquely before the eye, so that rays from F shall be reflected on to c, a plane mirror which is inclined

at such an angle that the rays falling on it are reflected towards *d*, a second plane mirror, which will reflect them into the eye B; a double convex lens of short focus, *L*, is interposed between

Fig. 13.

B and *d*, by means of which the usual inverted aerial image is formed, which will be seen by A apparently situate beyond the mirror *c*, although absolutely situate between the two mirrors, near *d*; the erect image may be produced by dispensing with the lens *L* and approximating the eyes to the mirrors. By this instrument the whole fundus of one eye may be examined by the other eye. I should mention that it is necessary to dilate the pupil for all these various experiments and examinations.

From the foregoing brief and imperfect sketch it will be seen that the ophthalmoscope is not the result of accident or some happy thought, nor the creation of some one inventive genius, but that it owes its origin to deep research and laborious study, to years of observation, reasoning, induction, and calculation on the part of many, pre-eminent amongst whom will always stand Helmholtz, the founder of ophthalmoscopy. The instrument may possibly be still in its infancy as a means of physical diagnosis, and further modifications and improvements may yet be carried out which will render the ophthalmoscope even more perfect and efficient than it at present undoubtedly is.