THE OPHTHALMOSCOPE.

Plate I.

Fig. I.

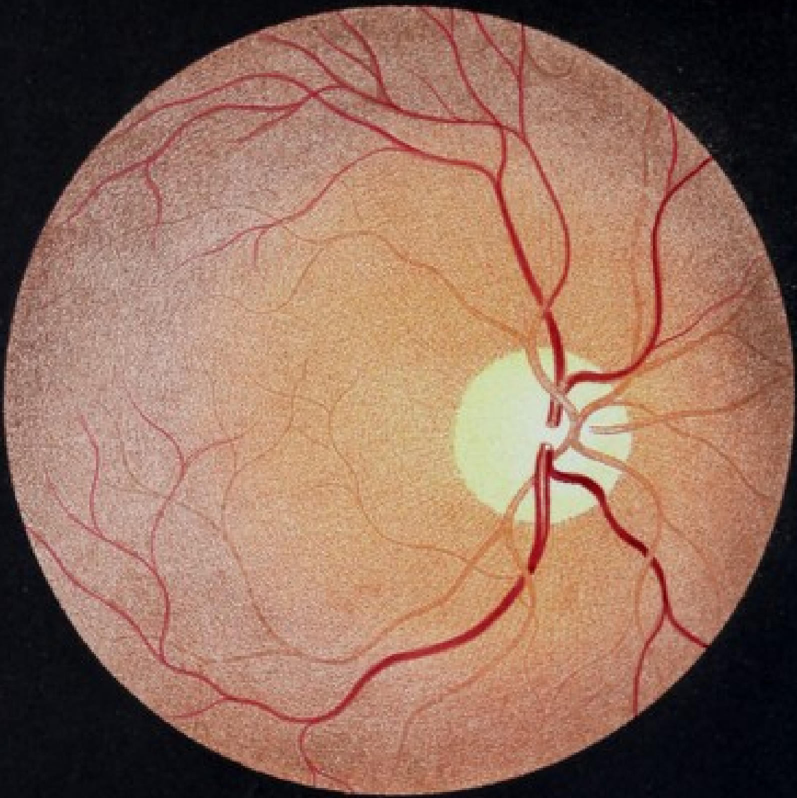
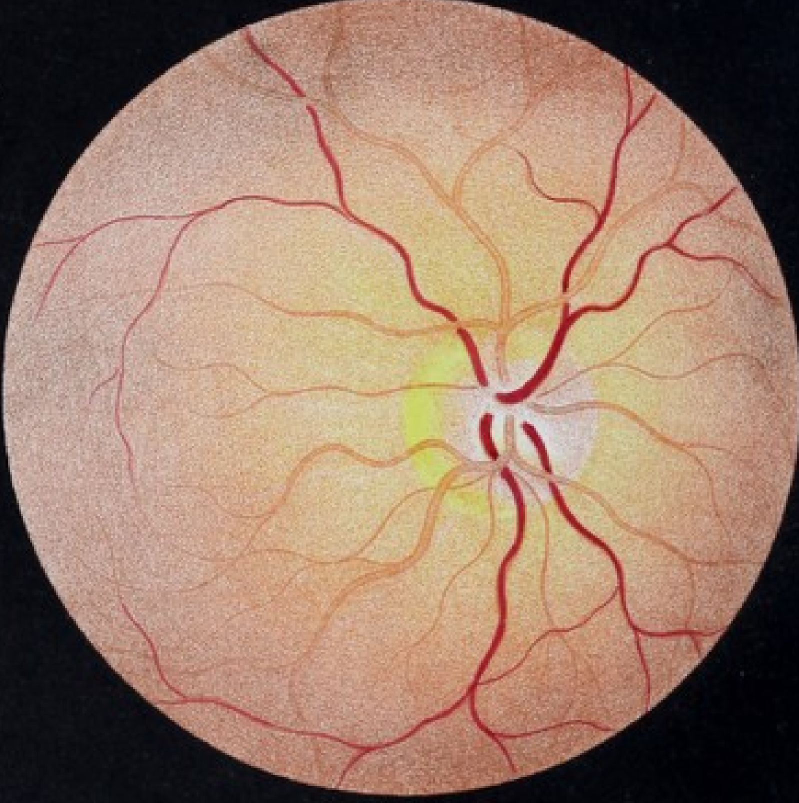


Fig. II.



Lith. Anst. v. M. Singer, Lpzg.

THE OPHTHALMOSCOPE:

ITS VARIETIES AND ITS USE.

TRANSLATED FROM THE GERMAN OF

DR. ADOLF ZANDER.

BY

ROBERT BRUDENELL CARTER, M.R.C.S.E.

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WITH NOTES AND ADDITIONS BY THE TRANSLATOR.

LONDON:
ROBERT HARDWICKE, 192, PICCADILLY.
1864.

TO

WILLIAM TINDAL ROBERTSON, M.D.

PHYSICIAN TO THE NOTTINGHAM GENERAL HOSPITAL;

WHO,

BY ORIGINATING THE NOTTINGHAM EYE DISPENSARY,

OPENED A NEW AND WIDE FIELD FOR OPHTHALMOSCOPIC RESEARCH,

IN ADMIRATION OF HIS DISTINGUISHED ATTAINMENTS,

AND IN GRATEFUL RECOGNITION OF MUCH PERSONAL KINDNESS,

THESE PAGES ARE DEDICATED,

BY THE TRANSLATOR.

PREFACE.

THIRTEEN years have elapsed since the discovery of the Ophthalmoscope.

An instrument that afforded methods of research so new and so extensive, rested for a while, of necessity, in the hands of a small number of observers; who, by the possession of special knowledge and special opportunities, were enabled thoroughly to test its usefulness, and rightly to appreciate its value.

The time has arrived, I believe, for the commencement of the second period in the history of this great invention. The knowledge laboriously obtained and perfected by a few, has now to be diffused through, and utilized by, the great bulk of the Profession. Specialists may yet effect improvements in matters of detail, and refinements in methods of observation; but the great principles on which these must depend are already ascertained and established. In this belief I have thought it desirable to prepare an English version of Dr. Zander's exhaustive and masterly treatise.

The premature and lamented death of the author rendered it impossible for me to obtain his co-operation in my task; although the lapse of nearly three years, since the publication of the original, has made it necessary to add considerably to the text. The new matter is printed in smaller type than the rest; and, in writing or compiling it, my ambition has been to produce such a volume as Dr. Zander would himself have issued at the present time. On the subject of the necessary additions, I have availed myself of the kind counsels of Dr. Liebreich and Professor Wecker; and I am therefore able to say, with some confidence, that nothing important has been omitted. The description of the method by which Dr. Liebreich has recently adapted his large ophthalmoscope for the observation of the erect image has, however, reached me too late for insertion.

In deference to the practical character of the English medical mind, I have been induced to add to the book a Sixth Section, not comprised in the original, and containing an attempt to set forth an outline of the influence of the ophthalmoscope upon treatment.

Dr. Zander's treatise being essentially a compilation, I do not consider that it possesses any literary claim to exact reproduction in a foreign tongue. I have endeavoured to render the precise meaning of every sentence; but I have never designedly sacrificed the spirit of the English language to the preservation of German idioms, or of German prolixity. I have sometimes added a word, in order to obtain greater clearness of expression; and, in a very few instances, I have detected slight inaccuracies, and have endeavoured to rectify them. In such cases, I have always either applied to the observer whose statement was under discussion, or to the work indicated by Dr. Zander as the source of his information.

The original contains a copious list of writings on the ophthalmoscope, in every European language. This list I have not thought it necessary to reprint; but, for the purpose of my own additions, I have consulted the following more recent authorities :—

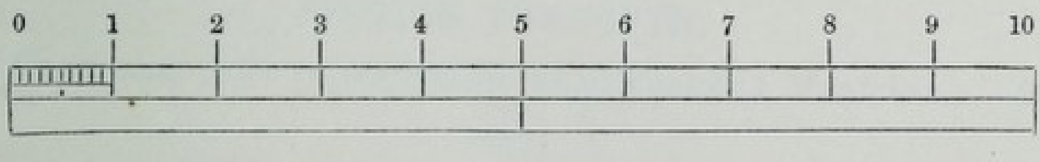
Argilagas, Dr. Francisco (de Cuba).—Sur la Lentille fluorescent. L'Union Médicale, 1862.
Blessig, Dr.—Ein Fall von Embolie der Arteria centralis Retinæ. Gräfe's Archiv, 1861.
Donders, Dr. F. C.—Astigmatismus und cylindrische Gläser. Berlin, 1862.
Follin, Dr. E.—Leçons sur l'Exploration de l'Œil. Paris, 1863.
Galenzowski, Dr. Xavier.—Recherches ophthalmoscopiques sur les Maladies de la Rétine et du Nerf optique. Annales d'Oculistique, 1863.
Nouvel Ophthalmoscope. L'Union Médicale, 1862.
Giraud-Teulon, Dr.—De l'Ophthalmoscope binoculaire. Bulletin général de Thérapeutique. Janvier, 1863.
Nouvelle Méthode pour l'Examen auto-Ophthalmoscopique. Annales d'Oculistique, 1863.
Gräfe, Dr. Alfred.—Ischæmia Retinæ. Archiv f. O., 1861.
Heddaeus, Dr.—Die Untersuchung der Augen bei concentrirtem seitlichem Tageslicht. Archiv f. O., 1861.
Heymann, Dr. F.—Frische Netzhauthæmorrhagien, section Microscopie. Arch. f. O., 1861.
Die Autoskopie des Auges, und eine neue Methode derselben. Leipzig, 1863.
Jackson, Dr. J. Hughlings.—Observations on Defects of Sight in Brain Disease, and Ophthalmoscopic Examination during Sleep. London, 1863.
Klebs, Dr.—Beitrag zur anatomischen und besonders histologischen Verhältnisse des N. Opticus. Virchow's Archiv, Bd. 19, Hfr. 3 u. 4.
Prager Vierteljahrschrift, 1861, Bd. II., s. 77.
Knapp, Dr.—Exposé des Avantages de l'Ophthalmoscope binoculaire. Annales l'Oculistique, 1864.
Laurence, Mr. J. Z.—On Binocular Ophthalmoscopy. Brit. Med. Jour., 1862.
On Astigmatism. Med. Mirror, 1864.

Liebreich, Dr. R.—Ueber Retinitis Leucæmica, und ueber Embolie der Arteria centralis Retinæ. Vortrag, gehalten in der Berliner Med. Ges., Dec. 1861.
Atlas der Ophthalmoscopie. Berlin, 1863.
Manz, Prof. W.—Tuberkulose der Chorioidea. Archiv f. O., Bd. IX., Abth. 3.
Martin, Dr. Emile.—Traité Médical pratique des Maladies des Yeux. Paris, 1863.
Rosow, Dr. B.—Ueber das körnige Augenpigment. Archiv f. O., Bd. IX., Abth. 3.
Sämisch, Dr. Th.—Beiträge zur normalen und pathologischen Anatomie des Auges. Leipzig, 1862.
Schneller, Dr.—Fall von Embolie der central-arterie der Netzhaut, mit Ausgang in Besserung. Archiv f. O., 1861.
Weber, Prof. C. O.—Bau des Glaskörpers und die pathologischen namentlich entzündlichen Veränderungen desselben. Virchow's Archiv, Bd. 19, Hefter 3 u. 4.
Prager Vierteljahrschrift, 1861, Bd. III.
Wecker, Prof. L.—Études ophthalmologiques. Paris, 1863.
Wordsworth, Mr.—Cases illustrative of the Value of the Ophthalmoscope. B. M. Journal, 1861 and 1862. On Tobacco Amaurosis. Lancet, 1863.
Zehender, Dr. W.—Ueber Autophthalmoskopie. Klinische Monatsblätter, Mai, 1863.

Among these, the magnificent "Atlas der Ophthalmoscopie" of Dr. Liebreich requires a more than passing notice, and I have given references to its plates and figures as parts of the headings of most of the descriptions in the third and fourth sections of the volume.

The measurements used throughout the work require a word of explanation. They are, generally, the metric system, or the Paris inch and foot.

The metric system is so likely to become naturalized in this country, that it would be almost a retrograde proceeding to convert its divisions into English feet and inches. Still, measurements appeal very much to sight-memory, and there are many persons whose eyes are not accustomed to use the parts of the metre as standards. The annexed figure



represents a decimetre, divided into centimetres, and one of these into millimetres. It may be occasionally useful for purposes of reference.

The Paris inch is commonly employed as the unit by which to express the focal lengths of lenses, and it cannot, therefore, be dispensed with. Twelve Paris lines make a Paris inch; and twelve Paris inches a Paris foot. The foot is expressed by ('), the inch by ("), and the line by (‴)—with numerals prefixed. The values slightly exceed those of the English measures of like denominations. In round numbers, the Paris foot exceeds the English by three quarters of an inch, and the Paris inch exceeds the English by one-sixteenth.

Dr. E. Jaeger gives his measurements in Vienna inches, and decimal instead of duodecimal lines. The Vienna inch is intermediate between the Paris and the English, and is to the latter as 1·0371 to 1.

To many English and foreign ophthalmologists I am grateful for valuable help, promptly and cordially rendered. Mr. Zachariah Laurence and Mr. Heisch, Dr. Giraud-Teulon of Paris, and Dr. Heymann of Dresden, have given me much assistance in my inquiries about the instruments they have respectively contrived.

It remains to say to those readers to whom this book may be welcome, that they are indebted, for any pleasure or profit they may derive from it, to the enterprise of Mr. Hardwicke. I may be allowed to express a hope that this enterprise will be appreciated by the Profession.

Stroud, Gloucestershire,
April, 1864.

CONTENTS.

EXPLANATION OF THE PLATES.

THE annexed figures are intended to furnish ideal representations of the most important appearances of the fundus oculi, and to render the descriptions given in the text more intelligible. They represent :—

Plate I.—Figure 1. The normal fundus oculi.
„ 2. Hyperæmia of the retina.

II.—Figure 1. Inflammation of the retina.
„ 2. Retinal changes in Bright's disease.

III.—Figure 1. Sclerectasia posterior.
„ 2. Glaucomatous excavation of the optic nerve.

In order to obtain, from these figures, the greatest possible resemblance to the actual conditions represented, the figures should be studied by artificial light, and through a biconvex lens, fixed in a short paper tube. The images, formed in the focal point of the lens, and within the tube, and regarded from the distance for clear vision of the observer, approach very near to nature. The large ophthalmoscope of Hasner is well adapted for this experiment.

Plate II.

Fig. I.

Fig II.

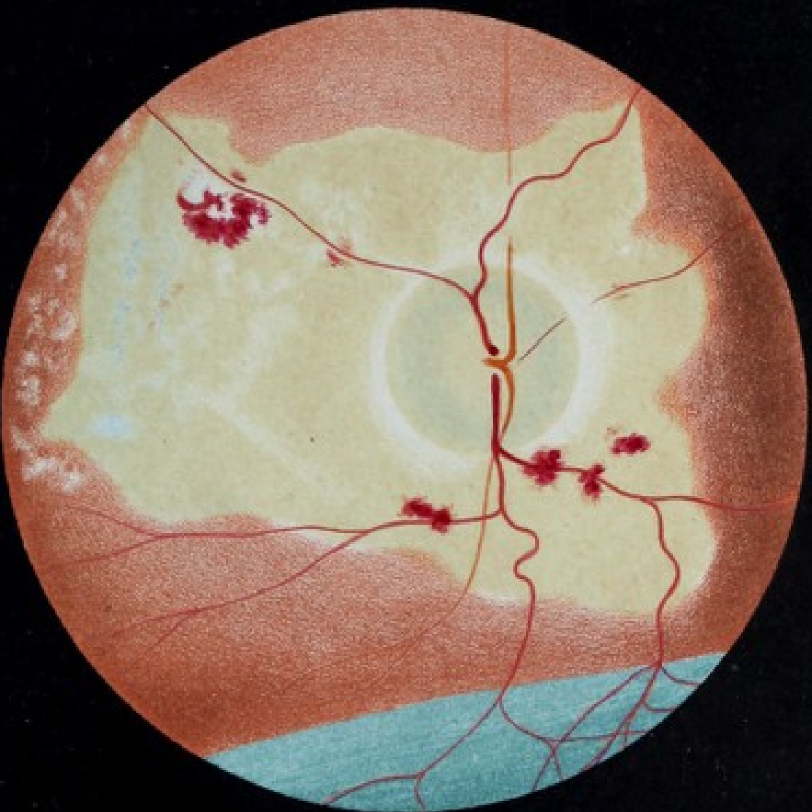


Plate III.

Fig. I

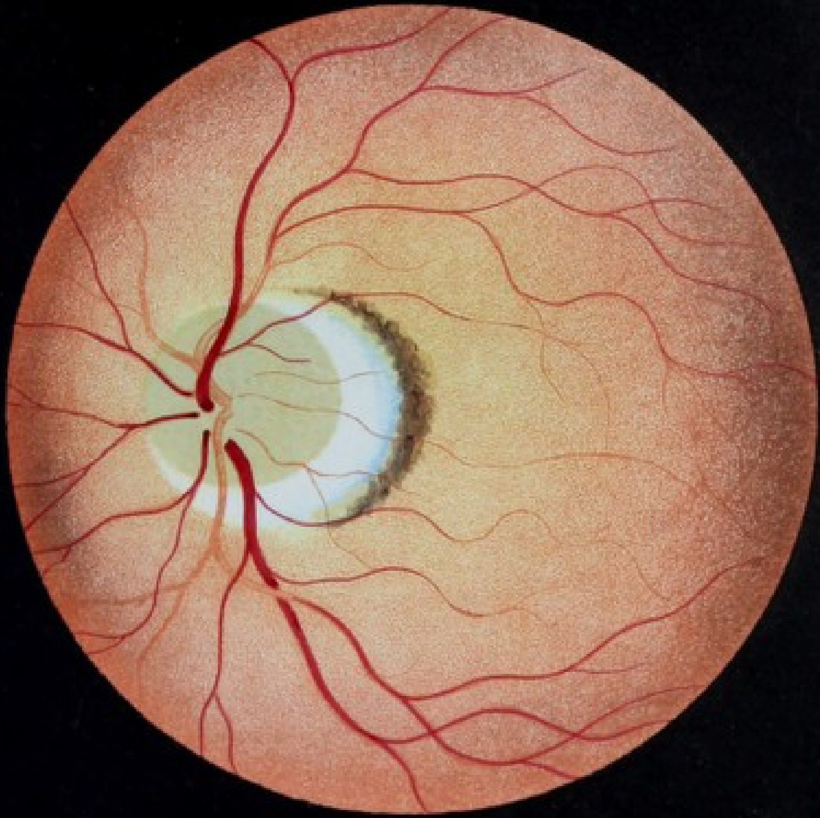
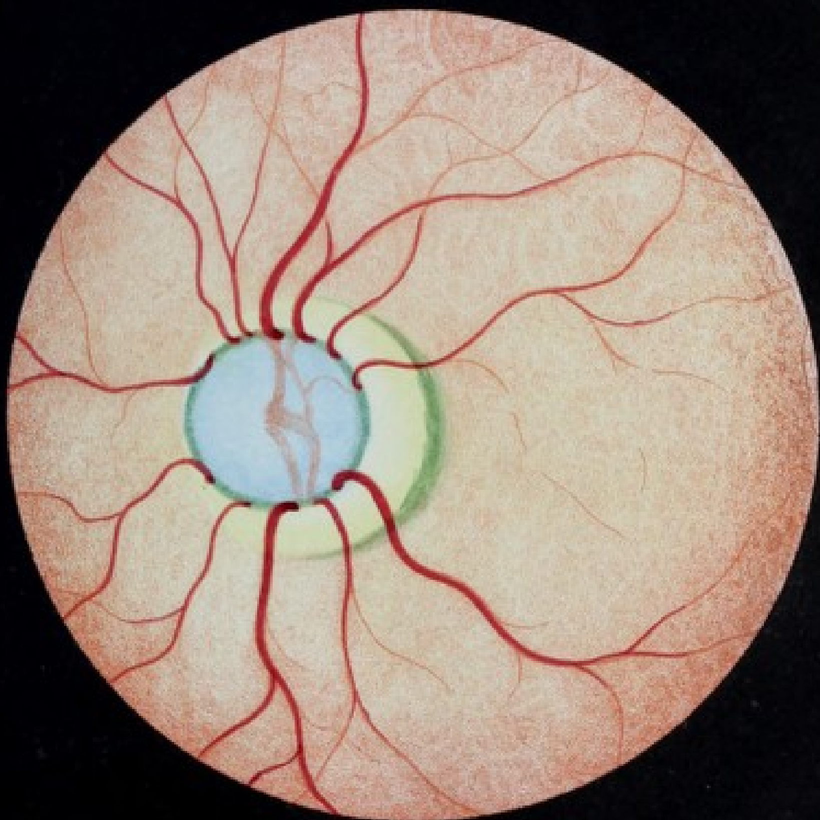


Fig II.



THE OPHTHALMOSCOPE.

INTRODUCTION.

EVERY great discovery, that marks an epoch in the history of science, must be in preparation for a variable length of time, and in different ways, prior to the advent of the genius who calls it into being; and who may have, as one of his chief functions, to estimate at their true value, and to unite into a coherent whole, scattered materials of much importance, but previously wasted because misunderstood. Thus also it befel with regard to the invention of the Ophthalmoscope. This instrument, after being foreshadowed in a twofold manner, at length received from Professor Heinrich Helmholtz a realization that has rendered it the greatest discovery of modern times in the domain of Ophthalmology; a discovery the fruits of which we are not yet in a position to estimate completely. Its origin may be traced to successive endeavours to solve two problems: the first being, why the eyes of men and animals sometimes shine with a reddish lustre; and the second, why the interior of an eye more usually appears dark.

From the most ancient times a glittering of the eyes had been observed in animals possessing a tapetum, especially in dogs and cats. It was ascribed to a spontaneous development of light from the eye, under the influence of the nervous system, and was supposed to become more vivid when the animal was excited; an opinion that had its adherents even until very recently. The first to controvert it were Prevost, Rudolphi, and Gruithuisen (1810), the first of whom discovered that no glitter could be seen in a completely darkened room, and that the appearance was therefore to be considered only as a reflection of incident rays. The last traced the effect to the operation of the tapetum, combined with a great refraction by the crystalline lens; and Rudolphi first observed that, in order to see the glitter, the spectator must look into the eye in a certain determinate direction.

In examining the luminous eyes of dogs and cats, it was observed that the colour of the shining ocular background did not remain the same, but varied between different tints of red and green. Esser (1826) gave the first complete explanation of this phenomenon; from which he inferred that in movements of the globe differently coloured portions of the tapetum came successively into view, and determined the different tints of the reflected rays. Hassenstein (1836) sought to explain the luminosity by these very movements themselves. He observed that the light became more brilliant when the globe was compressed in the direction of its axis; and he therefore supposed that it was emitted when, by contraction of the orbital muscles, a similar pressure was exerted.

The exact conditions of the luminosity, without any further explanation of it, were determined by Behr (1839), who, in describing a case of total irideremia in a girl, stated that, in order to see the reflection, the eye of the observer must look in a direction parallel to that of the rays incident upon the eye of the child; and that the luminosity diminished or disappeared as soon as the observer looked below the axis of vision of the eye observed.

The various questions about this subject were brought to a scientific conclusion by the works of Cumming (1846), and more especially of Brücke (1844-7). With these authors must be placed Coccius (1853), who, in his Treatise upon the Ophthalmoscope (pp. 198 *et seq.*), has completely exhausted the conditions of the apparently spontaneous luminosity of the human eye.

The second problem was proposed by Méry (1704), who, as he accidentally held a cat under water, saw the vessels of the retina and the colour of the fundus of the eye. It was first answered by De la Hire (1709); but neither De la Hire's explanation, to which we shall come hereafter, nor Kussmaul's (1845)—contained in his brilliant Essay, rich in observations, for the Prize instituted by the Medical Faculty of Heidelberg for the anatomical, physiological, and pathological examination of the different colours seen in the background of the eye, independently of turbidity of the dioptric media—could perfectly satisfy all the conditions of the proposed problem, which was first done by Helmholtz, in 1851.

The preceding paragraphs contain, in the merest outline, the history of a discovery that, like many other German inventions, remained long unnoticed in foreign countries. For the first four years, with few exceptions, the ophthalmoscope was little valued out of Germany; but, as the benefits to be gained from it became apparent, it assumed its proper place in France, while the more far-seeing English had still earlier turned it to advantage. In Germany, however, the country of its origin, it was, from the first, employed by the most learned and distinguished men; so that, by the side of Helmholtz, we find Arlt, Coccius, Von Graefe, Hasner, Jäger, Liebreich, Ruete, and Stellwag, occupying the front rank among the observers who estimated the new instrument at its proper value, and raised it to its present position.

And what is that position? Ten years ago, when Helmholtz published to the world the first intimation of his discovery, he wrote as follows concerning its possible utility:—"I do not doubt, judging from what can be seen of the state of the healthy retina, that it will be possible to discern all its diseased conditions, so far as these, if seated in other transparent parts, such as the cornea, would admit of diagnosis by the sense of sight. Distension or varicosity of the retinal vessels will be easily perceptible. Exudations in the retinal substance, or between the retina and choroid, will be seen precisely as in the cornea, by their brightness upon a dark ground. . . . Fibrinous exudations, usually much less transparent than the ocular media, will, when lying upon the fundus, considerably increase its reflection. I believe, also, that turbidity of the vitreous body will be determined with greatly increased ease and certainty. . . . In brief, I do not consider it an overstrained expectation that all the morbid changes of the retina or the vitreous body that have been found in the dead subject will admit of recognition in the living eye; an expectation that appears to promise the greatest progress in the hitherto incomplete pathology of the organ." That this expectation has been not only fulfilled, but exceeded, is a statement that will be justified by the following pages, in which I shall endeavour briefly to exhibit the influence that has been exercised by the discovery of the ophthalmoscope upon the study of the diseases of the internal eye.

Commencing with the diseases of the lenticular system, it is necessary to remember the present state of knowledge with regard both to stationary opacities of the lens, and the different progressive forms of cataract, about which a more exact judgment can now be formed of their seat, progress, and the probable duration of their stages of development, as well as a more exact comparison be made between the degree of opacity and the impairment of vision, than was formerly possible. The ophthalmoscope first taught the difference between stationary opacities of the lens and cataractous turbidity; showing that the latter follows a definite course that cannot be arrested, while the former remain fixed at a certain stage of development. It taught also, with regard to the course of real cataract, that the breadth of the primitive striæ is proportionate to the rate of increase; so that the finer the striæ the more tardy, and the broader the striæ the more rapid, will be the progress of the disease. Concerning the mode of development of cataract, it has taught that the commencement of opacity is neither in the nucleus nor in the cortical substance, but in the intermediate or transitional strata of the lens. In common senile cataract, for example, the turbidity does not begin in the nucleus, long previously yellow, but in the anterior and posterior layers immediately surrounding it. We now know also, that all the opacities that are connected with diseases of the choroid or of the vitreous body, have their point of origin at the posterior pole of the lens; and, formerly, the different signs which were relied upon in order to distinguish commencing cataract from amblyopia were so uncertain that the surgeon would often subject his patient to months or years of harassing treatment, and would only discover his error when it became evident, even to a layman, that the case was one of grey cataract, and not the commencement of amaurosis.

With regard to affections of the vitreous body, the ophthalmoscope has revealed the frequent occurrence of effusions of blood into its substance; and that such effusions may, in the course of a few weeks, become absorbed. It has enabled us to estimate the connection and ætiological relations between floating opacities and choroidal disease. It has shown the peculiar seat of cholesterine crystals, the presence of living entozoa, and of foreign bodies that have penetrated the organ; and, in the form of iritis known as aquo-capsulitis, in which the impairment of sight is often disproportionate to the degree of opacity visible either to the naked eye, or with a lens and oblique illumination, the ophthalmoscope has shown that this impairment is caused by the infiltration of the whole vitreous body with floating molecules, and has thus proved the frequent sympathy of the inner membranes with the more evident disease.

In the disorders of the inner membranes themselves, of the choroid, retina, and optic nerve—almost a *terra incognita* before its discovery—the ophthalmoscope has rendered assistance equally great. We are indebted to it for an exact knowledge of inflammation, pigmentary changes, apoplexy, and posterior staphyloma of the choroid, as well as of hyperæmia, inflammation, hæmorrhage, atrophy, fatty degeneration, and separation of the retina. It has reduced to an impossibility Walther's definition of amaurosis, as a state in which "the patient sees nothing and the surgeon likewise nothing," since the bugbears of ophthalmology, that formerly concealed themselves under the names glaucoma, amblyopia, and amaurosis, have been for the most part traced to definite anatomical conditions. Through its assistance, therefore, in the place of doubt we have certainty; and in the place of inductive reasoning the direct perceptions of sense; which last alone can be accepted as certain truths by the inquiring spirit of natural science.

The instrument has been not less valuable as a help to rational therapeutics, than as the basis of rational pathology. So long as the old Hippocratic maxim, "qui bene noscit, bene curat," expresses a truth—so long as an exact knowledge of the seat and causes of disease is essential to the application of rational treatment—so long may we ascribe to the ophthalmoscope a greater value, as a source of therapeutic indications, than even to the stethoscope and the pleximeter; since it is, as a means of diagnosis, more immediate, certain, and indispensable than they. For, since the perceptions of sense are more definite in proportion to the more direct and complete exhibition of the nature, shape, and material conditions of their object, it is impossible to doubt that the information afforded by sight is more certain and exact than that derived from hearing, or any other sense. The instrument is more indispensable, inasmuch as the practitioner, in his diagnosis of various bodily affections, is not entirely dependent upon physical signs, and may find in functional symptoms a sufficient foundation for his opinion. In the diseases of the internal eye, on the contrary, the numerous symptoms of functional disturbance are inadequate by themselves to indicate the proximate morbid state on which they depend; and they first attain a positive value when the material conditions that cause them have been determined, in the only possible way, by examination with the ophthalmoscope. To the exactness of such examination we are therefore indebted, in fact, for a system of therapeutics in which the rational application of remedies has superseded a blind empiricism. And even when the ophthalmoscope reveals organic changes against which our remedies are useless, it is still of great value in affording positive data for a sure prognosis; and in sparing the patient that course of treatment, often painful and debilitating, and always useless, that the empiricism of former times was accustomed to prescribe for the multitude of amaurotic patients. Lastly, the cultivation of ophthalmoscopy is of no small advantage as an antagonist to the counsels, often ridiculous, often even dangerous, of the quack; since it enables us to recognize the earliest stages of those changes in the internal ocular textures from which amblyopic or amaurotic affections proceed; and to employ, with comparative ease and certainty, means to stop their progress, or, at least, to delay their consequences, against which, at a late period, all treatment might be inefficient or wholly useless. (Quaglino.)

I shall endeavour to show hereafter, in the Fifth Section, in what manner the ophthalmoscope can be made useful in forensic medicine, and will only mention here, as by no means the least merit of the discovery, that it has been the cause of bringing to perfection other means of objective examination. Of such it is sufficient to remember lateral illumination, the new method of examining the field of vision in affections of the choroid, retina, and optic nerve, and the tests of the quantitative perception of light.

After thus reviewing what has been accomplished by the ophthalmoscope, and is barely indicated above, it is impossible to refuse assent to the words of Hasner:—"The ophthalmoscope is not only the most valuable boon to ophthalmology, but is also one of the greatest creations of our century. What the telescope is to astronomy, the ophthalmoscope is to ophthalmology. The telescope owed its existence to accident; but the opthalmoscope is absolutely the mature offspring of theory, and is therefore a greater ornament than the former, not only to Helmholtz its originator, but also to the age itself, which has not been indebted to blind chance for its greatest discoveries, but has known how to deduce them from exact and laborious scientific investigations."

SECTION THE FIRST.

THE VARIETIES OF THE OPHTHALMOSCOPE, AND THE PRINCIPLES ON WHICH THEY DEPEND.

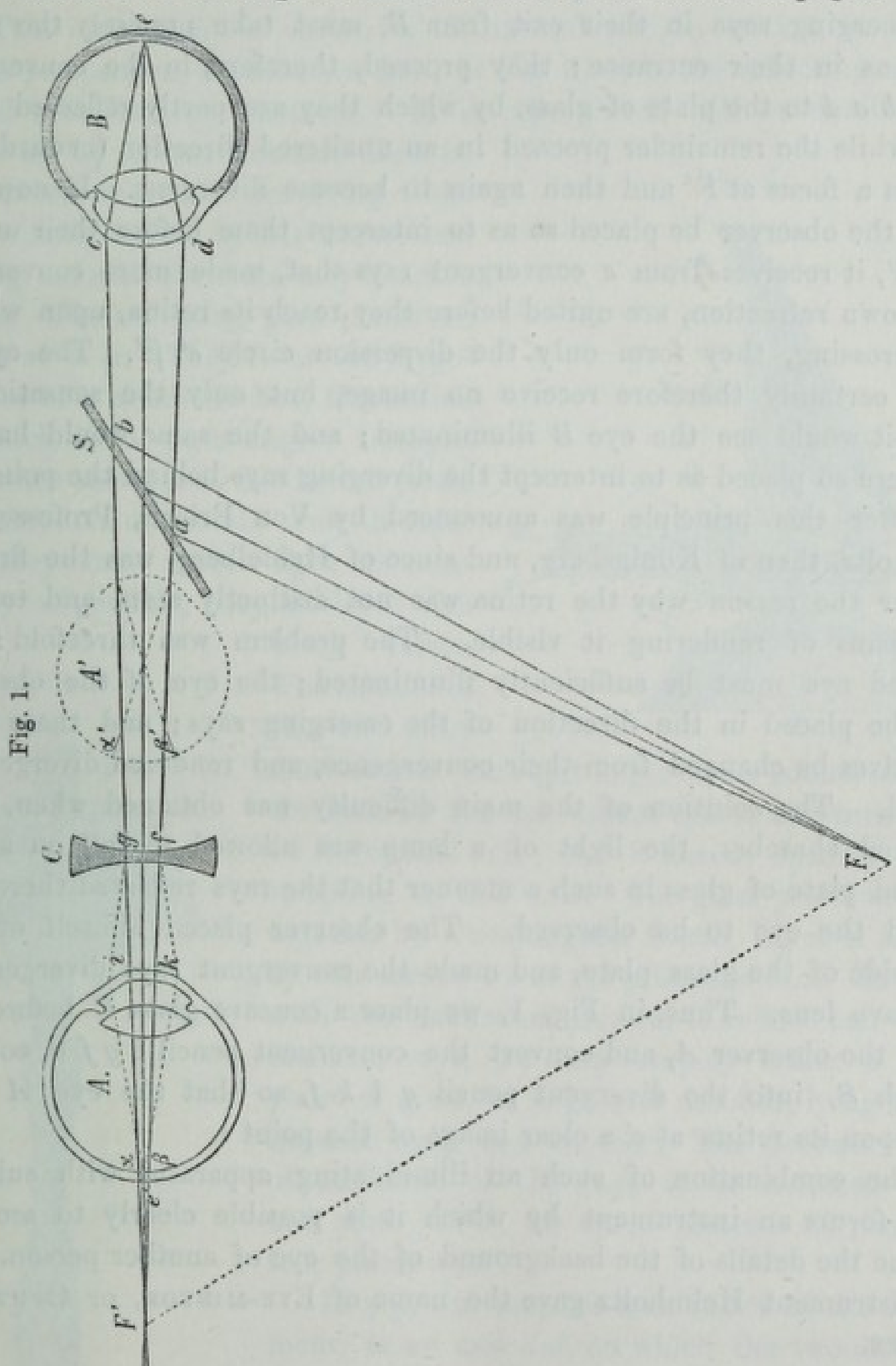
WHEN we look at the eye of another person, the pupillary space usually appears black, and the interior of the organ does not return to the spectator a single reflected ray. We have here, therefore, an apparent exception to the well-known physical law that the passage of light from one medium to another is never complete, and that some of the rays that fall upon the new medium are in all cases bent back again or reflected.

The reasons of the dark appearance are briefly as follows:—Let us suppose that a luminous point is placed at such a distance from the eye, that, by proper accommodation of the latter, an exact image of the point is formed on the sensitive layer of the retina. As the retina, notwithstanding its complicated elementary structure, is so far transparent that nearly all rays pass through it, and only a few are reflected by its surface, the former portion will reach the choroid, and will, in great measure, be absorbed by its dense layer of dark pigment. The darker the pigment, the more complete will be the absorption; but, as an absolutely black surface, capable of retaining all the light it receives, does not exist in the eye, some portion of the incident rays must always be reflected, both by the choroid and by the sclerotic beneath it. This reflection, if we disregard what is effected by the polished boundary membranes within the eye (the membrana limitans, choroidal epithelium, &c., &c.), is wholly irregular, and is dispersed throughout the entire vitreous body. If the fundus of the eye reflected light regularly, "it would have precisely the action of a concave mirror, and the observer with the ophthalmoscope would see only luminous reflection, or floating images of his lamp and his instrument, but not the vessels of the retina, the surface of the nerve, the vascular network of the choroid, and so forth." The irregularity of the reflection is proved also by the fact that, "in an eye in which two excentric artificial pupils had been made, or in which partial irideremia was present, when the fundus was illuminated through one opening only, the reflected light returned equally and in the same quantity through both; and through both the colours and objects of the interior were perceptible." (Businelli.)

There is, moreover, still farther evidence afforded by pathological conditions known to the earliest oculists, such as separation of the retina from the choroid by serous effusion, or cat's-eye amaurosis; as well as by albinoes, in whom the iris is translucent. The brightness of the interior of albinotic eyes depends entirely upon the light diffused over every portion of the retina from the illuminated iris, and not at all upon a more abundant reflection, in consequence of the deficiency of pigment, of the rays entering through the pupil. It has been shown by Donders that such eyes present the ordinary complete darkness of the interior, as soon as they are protected by a screen having a small circular opening, through which light is admitted to the pupil alone, the general surface of the iris being in shadow. Lastly, Helmholtz has suggested the experimental proof furnished by taking "a small camera obscura (for example, an artificial eye), well blackened within, and having an opaque white surface, such as a piece of thick drawing paper, placed in the position to receive the image. The eye-piece of a microscope, with the drawing-paper substituted for the ocular glass, will usually answer the desired purpose, as its tube mostly corresponds exactly with the focal length of its objective. It follows that this objective will form upon the white paper clear images of surrounding objects; and yet, if we attempt to look through the objective, the interior of the tube will appear absolutely dark. We have in this an apparatus analogous to the eye; the objective representing the cornea and crystalline lens, and the white paper representing the retina; and we find in it the same complete interior darkness as in the eye itself, so long as the paper is accurately placed to receive clear images of external objects. But if the objective be removed from the tube, or if its distance from the paper be considerably varied, the bright whiteness of the latter becomes immediately visible to the spectator."

Of the light reflected from the ocular background, a portion returns through the dioptric media and passes out of the eye. But, in consequence of the action of the refracting apparatus, and especially of the cornea and crystalline lens, the incident and emergent luminous cones coincide precisely; insomuch that, if the eye be exactly accommodated for any luminous point, the rays leaving the organ will return to, and be again united in, that point itself. The object and its retinal image are in the position of conjugate foci; and the rays proceeding from either focus are reunited in the other; so that every ray, in its exit from the eye, follows precisely the same course as in its entrance, and the image of the retinal image is formed only at the luminous object-point. In order to perceive the returning rays, it is evident that the eye of the spectator must be interposed between the source of light and the eye that is illuminated, which cannot be done without cutting off the illumination from the latter.

It is just as little possible to perceive light from the eye of another person when the latter is exactly accommodated for the pupil of the observer. For, under these circumstances, a perfectly dark image of the pupil of the observer will be formed on the retina of the eye that is observed. Conversely, the dioptric media of the latter will return an image of this dark portion of the retina to the former, and the observer will therefore see nothing but the reflection of his own dark pupil.



Under certain conditions, however, we may see the fundus of the human eye shine with a reddish lustre. Such conditions are shown in

Fig. 1, where *F* is a luminous point, and *S* a polished plate of glass, which reflects the light *a b* falling upon it, into the observed eye *B*, in a direction as if it came from a point *F'*, lying as far behind the plate *S* as the actual point *F* lies before it. Disregarding the loss of light caused by irregular reflection and other circumstances, the rays *a d* and *b c*, reflected from *S*, enter the observed eye, and become united upon its retina at *e*. The emerging rays in their exit from *B*, must take precisely the same course as in their entrance; they proceed, therefore, in the converging cone *c b a d* to the plate of glass, by which they are partly reflected back to *F*, while the remainder proceed in an unaltered direction forwards, to unite in a focus at *F'* and then again to become divergent. If now the eye of the observer be placed so as to intercept them before their union, as at *A'*, it receives from *e* convergent rays that, made more convergent by its own refraction, are united before they reach its retina, upon which, after crossing, they form only the dispersion circle $\alpha' \ \beta'$. The eye *A'* would certainly therefore receive no image, but only the sensation of light—it would see the eye *B* illuminated; and the same would happen if it were so placed as to intercept the diverging rays behind the point *F'*.

After this principle was announced by Von Erlach, Professor H. Helmholtz, then of Königsberg, and since of Heidelberg, was the first to discover the reason why the retina was not distinctly seen, and to find the means of rendering it visible. The problem was threefold: the observed eye must be sufficiently illuminated; the eye of the observer must be placed in the direction of the emerging rays; and these must themselves be changed from their convergence, and rendered divergent or parallel. The solution of the main difficulty was obtained when, in a darkened chamber, the light of a lamp was allowed to fall on a well polished plate of glass in such a manner that the rays reflected therefrom entered the eye to be observed. The observer placed himself on the other side of the glass plate, and made the convergent rays divergent by a concave lens. Thus, in Fig. 1, we place a concave glass *C* before the eye of the observer *A*, and convert the convergent pencil *b g f a*, coming through *S*, into the divergent pencil *g i k f*, so that the eye *A* may form upon its retina at *e'* a clear image of the point *e*.

The combination of such an illuminating apparatus with suitable lenses forms an instrument by which it is possible clearly to see and examine the details of the background of the eye of another person. To this instrument Helmholtz gave the name of EYE-MIRROR, or OPHTHALMOSCOPE.

I.—OPHTHALMOSCOPES WITH REFLECTORS FORMED BY PARALLEL SURFACES OF GLASS.

1. HELMHOLTZ'S OPHTHALMOSCOPE.

This instrument is shown of its natural size, in section, in Fig. 2, and in perspective, reduced one half, in Fig. 3, with the reflecting surface turned towards the spectator. It is represented with a modification contrived by the mechanician Rekoss, who added to it the revolving disks now usually called by his name, and serving to hold the necessary concave lenses. The reflecting glass plates are shown at *a a*. They form the hypothenuse of a prismatic box, the section of which is a right-angled triangle. The other surfaces of this hollow prism are composed of metal; and, in order that they may absorb light as completely as possible, they are lined with black velvet. The smaller of the two sides that contain the right angle is so connected with the basis of the instrument that it can turn freely on its optical axis; and it has an opening corresponding to this axis. The glass plates are held together by a rectangular frame, which is secured by two screws *e e* to the prismatic box. In order, with the unsilvered mirror, to reflect half of the incident rays, we may employ either a single plate of glass, or a greater number, lying superimposed upon one another. The necessary angle of incidence of the rays to be reflected is, for one plate $=70°$, for three plates $=60°$, and for four plates $=56°$.

Fig. 2.

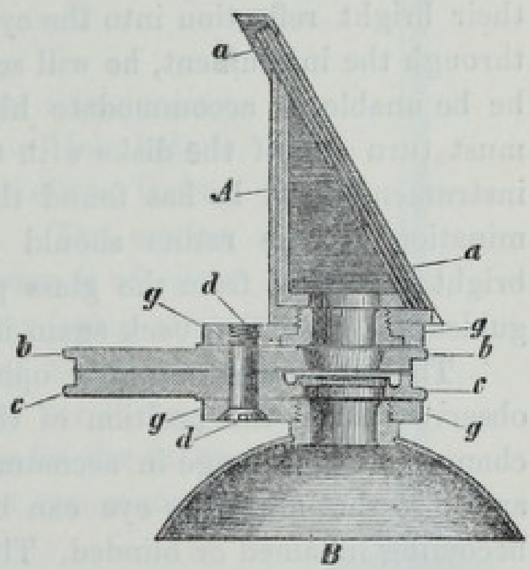
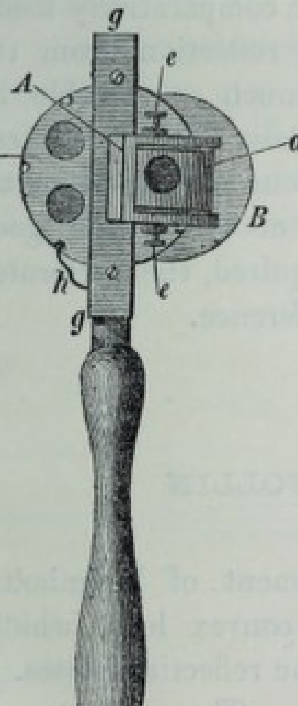


Fig. 3.



In *g g*, the metallic framework of the instrument, is an axis *d d*, on which the two disks *b b* and *c c* revolve. Each of these disks has five openings; and in eight out of the ten are placed a series of concave lenses, of from 6″ to 13″ focal length, the other two openings being empty. By turning the disks, these openings can be brought one after another into the optical axis of the instrument, so that the observer, applying his eye to the basin-shaped eye-piece *B*, may look through any of them, and also through the glass plates *a a*. In order that the disks may not change their position, they have indentations on their margins, to receive the ends of two springs, one of which is shown at *h*.

In using this ophthalmoscope, the observer sits close in front of the patient, and places at his side a brightly burning lamp. An opaque screen is then so arranged that it shades the face of the patient. The observer first brings the mirror nearly into its right position before the patient's face, and so manœuvres it, that the plates of glass throw their bright reflection into the eye to be examined; upon which, looking through the instrument, he will see the retina shine with a red glow. If he be unable to accommodate his eye for the vision of fine details, he must turn one of the disks with the forefinger of the hand that holds the instrument, until he has found the necessary concave lens. If the illumination of the retina should disappear, the observer looks for the bright reflection from the glass plates upon the face of the patient, and guides this reflection back again into the eye.

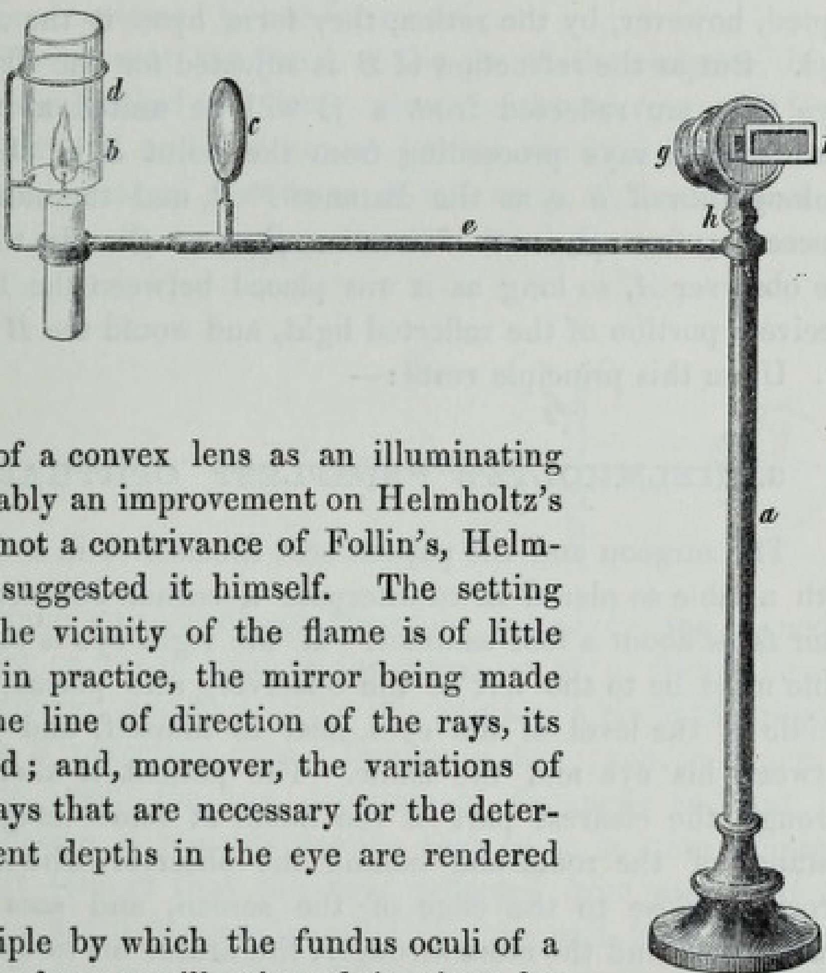
The advantages of this ophthalmoscope are, that it allows us to observe exactly the position of the retinal image of the flame, and the changes of this image in accommodation for nearer or farther distance; and also that a healthy eye can bear its illumination for hours without becoming inflamed or blinded. The disadvantages are comparatively feeble illumination of the fundus oculi, and disturbing reflection from the cornea; which last objection is diminished as much as possible by polarization of the light by means of four plates of glass. The instrument is chiefly useful, however, in physiological observations and experiments; and in surgical examinations, where a larger field of vision and good definition with less magnifying power are mostly required, the perforated mirror with a convex lens is found to deserve the preference.

2. THE OPHTHALMOSCOPE OF FOLLIN

is shown in Fig. 4. It is essentially the instrument of Helmholtz, rendered stationary, and with the addition of a convex lens, which, placed near the lamp, throws divergent light upon the reflecting plates.

The instrument consists of the following parts. The apparatus of Helmholtz, with its reflecting glass plates *f*, is connected to a wooden pillar *a* by means of a hinge *h*, which permits of revolution about its vertical axis. The concave lenses necessary as ocular glasses are secured in the frame *g*, moveable on its horizontal axis. The stand *a* bears also the slender arm *e*, on the end of which the light *b* together with its chimney-glass are fastened. This arm carries also the biconvex lens *c*, placed between the light and the instrument, and sliding backwards and forwards.

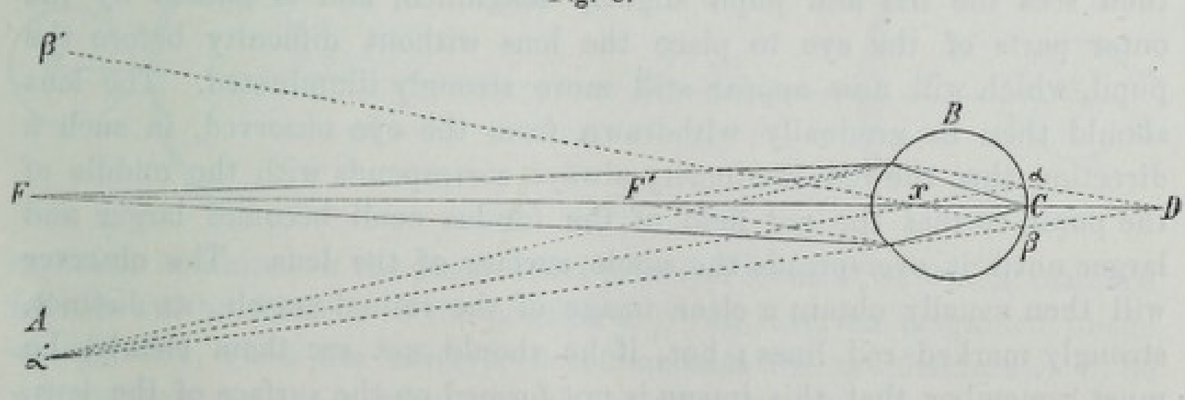
Fig. 4.



The addition of a convex lens as an illuminating glass is unquestionably an improvement on Helmholtz's instrument, but is not a contrivance of Follin's, Helmholtz having first suggested it himself. The setting up of the lens in the vicinity of the flame is of little advantage; since, in practice, the mirror being made dependent upon the line of direction of the rays, its mobility is hindered; and, moreover, the variations of the focus of the rays that are necessary for the determination of different depths in the eye are rendered impossible.

Another principle by which the fundus oculi of a second person may be seen illuminated is given by Brücke. In Fig. 5, let *F* be a luminous point, and *B* the eye to be observed, accommodated for the distance *B F*, and *C* the image of the point *F* upon the retina of *B*. In such case, the whole of the rays

Fig. 5.



reflected from *C* would be again united in *F*, and the eye of the observer *A* placed near *F* and looking towards *B* would receive none of them and would see *B*'s pupil black. If, now, the accommodation of B for the distance $B\ F$ being steadily maintained, the luminous point be moved nearer B to F', then the rays proceeding from F' would have their point of union behind B's retina in D. Being intercepted, however, by the retina, they form upon it the circle of dispersion $\alpha\ \beta$. But as the refraction of B is adjusted for the distance $F\ B$, so the rays that are reflected from $\alpha\ \beta$ will be united at that distance: for example, the rays proceeding from the point α, in the direction of the prolongation of $\alpha\ x$, at the distance $F\ B$, and therefore at α'; and those proceeding from β, in the direction $\beta\ x$, at β'. In this case, the eye of the observer A, so long as it was placed between the limits $\alpha'\ \beta'$, would receive a portion of the reflected light, and would see B illuminated.

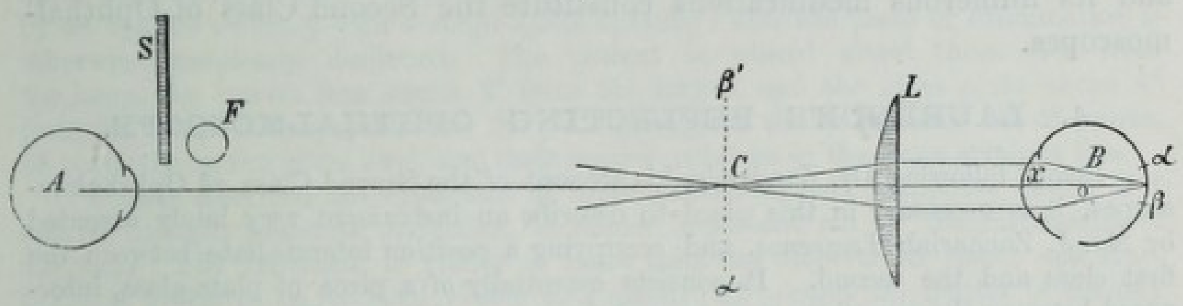
Upon this principle rests :—

3. HELMHOLTZ'S "SIMPLEST OPHTHALMOSCOPE."

The surgeon and the patient seat themselves in a darkened chamber, with a table so placed as to interpose a corner between them, and with their faces about a foot asunder. If the right eye is to be examined, the table must be to the left of the observer, who places upon it a lighted candle at the level of the eyes, near to himself, and interposes a screen between his eye and the flame. The patient is then directed to look through the clearest part of the flame at some imaginary point in the distance of the room and behind the observer, who himself looks in a direction close to the edge of the screen, and sees the observed eye illuminated, and the more strongly, the nearer his line of sight approaches to the margin of the flame. In blue and myopic eyes the illumination is stronger than in brown and normal eyes; but in these it is recognizable. As soon as the surgeon has found the best position of his eye for the observation, he interposes a convex lens of $1\frac{1}{2}''$ or $2''$ focal length and $\frac{1}{2}''$ diameter, and holds it close before the patient's eye. He then sees the iris and pupil slightly magnified, and is guided by the outer parts of the eye to place the lens without difficulty before the pupil, which will now appear still more strongly illuminated. The lens should then be gradually withdrawn from the eye observed, in such a direction that the red luminosity always corresponds with the middle of the pupil, so that the red field of the fundus oculi becomes larger and larger until it overspreads the whole surface of the lens. The observer will then usually obtain a clear image of the retinal vessels, as distinct, strongly marked red lines; but, if he should not see them clearly, he must remember that this image is not formed on the surface of the lens, but nearer to himself by the length of its focal distance, $1\frac{1}{2}''$ or $2''$, and that he must therefore accommodate his eye for vision at such a nearer distance as the position of the lens may indicate. When the two eyes are 12″ apart, the observer will have the image about 8″ or 9″ in front of him, and therefore at a convenient distance for normal vision; but, if he be either near-sighted or presbyopic, he will require the further aid of the same glass that he is accustomed to use for reading.

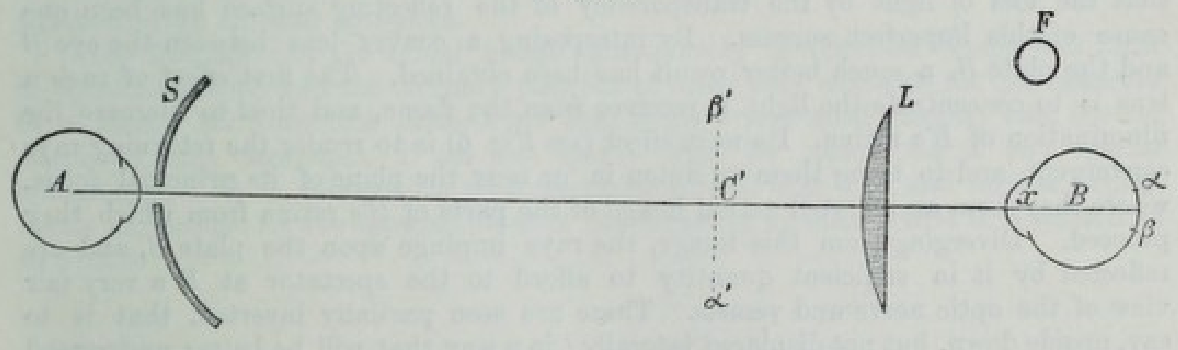
In Fig. 6, let *F* represent the flame, *A* the eye of the observer, *B* of the patient, *S* a screen behind the flame, close to the margin of which the eye *A* looks towards *B*, and *L* a convex lens of the focal length *L C*. Rays that from some point of the flame *F* fall upon *B*, having passed

Fig. 6.



through *L*, and become convergent, are therefore united by the dioptric apparatus of *B* more or less in front of the retina, as at *o*, from whence they overcross and diverge, and first strike the retina as a circle of dispersion $\alpha\ \beta$. The eye *B* perceives only a luminous disk; and, in general, cannot accommodate itself for any determinate distance; so that in respect of accommodation it remains passive, that is, in a state adapted for parallel rays. It follows that the rays reflected from any point of the luminous circle $\alpha\ \beta$ will become parallel on their exit from the eye, and will follow the direction of a line drawn from their point of origin through the crossing-point *x*. Falling upon the lens *L*, these parallel

Fig. 7.



rays will be united in the plane of its principal focus *C*, at which distance from *L* will be formed, in the position $\alpha'\ \beta'$, an inverted magnified image of $\alpha\ \beta$; and, when the observer accommodates for the distance *A C*, he will see there a clear inverted image of some part of the illuminated retina.

Let us now, as in Fig. 7, replace the screen *S* by a perforated concave mirror held directly before the eye of the observer, and let us place the flame by the side of the eye *B* in such a manner that the mirror reflects light through the lens L upon B. The arrangement of Fig. 6 is not altered in essentials, but we gain the advantages of looking as if through the middle of the flame, and of throwing from S light already convergent upon L.

The merit of having first applied this principle, by using as an ophthalmoscope a perforated concave mirror, which must always afford the best means of illuminating the eye, belongs to Professor Th. Ruete; who also was the first to demonstrate the practicability, and to prove the great value, of the examination of the inverted image. His apparatus and its numerous modifications constitute the Second Class of Ophthalmoscopes.

4. LAURENCE'S REFLECTING OPHTHALMOSCOPE.

Before following Dr. Zander in his account of the Second Class of Ophthalmoscopes, it is necessary in this place to describe an instrument very lately invented by Mr. J. Zachariah Laurence, and occupying a position intermediate between the first class and the second. It consists essentially of a piece of plate-glass, interposed between the eye of the patient and the source of light. The arrangement will be readily understood by reference to Fig. 1, in which, for our present purpose, B will represent the eye to be examined, F' the flame, and F the eye of the observer; and the eyes A and A', and the lens C, may be left wholly out of account. The rays of light from F' penetrate the glass plate S, and enter the eye B, from which they return, either divergent, convergent, or parallel, according to the state of B's refraction and accommodation. Of these returning rays, the greater part again pass through S, and regain their source; but some portion will be reflected by S to F, and will there become visible to an observer. It is quite conceivable that an observer might, under these circumstances, see an erect virtual image of the fundus, for which purpose he would require the aid of a concave lens if the eye under examination were myopic, or even if it were emmetropic, but accommodated for some nearer point than infinite distance. As the apparatus has been hitherto arranged, however, no details of a virtual image have been rendered visible, and nothing has been seen in this way but the red reflex of the fundus. It is probable that the loss of light by the transparency of the reflecting surface has been one cause of this imperfect success. By interposing a convex lens between the eye B and the plate S, a much better result has been obtained. The first effect of such a lens is to concentrate the light it receives from the flame, and thus to increase the illumination of B's retina. Its next effect (*see* Fig. 6) is to render the returning rays convergent, and to bring them to union in or near the plane of its principal focus, where they form an inverted actual image of the parts of B's retina from which they proceed. Diverging from this image, the rays impinge upon the plate S, and are reflected by it in sufficient quantity to afford to the spectator at F a very fair view of the optic nerve and vessels. These are seen partially inverted, that is to say, upside down, but not displaced laterally; in a way that will be better understood when I come to describe the effect that is produced by Dr. Heymann's autophthalmoscope. It is, of course, essential that the convex lens and the glass plate should be separated by a greater interval than the principal focal length of the former; and the more this interval is increased, the larger will be the size of the image, and the fainter its illumination. The surfaces of the glass plate must be perfectly parallel and perfectly smooth; as, otherwise, a separate image will be reflected from each of them, and the two images will confuse one another. There will also be an image reflected backwards from the lens, and visible to a spectator looking over the shoulder of the patient.

By modifying the inclination of the plate *S*, the position of the point *F* may be greatly varied, and the reflection may even be thrown into the other eye of the person under examination, so as to convert the apparatus into an aut-ophthalmoscope. By such an arrangement I have found it easy to see with either of my eyes the luminosity of the other; but I have not succeeded in observing details. The acuteness of the angles of incidence and reflection is a formidable difficulty in the way of self-examination by such a method.

The experimental instrument employed by Mr. Laurence consists of a horizontal stem about a foot long, supported by an upright stand. Two small uprights slide in a groove on the upper surface of the stem; and carry, one a convex lens of 2″ focal distance, the other a small square of plate glass, both so arranged as to turn upon their vertical axes. The light is furnished by an argand burner, surrounded by an opaque chimney with a single small opening; and the place of examination is otherwise completely darkened. The patient is placed about three feet from the lamp, the convex lens about 2″ from the cornea, and the glass plate about 4″ from the lens. The eye, the lens, the plate glass, and the flame, must all, of course, be perfectly on the same level, and their centres must be in the same straight line.

I have described the apparatus at some length, because it appears likely, if it can be brought nearer to perfection, to render important aid in the instruction of students. The reflection is visible to more than one observer at once; and may, perhaps, hereafter be rendered visible to a class. At present the matter is entirely in its infancy; and nothing but the principle can be considered as established. The idea was suggested to Mr. Laurence by the celebrated "Ghost" of Messrs. Dirckes and Pepper, which is produced in a very similar manner.

Still more recently, Mr. Laurence has modified his instrument in the following way:—He illuminates the eye by a lantern having only one opening for the exit of light; and places in this opening a convex lens of such power that the flame is in its principal focus. By this arrangement the rays proceeding from the lantern are rendered parallel. They pass through the plate of glass to reach the eye; and, under ordinary circumstances, will retain their parallelism on their backward course. The biconvex lens is then placed, not between the plate and the eye observed, but between the plate and the spectator; so as to unite the rays into an actual image after they have undergone reflection, instead of before. The image thus formed may be magnified by a second lens; and Mr. Laurence unites the two in a tube, which thus resembles an astronomical telescope, and is levelled at the reflecting plate. Mr. Laurence proposes to convert this tube into a terrestrial telescope by the addition of an erecting eye-piece.

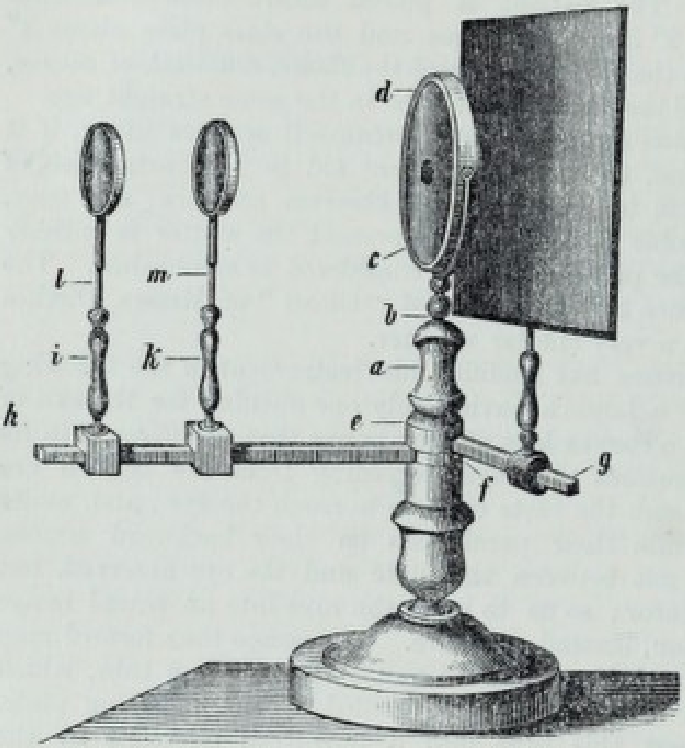
The formation of the actual image subsequently to reflection brings this form of ophthalmoscope into the ordinary position of being only available for one observer at a time. Mr. Laurence informs me that it gives very good results; but, beyond simplicity and cheapness, I am not aware that he claims for it any special advantages. It is, however, of such recent invention, that time and further experiments are needed for the determination of the degree of excellence that it is calculated to attain.

II.—HOMOCENTRIC OPHTHALMOSCOPES.

5. THE OPHTHALMOSCOPE OF RUETE

is shown in Fig. 8, one-eighth of the natural size. A pillar *a*, rising from a round wooden foot, has in its axis a cylindrical wooden rod *b*, sliding up and down, and retained at any desired height by a spring on its lower end. To the top of this rod is secured a brass semicircle *c*, which may thus be raised or depressed, turned right or left, at pleasure. A concave mirror *d*, of about three Paris inches diameter, and 10″ focal length, with a central perforation, is attached to the semicircle by screws, so that it may turn upon its own horizontal axis. Half-way up the pillar *a* are two wooden rings, *e* and *f*, turning freely. Each ring carries an arm projecting horizontally. The arm *g* supports a blackened screen, the arm *h* is graduated in twelve Paris inches, and supports two vertical pillars, *i* and *k*, made to slide backwards and forwards. These contain small rods, *l* and *m*, sliding up and down, furnished with springs like that of the rod *b*, and carrying the necessary concave or convex lenses.

Fig. 8.



To use this instrument, it is placed upon a small table in front of the patient, whose pupil has first been dilated by atropine, and who sits upon a stool in a darkened chamber. Upon a table near him, but on the contrary side to the eye that is to be examined, stands a lamp that can be raised or lowered. The perforation of the mirror, the axis of the dioptric lens, and the flame of the lamp, must all be on the same level as the eye. While the patient looks at the lens nearest to him, placed at a suitable distance, the observer directs the light, reflected from the mirror, into the eye; and then, sitting behind the screen, looks through the perforation. If it be desired, by means of the formation of a dispersion circle on the retina, to include a larger portion within the field, the lamp must be moved forwards or backwards; and if it be desired to diminish the illumination, a third or a half of the mirror may be covered by the screen.

For examination of a virtual, erect image, it is necessary to place in the stem *l* a concave lens of from 8″ to 9″ focal length. This should be distant from 1″ to 3″ from a short-sighted, and from 3″ to 5″ from a far-sighted eye; but by sliding it backwards and forwards the exact distance required by the accommodation of any particular eye may be found. A short-sighted observer must use his accustomed spectacle glass. The inspection of the erect image is more especially useful in order to examine in detail the objects of the fundus oculi, and to determine their peculiar colours, as well as the transparency of the whole refracting media.

For examination of an actual inverted image, it is necessary to substitute a convex for the concave lens. If the stem *l* carry a convex lens of about 1½″ focal length, the observer will obtain, when this lens is distant nine or ten inches from his own eye, and about one inch from the eye of the patient, an inverted picture of the retina, magnified from 2 to 3½ diameters, and showing the finest branches of the central vessels, small aneurisms, extravasations, and so forth. If two convex lenses be used, the first of 1½″, about one inch from the eye of the patient,—the second of 4½″, about 5½″ distant; this combination will afford an inverted image about three times magnified, but apparently filling a larger field than the former. The annoyance of reflected mirror images may be removed by turning the lenses on their vertical axes, so that they stand somewhat obliquely to the optical axis of the eye. An image magnified nine or ten times is afforded by two convex lenses, one of 1½″ focal length, the other of 3″, the first about two inches, the second about six inches, from the eye of the patient; but the steadiness of the eye required by this combination can seldom be obtained.

This, and all other concave mirrors, produce their effects according to the following optical principles:—

In Examination of the virtual, erect Image.—In Fig. 9, *F* represents the flame, *S* the mirror, *L* the concave lens, *B* the eye examined. From the flame *F*, rays of light *F a* and *F b* fall upon the mirror, and are reflected from it in directions converging towards its focus. They are intercepted before they meet by the concave lens *L*, and rendered divergent. Proceeding, they strike divergent upon *B*'s cornea, and form upon its retina the dispersion image $\alpha\ \beta$. Returning in their course of entrance, the rays $\alpha\ d\ e$ and $\beta\ c\ f$ would unite in *g*, were they not again rendered divergent by *L*, so that the observer at *A* sees a magnified erect image $\alpha''\ \beta''$, apparently situated behind $\alpha\ \beta$.

IN EXAMINATION OF THE ACTUAL INVERTED IMAGE.—In Fig. 10, *F* is again the flame, *S* the mirror, *L* the convex lens, and *B* the eye observed.

Fig. 9.

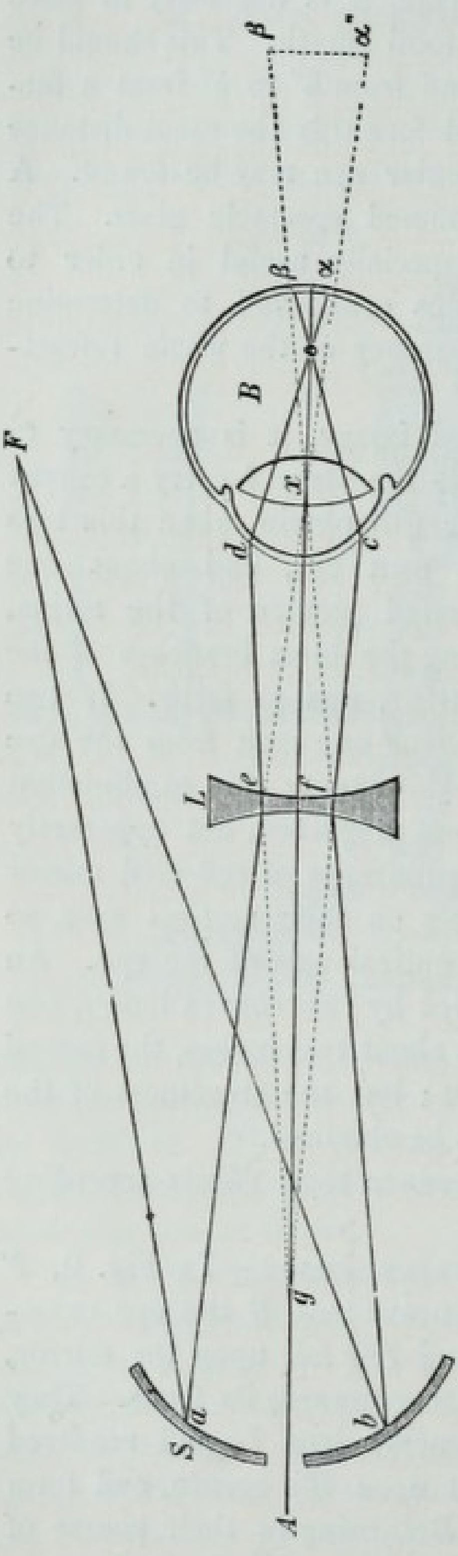
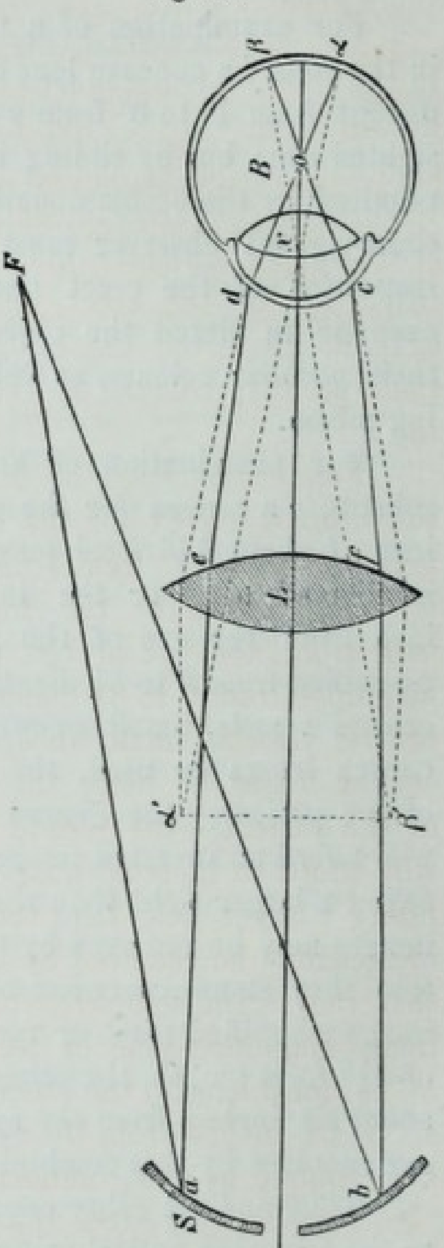


Fig. 10.



The rays *a e*, *b f*, proceeding convergent from the mirror, and rendered more convergent by their passage through the lens, strike the cornea of

B in *c* and *d*. Rendered still more convergent by the dioptric apparatus of *B*, they intersect at some point in front of the retina, for example, at *o*, and form on the retina the dispersion circle $\alpha\ \beta$. As shown in Fig. 6, on account of the passive state of accommodation of the eye, the rays proceeding from it will follow courses parallel to the lines of direction $\alpha\ x$ and $\beta\ x$, and after their refraction by the lens *L* will unite to form at $\alpha'\ \beta'$ an actual inverted image of $\alpha\ \beta$.

While the great advantages of this instrument in respect of the brightness, sharpness, and beauty of its images strongly recommend it for clinical demonstrations, where the head of the patient can be supported by an assistant, yet the fact that it is somewhat difficult to manage diminishes its practical utility for ordinary purposes.

6. THE SMALLER OPHTHALMOSCOPE OF RUETE.

To obviate this inconvenience, Ruete has constructed a smaller, portable instrument, of which the following is a description:—

A small, centrally-perforated concave mirror (of $1\frac{1}{2}''$ diameter, and $4''$—$6''$ focal length) is attached by a hinge-joint to a brass staff, like, but larger than, that of Coccius's ophthalmoscope. Behind the mirror is a spring clip to contain ocular lenses. Immediately below the hinge the staff carries a longer rod, divided into six or eight joints, sliding backwards and forwards one upon another. At the farther end of this is a spring ring to carry concave or convex lenses—the whole corresponding to the arm *h*, Fig. 8. Above the handle is a cross-bar, like that of the arm *d*, Fig. 29, which carries a pasteboard screen on a short stem. This instrument gives very good images; but in consequence of the length of the handle and arms, its management and its application to the eye of the patient are sometimes difficult.

7. THE OPHTHALMOSCOPE OF ANAGNOSTAKIS.

This instrument consists of a small, round, concave mirror, 5 centimetres in diameter, having a focal length of $4\frac{1}{2}''$. Its silvered surface is protected by a blackened plate of copper. The centre of the mirror is perforated, the opening having a diameter of 4 millimetres. For convenience in use, the mirror is attached to a short handle. The manner of using is the same as for other ophthalmoscopes.

8. THE OPHTHALMOSCOPE OF ULRICH

is shown in Fig. 11 in perspective, in Fig. 12 in section. It consists of two tubes, blackened within, and united at an angle of about 40°; one of them, *a b*, inclosing the mirror and lenses, the other admitting the light to the first. The length of the first tube, which Ulrich calls the "ocular, or observer's tube," is about 5″, its diameter 1″ 8‴. The second, or "light tube," has a smaller diameter, and on its hinder margin a length of about 2″, greater length being forbidden by the necessity of keeping the source of light away from the patient's head. The end *b* of the tube is provided with an opening ½″ in width, adapted to the eye of the observer; the other end *a* is open in its whole diameter, and incloses the eye of the patient. Both are finished by proper margins. The free end of the second tube has a screen *d* that shuts off side light from the observer, and acts also as a cover for the tube itself. The source of light can either stand alone at a distance; or, as at *f* in the figure, be attached to the instrument itself by means of the collar and screw *g* and *x*,—the light being held in a ring turning on a horizontal axis. This ring is furnished with the screen *h* to cut off rays from the head of the patient.

Fig. 11.

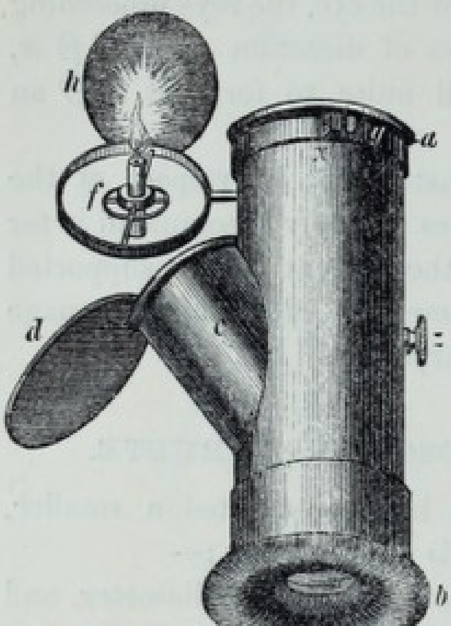
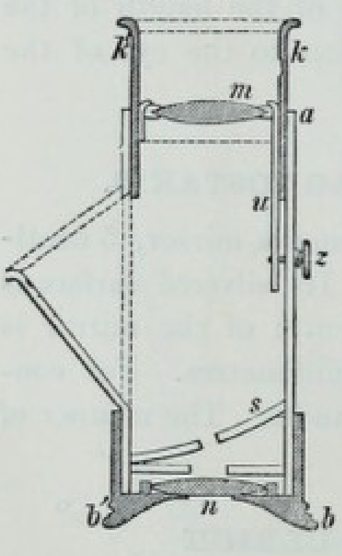


Fig. 12 shows the internal parts in section. They consist of a small concave mirror of 1″ 8‴ diameter, 1½‴ central perforation, and 3″ focal length, and two convex lenses, *m* and *n*. The mirror is set obliquely across the tube, so that its incident and reflected rays correspond with the axes of the two tubes respectively. Its distance from the opening of the ocular tube is about 4″. Behind the mirror, separated from it by a perforated diaphragm, is the 4½″ ocular lens *n*, fixed in the moveable sliding tube or eyepiece *b b′*. The 1½″ object-glass *m* is placed in front of the mirror, and has, attached to its setting, a rod *u*, fastened to a button and screw *z*, which passes through a slit in the side of the ocular tube, so that the object-glass can be moved to and fro, and fixed at any point. The ocular tube is also furnished with the draw-tube *k k′*, which serves to steady the apparatus upon the eye of the patient, and also to retain the eye in any desired position.

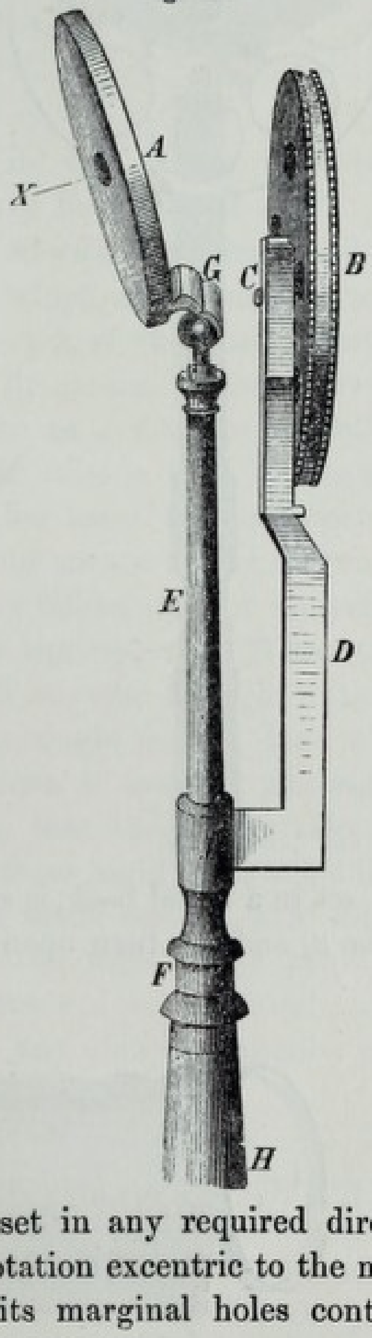
Fig. 12.



To use this instrument it is held in the left hand for examination of the left eye, and *vice versâ*; while the free hand regulates the positions of the object-lens and of the draw-tube. With clear vision at a distance of nine inches no elongation by means of the draw-tube is required, but only movement of the object-lens to the extent of ¼″ or ½″. In presbyopia the tube must be lengthened ½″ or ¾″; and in myopia it may be necessary to move the object-lens as much as 1″, and to substitute a weaker ocular (a biconvex of 6″) for the one ordinarily employed.

For examination of the cornea, iris, or lens, the ocular is removed by withdrawing the tube in which it is set; thus reducing the instrument to a simple magnifying glass.

Fig. 13.



This ophthalmoscope can also be employed in daylight.

Its advantages, for examination of the inverted image only, are these;—that the whole of the necessary apparatus is united in a portable form; and that the tube, by totally excluding side light, facilitates the perception of aërial images.

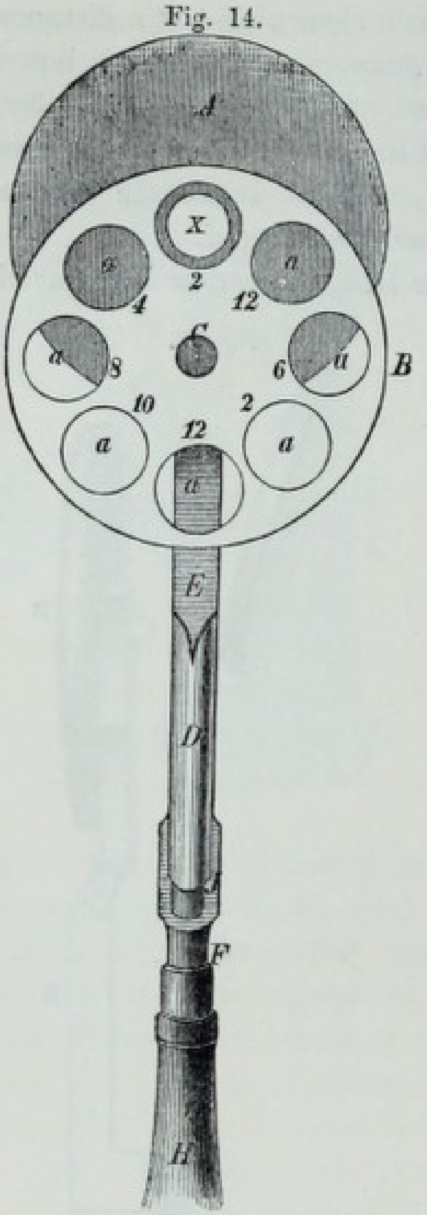
They are much outweighed by the disadvantages of having the source of light united to the instrument; of having the object-lens with its axis straight, so as to transmit reflected mirror images; and of having the mirror stationary.

9. THE OPHTHALMOSCOPE OF STELLWAG VON CARION

is shown in Figs. 13 and 14 in natural size. It consists of a concave mirror, having a focal distance of some inches, perforated through the middle, and attached by a joint at its edge to a handle. By this joint the mirror can be set in any required direction. Behind is a Rekoss's disk with its axis of rotation excentric to the mirror; so that, by turning the disk, any one of its marginal holes containing lenses can be brought opposite to the mirror opening.

Fig. 13 shows the instrument from the side, and Fig. 14 from behind. *A* is the concave mirror, with its central opening *X*. At *G* the mirror is united by a joint to the stem *E*, which is secured by a screw to the handle (*H*) at *F*. To the stem *E* a second stem *D* is fastened at *J*,

Fig. 14.



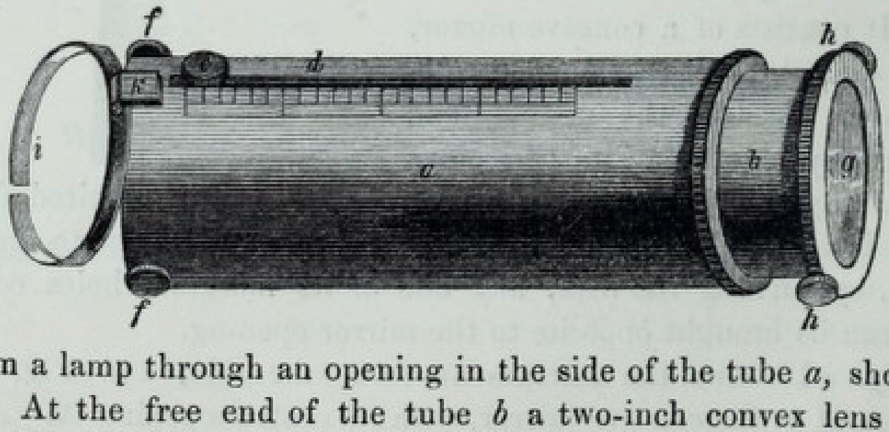
and carries at its upper end the Rekoss's disk *B*, which revolves on the pivot *C;* so that any one of its eight lenses *a a* can be brought opposite the opening *X* of the mirror *A*. The lenses are 2″, 4″, 8,″ 10″, and 12″, concave; and 2″, 6″, 12″, convex.

In order to reduce the size of the instrument as much as possible, and to bring it within the compass of a small case, the distance between the stems *D* and *E* must be very small; so that the mirror can only receive a trifling degree of inclination; and the light must be so placed that the angles of incidence and reflection are also small.

10. THE OPHTHALMOSCOPE OF HASNER

is shown in Figs. 15, 16, and 17 in half size. It consists of the following parts:—In a brass tube *a* is a second tube *b* sliding freely, and capable of being fixed in any position by the screw *c*, which projects through *d*, a slit in the outer tube. A perforated glass concave mirror of 7″ focal length, set in a metal back, is suspended by the screws *f f* at the free end of the tube *a*, and can turn upon these screws as on an axis. It receives the

Fig. 15.



light from a lamp through an opening in the side of the tube *a*, shown in Fig. 16. At the free end of the tube *b* a two-inch convex lens *g*, set in a metal ring, is suspended by the screws *h h* in the same manner as the mirror. Behind the mirror is a spring clip united to the tube *a* by the joint *k*, and capable of being set at any desired obliquity. The

Fig. 16.

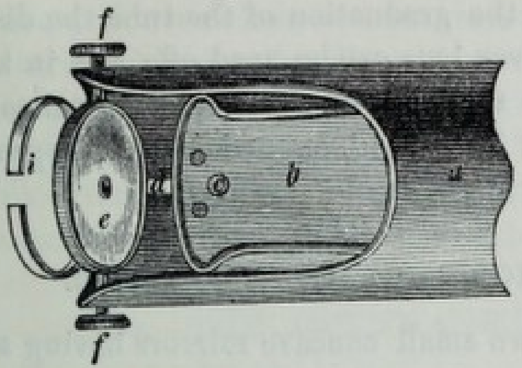
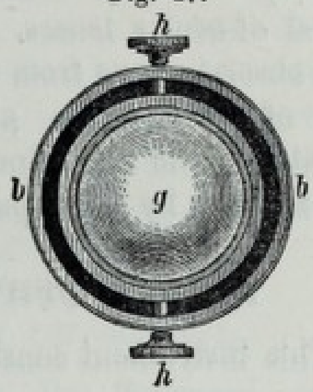


Fig. 17.



distance of the lens *g* from the opening in the mirror is shown in Paris inches by the graduated scale *d*, and may be increased to 8″.

In use, the observer holds the screws *h h* with the thumb and index finger of one hand, the remaining fingers of which rest upon the cheek or forehead of the patient, and maintain the end of the instrument at a distance of from ½″ to 1½″ from his eye. By means of the screws, the necessary obliquity is given to the lens *g*, so as to displace laterally the reflected images of the mirror. The ocular tube is held by the screws *f f* with the thumb and forefinger of the other hand, the side opening is turned towards a lamp suitably placed; and, by means of the screws, such a direction is given to the mirror that the rays falling upon it are reflected down the axis of the tube into the eye of the patient. When this is illuminated, the details of the fundus oculi may be brought into view by sliding the tubes. For ordinary cases, a single convex lens will be sufficient; but in high degrees of presbyopia it may be necessary to place a second, of 15″ or 20″ focal length, into the spring clip. The same may also be done in order to obtain a more highly magnified image.

Professor Ryba makes the spring ring *i* much smaller, and connects it by a twice-jointed stem to the edge of the metal plate behind the mirror. By this arrangement the ocular lens can be accurately applied to the central perforation of the mirror, in any oblique direction of the latter, and in any direction of the axis of the tube.

Among the merits of this instrument Hasner enumerates:—(1) Being composed of solid metal it occupies little room, and is very portable. (2) The inverted image of the retina is easily found, because the tubes slide freely, and because their considerable diameter renders it unnecessary to look exactly in the line of their axis. (3) Its connection with the patient by the hands of the observer keeps it steady in its place. (4) The mobility of the mirror renders it easy to give any direction to the instrument without altering the position of the flame. (5) The reflected images of the object-lens are readily set aside by shifting it. (6) The retinal image contained within a blackened tube, from which all side light is excluded, appears much more clearly than when formed in the open air. (7) The clip behind the mirror facilitates the application and removal of ocular lenses. (8) By the graduation of the tube the distance of the observing eye from the convex lens can be read off; and in known vision of the observer, and with the lens at a constant distance from the patient, the refraction of the latter can be determined, approximatively at least, by a comparison of different observations.

11. THE OPHTHALMOSCOPE OF WILLIAMS.

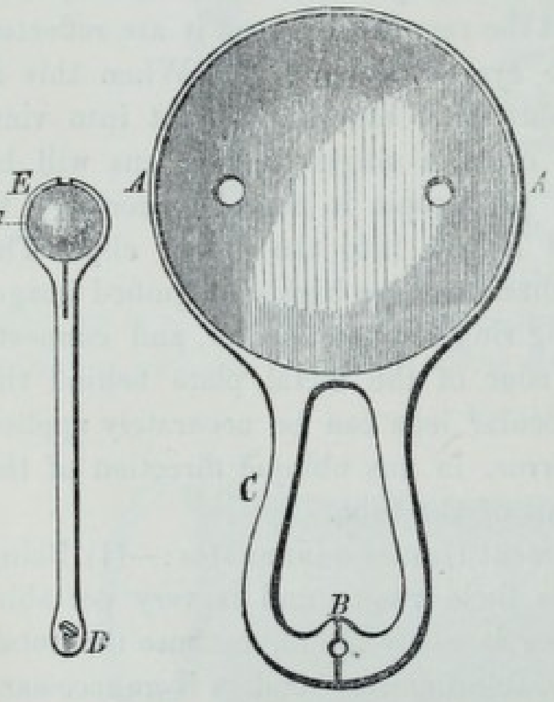
This instrument consists of two small concave mirrors having a focal length corresponding to the distance at which the observer sees small objects clearly. They are set in a spectacle frame in such a manner as to turn on vertical axes; and, this frame being worn by the observer, the light from a side lamp is directed into the eye observed.

The advantage of having both hands at liberty, claimed by Williams, is far overbalanced by the evils of difficult adjustment and uncertain fixation.

12. THE OPHTHALMOSCOPE OF DESMARRES.

This ophthalmoscope, shown in Fig. 18, consists of a concave mirror four centimetres in diameter, and of 7″ focal length, with two parallel holes *A A* for the observer, according as he may examine the right or the left eye. An ocular lens of $1\frac{3}{4}''$ is fixed by a pin *D* to an opening *B* in the handle of the mirror, and can be applied to either of the perforations.

Fig. 18.



Another instrument likewise used by Desmarres, consists of two concave mirrors, united together back to back. The two mirrors have different foci—one at 12, the other at 9 centimetres. Instead of a central opening there is in each mirror a small one near the margin. The whole instrument, together with a convex lens, is mounted in a tortoiseshell frame.

13. THE OPHTHALMOSCOPE OF HEYFELDER.

This consists of a small concave mirror the size of an English florin, having a moveable handle of blackened wood. In the centre the metal covering of the mirror has a circular perforation two lines in diameter, the glass itself remaining entire. The concave and convex lenses may be inserted in a moveable black ring, that may either be attached to a second wooden handle and used by the free hand, or, more conveniently, may be fixed to a small cross-piece of brass on the mirror, and thus placed at a distance of from ½″ to 2″ either before or behind it. In this arrangement the whole apparatus is managed by one hand, and the other is left at liberty to steady the head of the patient.

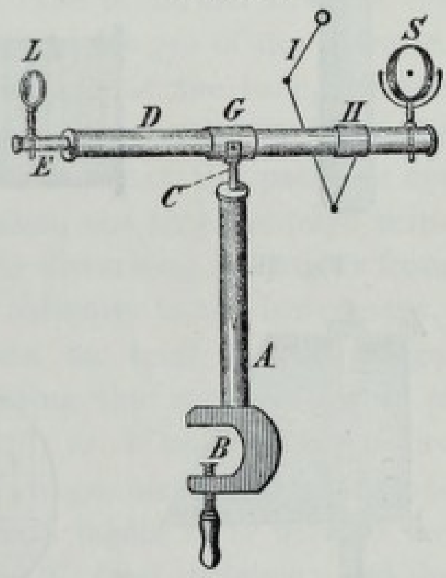
14. THE OPHTHALMOSCOPE OF SOLEIL,

according to the description furnished by Dr. Castorani, precisely resembles in appearance a botanical lens. It consists of a common centrally-perforated concave mirror of 20 centimetres focal distance and 32 millimetres diameter, of a biconvex lens of 55 millimetres focal distance, and of a handle. When closed, it is 8 centimetres in length, 4 in breadth, and 18 millimetres in thickness.

15. THE OPHTHALMOSCOPE OF CUSCO

consists of a hollow upright stem of wood, *A*, Fig. 19, 10″ in height, and furnished with a screw *B* by which it can be fastened to the edge of a table. In this stem a wooden pillar *C* slides up and down and is retained in any desired position by a spring at its lower extremity. Its upper end is united by a simple joint to the brass ring *G*, which is lined with cloth, and carries the moveable wooden tube *D*. This again contains the sliding stem *E*, and carries the brass ring *H* with its jointed brass rod *I* terminated by a little knob. It carries also the concave mirror *S* supported by a brass semicircle and turning in the tube *D* on its vertical axis. The stem *E* supports in the same manner the lens *L*. The focal length of the mirror is 8″, and that of the lens is 2″.

Fig. 19.



16. THE OPHTHALMOSCOPE OF JÄGER

is shown in half-size in Figs. 20 to 25. In order to unite in one apparatus the advantages of Helmholtz's, Ruete's, and other ophthalmoscopes, Jäger has constructed an apparently complicated instrument, the description of which belongs to this place, since it is chiefly used with a concave mirror.

It consists of a short tube *a* which turns on its axis in a ring *c*, attached to the handle *b*. The tube at its anterior extremity is sloped off at an angle of 60°, and has two opposite slits *d* for the reception of the trunnions of the mirror *e*. Outside the tube are two springs *f f* corresponding to these slits, and serving to secure the mirror in its position.

Fig. 20.

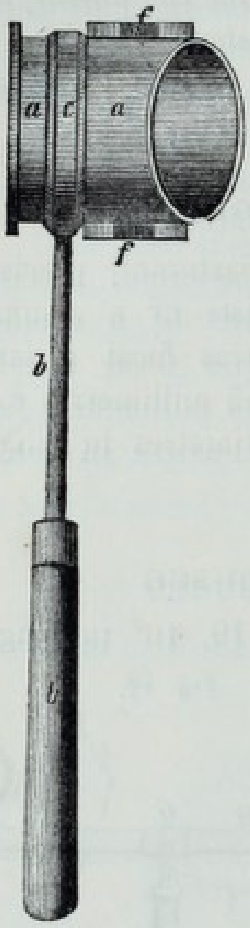


Fig. 22.

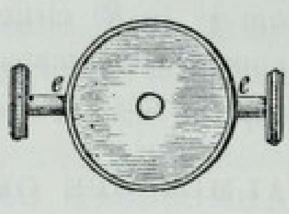


Fig. 23.

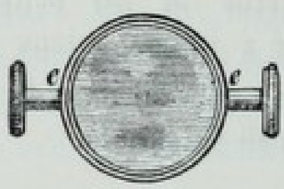


Fig. 24.

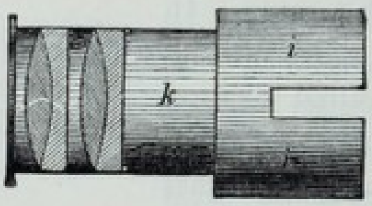


Fig. 21.

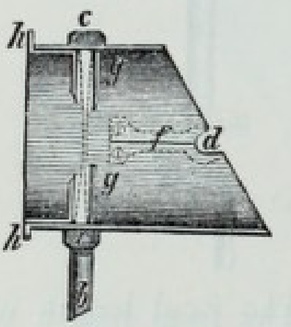
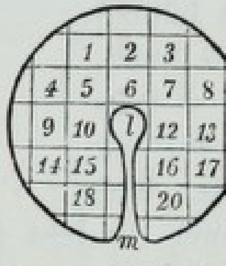


Fig. 25.



Within the tube is a diaphragm *g* with a central perforation one centimetre in diameter. At the hinder end of the tube is a sliding ring *h*, also with a diaphragm and a corresponding perforation. This ring can be easily removed and replaced, and serves to hold a lens securely between the two diaphragms.

Fig. 22 shows a concave mirror, of 7″ or 4″ focal length, fixed in a metal ring with two trunnions *e e*, and protected on its silvered side by a thin metal plate. The latter has a central opening two decimal lines in diameter, and the mirror itself is drilled to correspond.

Fig. 23 shows a metal ring, also with two trunnions, and holding three or more plates of plane glass, which are secured by a second ring screwed into the first.

Fig. 24 is a metal tube, of which the broader part *i* is made to slide over the front part of the tube *a*, the slits in the sides of *i* corresponding to the springs *f f* and receiving them. In the narrower part *k* this tube will contain either a single biconvex lens, or two plano-convex lenses, or the objective of a Brücke's magnifier.

Fig. 25 exhibits a black paper disk of from 6″ to 12″ in diameter, slit to the centre and fastened to a metal ring, by means of which it can be placed upon the ring *c*, the slit corresponding to the handle of the instrument. The lines are a Vienna inch apart; and, as well as the numbers, are coloured white.

The instrument is commonly supplied with eight concaves, Nos. 2, 3, 4, 5, 6, 8, 10, and 12; and with four convex lenses, Nos. 2, 6, 8, and 12, which fit into the hinder end of the tube *a*.

By placing the ring with the plane glasses, Fig. 23, into the front of the instrument, we obtain Helmholtz's ophthalmoscope; by substituting the concave mirror, and holding a strong convex lens, No. 2 or 3, before the eye of the patient, we obtain Ruete's; and by placing the objective tube, Fig. 24, in its position, with the necessary convex or concave glass between the diaphragms, the instrument can be used as a magnifier.

To use this ophthalmoscope, the observer places himself close to and opposite the patient, in a darkened chamber, with their eyes at the same level, and with the patient's eye under the influence of atropine. A brightly burning lamp should be placed upon a table, from four to six inches from the side of the patient's head, and sufficiently far back to leave the eye in the shade. The mirror being fixed in its slits, and the tube rotated until the trunnions are directed upwards and downwards, parallel to the handle, the oblique section of the tube is turned towards the light, and the instrument is held upright, close to the eye of the observer, in such a direction that he, looking along the axis of the tube, through the perforation of the mirror, sees the eye of the patient. With the free hand, the trunnions are then so far turned that the patient's eye becomes thoroughly illuminated by the reflection, and that the pupil coincides with the centre of the illumination. The disturbing reflections from the cornea may be displaced by giving slight obliquity to the instrument.

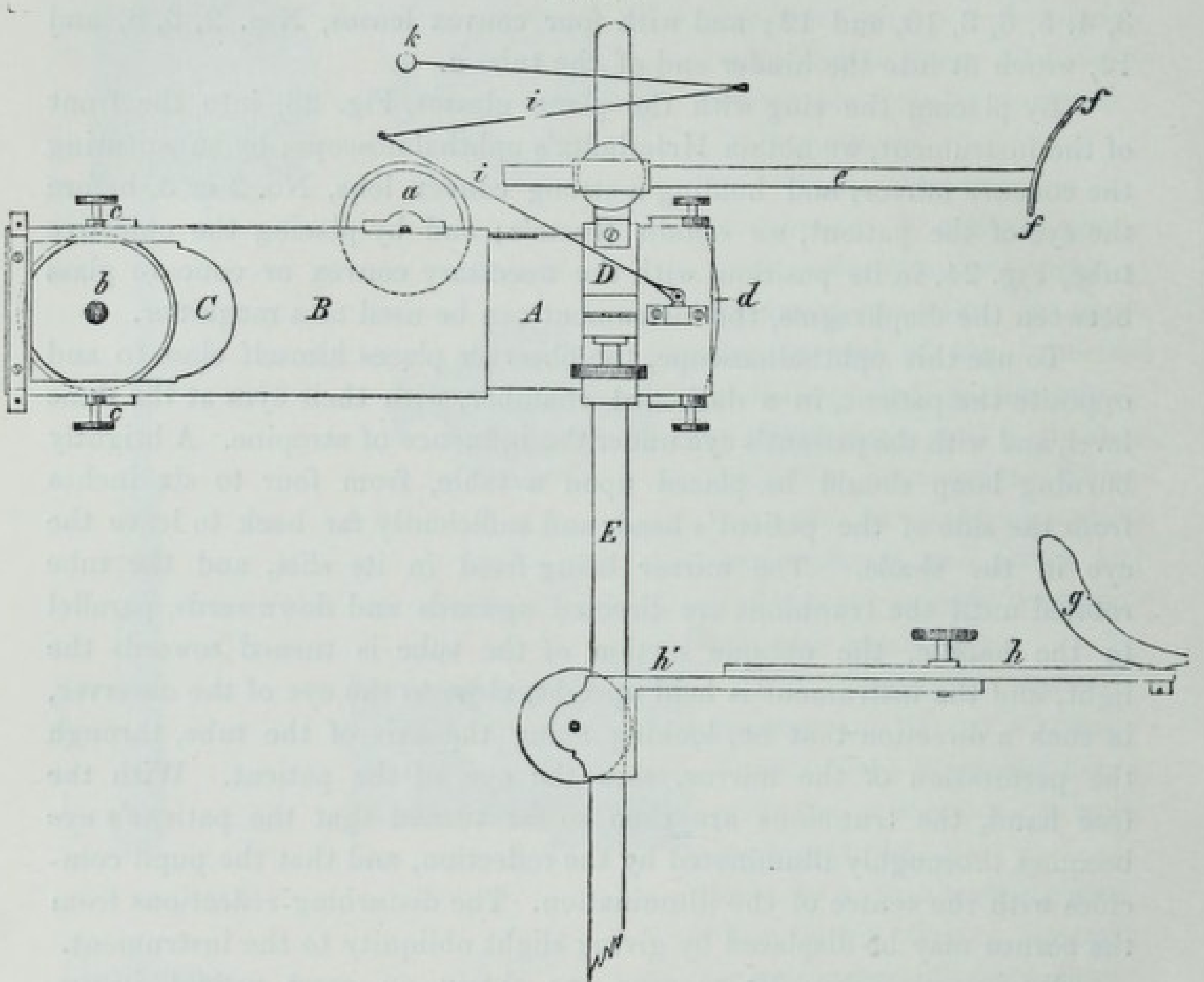
By inserting No. 10 concave, we obtain an erect retinal image, magnified about twenty-four times. By using the concave mirror of 4″ focus, and holding a convex lens of 2″, 3″, or 4″ immediately before the patient's eye, we obtain a clear, inverted image, magnified from twice to four times. For examining the transparent media it is best to use only the plane glasses, or a convex mirror of 7″ focal distance; and by placing between the diaphragms a convex glass of 12″, 8″, or 6″, we obtain any desired degree of enlargement.

To use this as Helmholtz's ophthalmoscope, the ring with plane glasses, and the necessary concave lens, must be inserted, the lamp brought forwards, and the patient shaded by the interposition of a screen, the shadow of which should just cover his eye. To shield the observer from the light, and to steady the eye observed, the disk, Fig. 25, may be slipped over the ring *c*, and the patient directed to look fixedly at some row, or some individual figure or line upon its surface.

17. THE OPHTHALMOSCOPE OF LIEBREICH

is shown in Fig. 26 one-half of its natural size. It consists of two short tubes *A, B,* moving one over the other by a rack and pinion *a*. The tube *B*,

Fig. 26.



nearest to the observer, has a piece cut out of its side at the free end, where hangs a small metallic concave mirror *b*, on trunnions, and spring clips *c c*, in such a manner that it turns readily on its vertical axis, and can be removed with facility. The other tube *A*, turned towards the patient, carries at its free end a convex lens *d*, of $1\frac{3}{4}''$ or $2''$ focal length, hung in the same way as the mirror.

The tube *A*, containing the lens, is securely united by the ring *D* to the standard *E*, which supports the whole instrument, and is provided with a clamp by which it can be screwed to a table. Above the ring *D* a quadrilateral brass stem, $4''$ long, and $3'''$ broad, is made to slide horizontally backwards and forwards, and is fixed, when desired, by a screw. At its farther extremity it carries a padded metallic arc *f f*, which receives the forehead of the patient, and holds the face at the same constant distance from the object-glass.

The fixation of the head is completed by a chin-holder independent of the tubes; but, like them, moving up and down upon the stem screwed to the table. The chin-holder terminates in a padded cup *g*, connected with the upright by two sliding bars *h h*, so that the cup can be fixed in any required position.

In order to give a determinate direction to the eye of the patient, a jointed stem *i* is attached to the end of the tube, and carries at its extremity a knob *k*. By moving this knob, and directing the patient to look at it, any necessary direction of the eye may be obtained.

A small semi-elliptical screen, fixed behind the mirror, shelters the observer; and another, somewhat larger, the patient, from the light of the lamp. The larger screen is hinged to the ring which unites the tubes to the vertical stand, so as to move in accordance with different positions of the lamp.

For more exact measurements, determinations of enlargement, and so forth, a scale of millimetres is marked upon the brow-holder, and also upon the inner tube, by which can be shown the distance of the patient's eye from the convex lens, and the distance of the lens from the mirror. The distance of the little knob from the eye, and from the axis of the tube, can be measured easily.

By means of a camera lucida the image formed in the tube can be thrown upon the surface of the table.

In use, the instrument should be screwed to the corner of a table, and the patient and observer seat themselves with this corner between them. The tube must be placed at the level of their eyes, and the lamp opposite to the gap *C* in the tube. The patient is secured as steadily as possible by the brow and chin-holders, with his eye distant from the lens about as far as its principal focus, namely $1\frac{3}{4}''$ to $2''$. This done, and the lens so arranged as to displace reflected images, the patient is directed to follow with his eyes the movements of the little knob, which may be fixed wherever necessary. The observer then commences the examination; for the conduct of which no special rules are required.

For microscopic examination Liebreich fixes the patient's head as for the ophthalmoscopic, withdraws the tubes from their containing ring, and replaces them by the body of a Schieck's microscope. The brow-holder (fixed to the ring) and the chin-holder determine the distance of the eye from the object-glass of the microscope, which can be moved forwards and backwards in a horizontal direction. For the purpose of lateral illumination by oblique rays, a convex glass of $1\frac{1}{2}''$ focal length is fixed to the ring by a jointed arm, and can be placed in any required position.

This manner of examination is especially useful in determining the seat of exudation or vessels in the cornea, in difficult diagnoses of the deeper diseases of the iris, in turbidity of the lens, of the posterior capsule, and even of the vitreous humour.

The best form of ophthalmo-microscope with which I am acquainted is one that has been described by Professor Wecker, of Paris. The body of a microscope slides in a ring attached to a tripod with adjusting feet. Two of these feet rest upon the forehead of the patient, and one upon his cheek, and they are padded to render their pressure painless. To one side of the ring is hinged a jointed rod, bearing a collecting lens to illuminate the surface of the eye. By this arrangement, the ring of the instrument being held by the surgeon, the whole moves with every movement of the patient, and the focal adjustment is not disturbed. In consequence, however, of slight movements of the globe removing the part under inspection from the field of view, Professor Wecker has found a power of 80 diameters to be the highest available. For inspection of the surface of the cornea he finds a power of 40, and for the crystalline lens or its capsule a power of 60 diameters to be the most generally useful. The instrument is figured in Wecker's "Études Ophthalmologiques," vol. i. p. 272, and would be made from the drawing by any optician.

For the purpose of very fine measurements Dr. Liebreich has lately added to his instrument a micrometer, contrived in the following manner:—

A circular plate of glass, fitted exactly to the inner tube, is graduated horizontally and vertically in millimetres; and, to facilitate reading, every fifth line is made somewhat broader and longer than the others. This plate is fixed to a short stem that passes through a slit in the tube, and can be moved backwards and forwards, or turned upon its vertical axis. This turning, which is necessary in order to displace reflected images, is still possible, when, by means of a screw on the stem, the plate is fixed at the required distance from the object.

If measurements be required in some other direction than the vertical or horizontal, the whole tube of the instrument may be rotated on its horizontal axis in the ring that supports it.

To accomplish photography of the fundus oculi, Liebreich employs a metallic concave mirror of short focus (also a Coccius's or Zehender's mirror), with a central perforation of about 5‴ in diameter. The mirror is so fastened to the objective end of a camera obscura that it may be moved to and fro, and may turn on its vertical axis. The camera is then arranged as for photography, and the operator allows a side light, either direct or condensed by a lens, to fall upon the mirror in such a manner that it is reflected through the dilated pupil of the eye of the patient so as to illuminate the fundus. The returning rays, rendered convergent by the refracting media, pass through the hole in the mirror to the object-lens behind it, and form beyond this an inverted image of the fundus. This image is received upon the plate of ground-glass at the back of the camera; and when, by movement of the objective, the best possible position is obtained, the ground glass is exchanged for a prepared plate in the ordinary way, and the image is fixed.

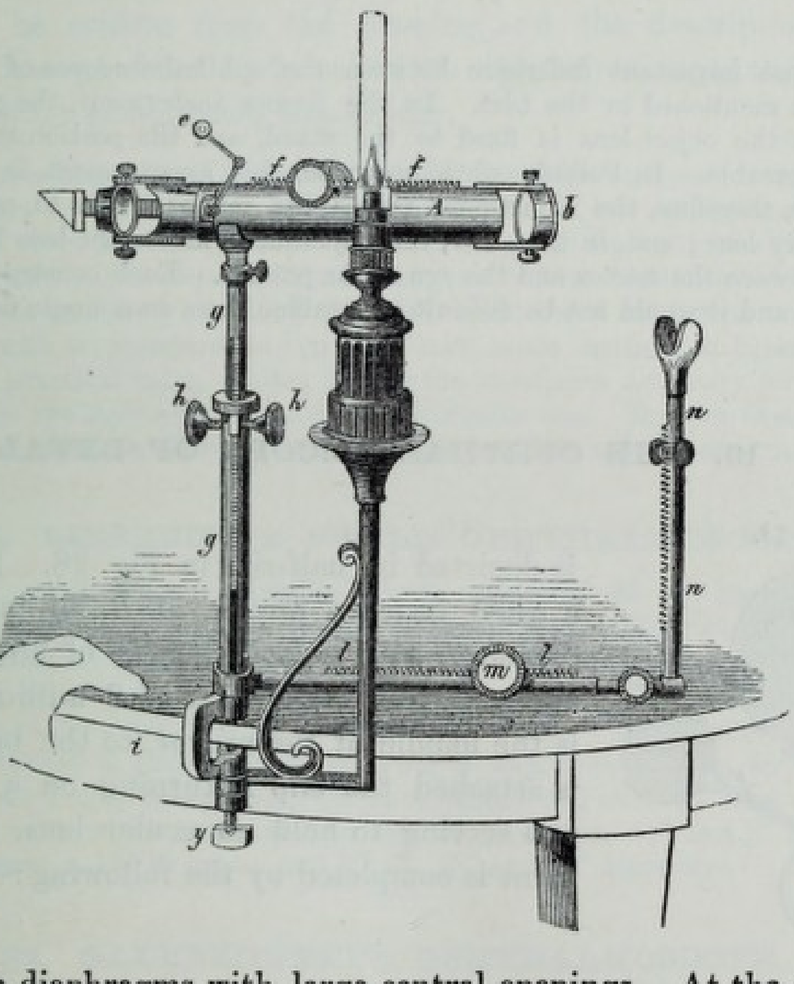
This apparatus is especially useful for demonstrations of the inverted image, for exact measurements, and for drawings.

18. THE OPHTHALMOSCOPE OF FOLLIN.

A new instrument contrived by Follin, for praising which the French can hardly find words enough, is, in essentials, nothing more than Liebreich's ophthalmoscope, with some small modifications that are shown in Fig. 27.

The body of the apparatus consists of two brass tubes *A* sliding one over the other by the rack *f f*. These tubes are blackened within,

Fig. 27.



and contain diaphragms with large central openings. At the extremity *b* there is placed a biconvex lens, fixed in a brass setting, and moveable on its vertical axis by means of a milled head underneath. At the other end *g* there is a glass concave mirror, covered everywhere but at the centre, and likewise moveable on its vertical axis. The entire body *A* is made to turn upon the stand *g g*, and can be raised and lowered by the rack-movement *h h*. By the screw *y* the stand is secured to a table.

From the lower part of the vertical stand there proceeds the horizontal arm *l l*, supporting the second upright *n n*, which carries a small socket, covered with leather, as a chin-holder. By means of the screw *m* on the horizontal bar, the patient can be drawn towards, or removed from, the object-lens, and a similar arrangement on the upright *n* provides for raising and lowering the head.

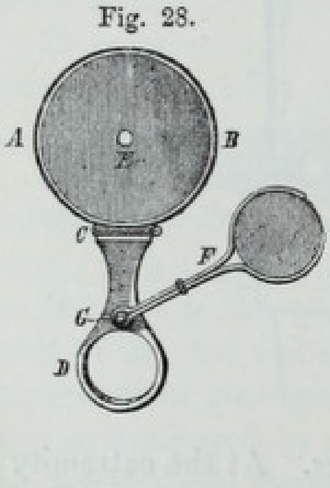
Behind the mirror is attached a ring to carry any necessary convex or concave ocular lens; and on the side turned towards the flame there is a small semicircular plate of metal to screen the observer from the light. The body of the apparatus is provided with a slender jointed stem, surmounted by the knob *e* to serve as an object to steady the eye of the patient.

By means of a prism adapted to the back of the mirror, the image that is formed can be reflected upon the surface of the table.

The most important difference between the ophthalmoscopes of Liebreich and Follin is not mentioned in the text. In the former instrument, the portion of tube that carries the object-lens is fixed to the stand, and the portion that carries the mirror is moveable. In Follin's ophthalmoscope, this arrangement is reversed. In the one case, therefore, the adjustment moves the mirror nearer to, or further from, the stationary lens; and, in the other, the adjustment moves the lens backwards and forwards between the mirror and the eye of the patient. Each construction has some advantages, and it would not be difficult to combine them in a single instrument.

19. THE OPHTHALMOSCOPE OF DEVAL

Fig. 28.

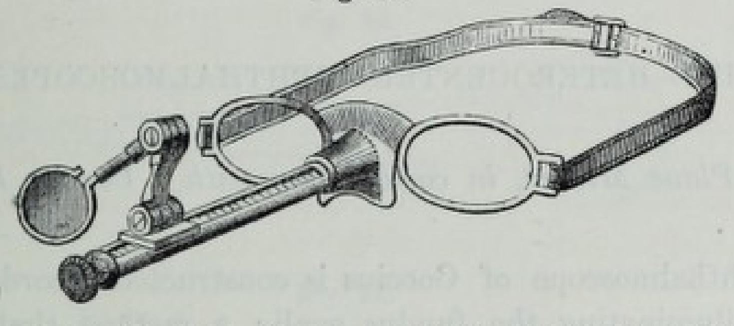


is depicted in half-size in Fig. 28. It consists of a glass concave mirror *A B* 35 millimetres in diameter, with a focal length of 25 centimetres, and a central perforation of 3 millimetres. *C D* is the handle of the mirror, to the back of which is attached the clip *F* turning on a pivot at *G*, and serving to hold an ocular lens. The instru ment is completed by the following:—

20. THE OPHTHALMOSCOPE OF ANATOLE DE GRANDMONT,

drawn in Fig. 29, and formed of a small concave plate of metal, shaped to fit upon the root of the nose. Above this is a second plate, flat, and made to bear upon the forehead. From this central portion there projects on either side an elliptical ring, intended to rest upon the margin of the orbit, and thus to secure the steadiness of the apparatus. From the

Fig. 29.



middle of the central plate there projects forwards a brass nozzle or proboscis, containing an endless screw, which supports the holder of a lens, of 2″ or $2\frac{1}{2}$″ focal length, moveable in all directions. By two elastic bands, united by a buckle, the machine can be secured to the head of a patient.

It will be evident from the drawing and the description that this instrument has no claim to be called an ophthalmoscope, and that it is only a somewhat complicated lens-holder.

In the preceding pages Dr. Zander has by no means exhausted the varieties of the homocentric ophthalmoscope, although the forms he has omitted are but slightly different from those he has described. Some English mechanicians have attached the single concave mirror to a spectacle-frame, or to an elastic head-band, so as to leave the hands at liberty; and others have constructed an instrument much like Cusco's, but with its standard and sliding bars made entirely of brass. This last form is of no practical value, neither having the steadiness necessary for a stationary apparatus, nor the lightness desirable in a portable one. Besides these, and some others of no importance, there are yet two varieties that require especial mention:—

21. LIEBREICH'S SMALL OPHTHALMOSCOPE

consists of a small concave metallic mirror, protected at the back by a bronze covering, and screwed to a simple handle 12 centimetres in length. The mirror has a central perforation $2\frac{1}{2}$ millimetres in diameter, with a sharp edge; and the larger perforation of the bronze setting is sloped down to it. The reflecting surface is 3 centimetres in diameter, and has a focal length of 8″. To the edge of the bronze setting is attached a jointed limb carrying a small spring clip for holding any ocular lens that it may be necessary to place behind the mirror. The whole is sold in a portable case, which contains also two object-lenses, $1\frac{1}{2}$″ and 2″ biconvex, and five ocular lenses, a 12″ biconvex, and 6″, 8″, 10″ and 12″ biconcave.

22. GALENZOWSKI'S OPHTHALMOSCOPE,

which was only introduced in 1862, presents the tubular arrangement in its most compact and convenient form. It bears a general resemblance to Hasner's, but with the following differences:—The end of the tube that carries the object-lens is prolonged beyond it, and sloped to fit the orbital ridge of the patient, so as absolutely to exclude side light. The lens itself has a movement backwards and forwards, and can also be turned on its vertical axis. The tube that contains the mirror draws in and out by two or three slides like those of a telescope, so as to combine great range of movement with comparative lightness and portability.

III.—HETEROCENTRIC OPHTHALMOSCOPES.

(a) *Plane Mirror, in combination with a Convex Lens.*

The ophthalmoscope of Coccius is constructed according to a third method of illuminating the fundus oculi; a method that requires the use of a small perforated plane mirror and a convex lens. The action of this mirror depends upon Brücke's principle (page 13); and therefore, if the mirror-image of the flame exactly represented a light placed near the eye of the observer, the eye of the patient, when accommodated for this image, would, as objected by Helmholtz, have its retina rendered only faintly luminous. It would be impossible, under such an arrangement, to see the characters (*e. g.* of the yellow spot), when the eye was accommodated for the luminous object. These characters, however, are perfectly well exhibited by the mirror of Coccius, on the following grounds:—It does not afford a mirror image of the flame that corresponds with an actual flame in the position of the reflecting surface; but with a flame placed as much behind the mirror as the actual source of light is in front of it. The rays reflected from the retina, in accommodation of the eye for the mirror-image, would therefore first unite behind the mirror; and a portion of this cone of rays will pass through the central perforation, and be continued towards the observer, by whom the retinal image of the flame will be perceived when his eye is placed in the line of direction of the rays. But again, if the eye observed be accommodated for the perforation itself, it will appear dark to the observer, and the image of the perforation will fall in the line of direct vision. The rays coming from the mirror-image of the flame (the perforation being seemingly nearer to the eye than this image) will be brought to union in front of the retina, and will, therefore, form upon it a dispersion circle, in which the image of the dark opening will fall. The principle upon which we see the observed eye luminous when it is accommodated for the mirror-image of the flame, and dark when it is accommodated for the opening in the mirror, is the same that is illustrated by the experiment of Scheiner.

In Fig. 30, let *B*, the observed eye, be accommodated for the mirror-image of the flame *a*;—so will there be formed at *a'* a clear picture of *a* upon *B*'s retina; while the rays coming from *b*, the opening of the mirror, which is within the point of *B*'s accommodation, would be first united behind the retina at *b'*, and therefore form upon the retina a dispersion circle, in which the image of the flame *a* shines brightly. In Fig. 31, on the contrary, the eye *B* is accommodated for the opening *b*, which

Fig. 30.

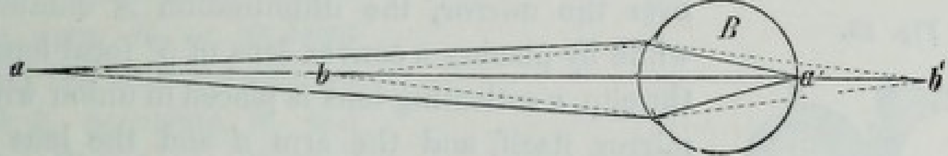
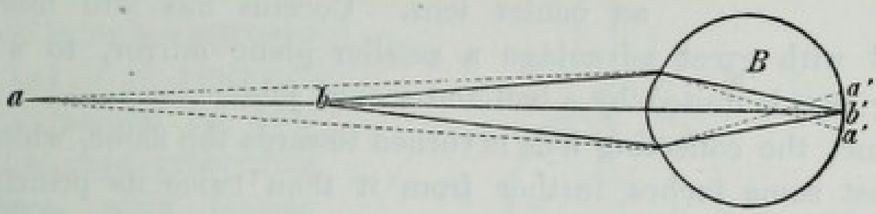


Fig. 31.

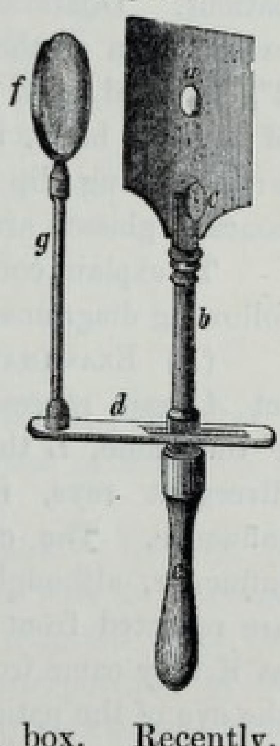


therefore forms its image at *b'*; while the rays of the image of the flame, already united in front of *B*'s retina, form upon it only the dispersion circle *a' a'*.

23. THE OPHTHALMOSCOPE OF COCCIUS

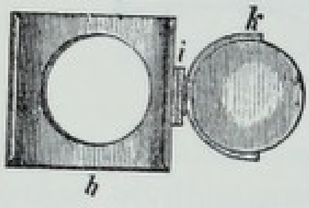
is shown in Fig. 32 in half-size. It consists of a small square plane mirror *a*, 14 Paris lines in diameter, and perforated in the centre. The opening is two Paris lines in diameter, and its front margin is somewhat bevelled. The mirror is fixed in a thin plate of brass, having on its lower border a projection, which, by means of a screw *c*, is fastened to the stem *b*. This stem is 1½ Paris lines in thickness, and, including the portion that holds the mirror, 21''' in length. At its lower end it carries the cross-piece *d*, which can be secured by a screw to the upper extremity of the handle *e*. The cross-piece is 18 Paris lines long, with a slit extending half its length, by which, after loosening the screw connecting it to the handle, the convex lens it carries can be moved nearer to, or farther from, the mirror. This convex lens, of 5'' focal length, rests in a spring clip *f* upon the stand *g*, so that the centre of the lens is opposite the opening of the mirror. All the metallic parts of the instrument are coloured black by caustic potash, and when taken to pieces the whole can be carried in a small box. Recently, Coccius's ophthalmoscope has been made after the manner shown in Fig. 33.

Fig. 32.



This exhibits a thin, blackened plate of brass *h*, pierced with an opening 4‴ in diameter, and by means of its grooved margin made to slide upon the edge of the mirror. The outer side is connected by the double hinge *i* to a spring clip *k* for the reception of a lens. By sliding this apparatus over the mirror, the illumination is diminished; while by placing a convex lens of 5″ focal length in the clip, a collecting lens is placed in union with the mirror itself, and the arm *d* and the lens *f* are rendered unnecessary. The ring *k* can also be turned behind the mirror, and employed to hold an ocular lens. Coccius has still more lately employed with great advantage a smaller plane mirror, to which the collecting lens is united by a ball-and-socket joint.

Fig. 33.

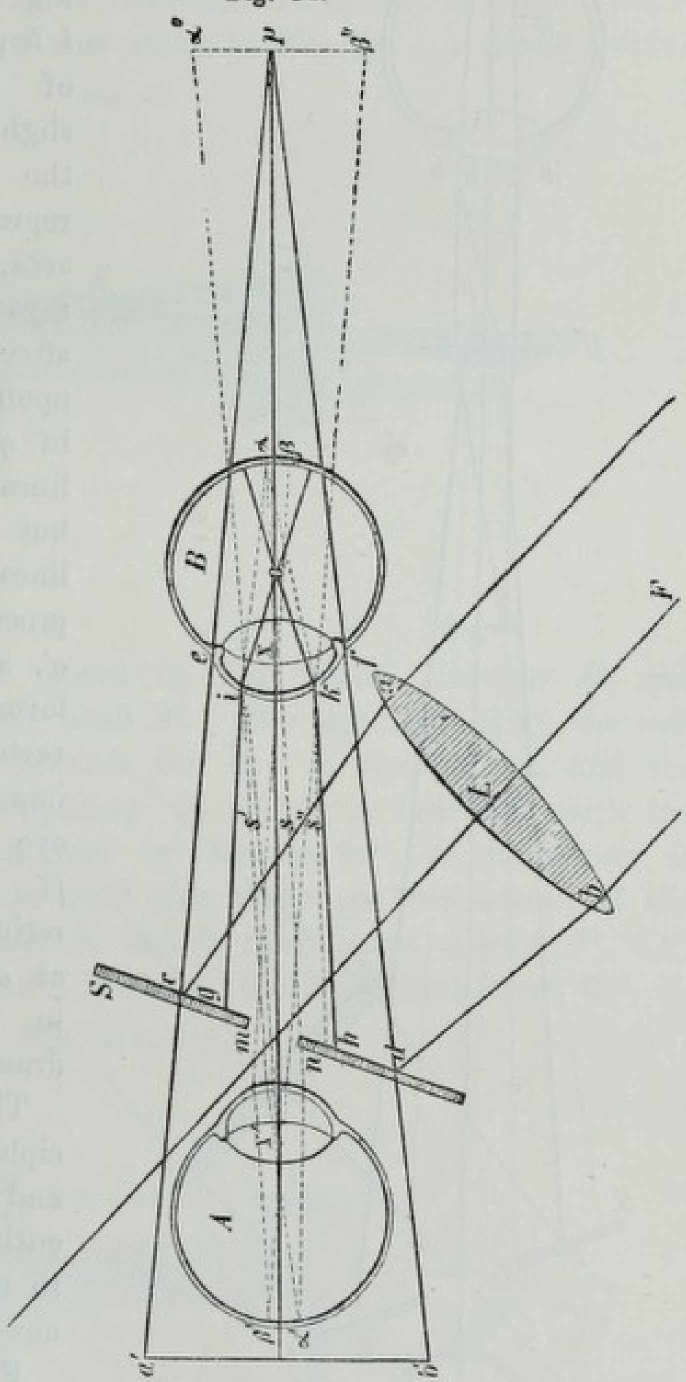


In use, the collecting lens is turned towards the flame, which should be at least some inches further from it than twice its principal focal length, and on the same level as the eye to be examined. By loosening the screw, the mirror is set obliquely to the lens and to the eye of the patient; and, when it is rightly directed, we see, by casting the enlarged image of the flame upon the patient's cheek, a luminous circle with a dark central spot, corresponding to the hole in the mirror. The patient must now look fixedly at an object behind the observer, and on the side opposite to that of the eye under examination, and the dark spot must then be thrown upon the centre of the pupil, while the observer, with his eye as close as possible behind the mirror, looks into the eye of the patient. Dilatation of the pupil by atropine is not necessary. For examination of the inverted image, a convex lens of 2½″ or less, often of 2″, is used, and is held, either between the thumb and forefinger of the free hand, in front of the eye examined, or upon a handle 6″ long with a spring clip at the top; while, in examination of the short-sighted, concave glasses are used—such as Nos. 12, 8, 6, 4, 3, or 2.

To explain completely the action of this and other plane mirrors, the following diagrams will be useful:—

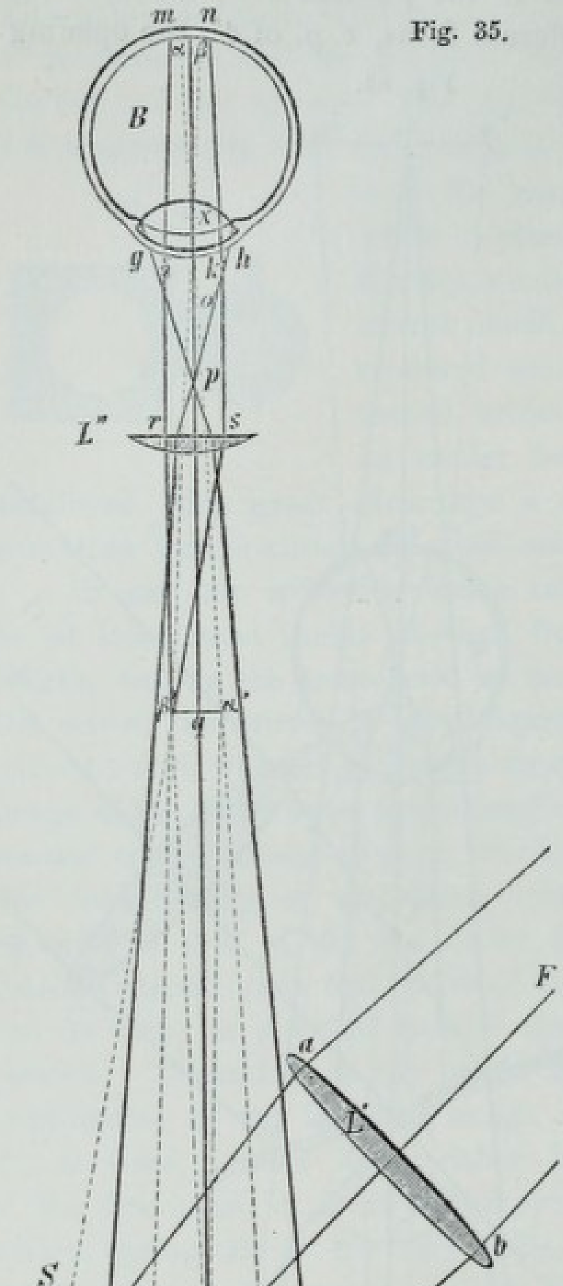
(A) Examination of the virtual erect Image.—In Fig. 34, let *A* again represent the eye of the observer, and *B* the eye observed; *F* the flame, *L* the lens, and *S* the mirror. From *F*, a cone *a b*, of divergent rays, falls upon *L*, and is rendered convergent by its influence. The convergent rays then strike the mirror *S*, and by its influence, although unchanged in their relative positions to each other, are reflected from its surface in a new direction, and proceed towards *p*, as if they came from a flame situate behind the mirror at *a′ b′*. But, as the eye of the patient, *B*, meets the rays before their union, they fall upon *B*, without regard to accidental loss, in the line of section *e f*. It will appear from the drawing that this combination of a plane mirror with a convex lens, acts like a concave mirror in the position *a′ b′*, but with the advantage, that by using a lens of different focus, *e. g.* of 4″, the opening and focus of the apparatus can be varied at pleasure. The rays of the cone of light falling upon *B*, or at least the rays included between *g i* and *h k*, penetrate it, and by its dioptric media are united in front of the retina, say at *o*, and proceed, over-crossed, to form a dispersion circle. Let *α β* represent any two points in this circle—the rays proceeding from them, after leaving the eye, will follow the course of the lines *α x*, *β x*; and, if the eye *B* be accommodated for infinite distance, the whole of the emerging rays from each point will continue parallel to the axial rays *s′ s s″*. The rays proceeding from *α*, and passing through *m n*, the opening in the mirror, will be received by *A*, the eye of the observer, and united at the point *α′* of its retina; and those proceeding from *β* will be united at *β′*; so as to form together, upon *A*'s retina, an erect and magnified image *α′ β′* of *α β*. Indeed, the action upon *A*'s retina will be as if the light came through the crossing-point of the lines of direction *x*, and therefore from a surface *α″ β″* behind the eye *B*.

Fig. 34.



(B) Examination of the actual inverted Image.—In Fig. 35 the light proceeding from *F* and passing through the lens *L′* impinges upon the mirror *S* between the points *c d*, and, reflected from this surface, would find its focus at *o*. But, by the interposition of the lens *L″*, it is brought to an earlier focus at *p*, from whence, over-crossed and again divergent, the rays proceed to illuminate the eye

Fig. 35.

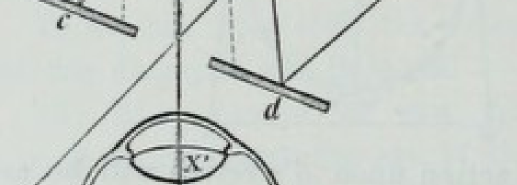


B on the surface *g h*. Through the portion of this corresponding to the pupillary area, rays *i k* pass into the dioptric media of *B*; and, thus rendered slightly convergent, fall upon the retinal area *m n*. Let α β represent two points in this area, and it will follow that rays returning from α β, and, after their exit from *B* falling upon the lens *L''*, will be united in *q*, its principal focus, if the lines *i r* and *k s* be parallel, but nearer to the lens if these lines be convergent. The rays proceeding from α will unite in α', and those from β in β', thus forming in α' β' an actual inverted image of α β. This image being observed by the eye *A*, the rays proceeding from β' will be united upon its retina at β'', and those from α' at α'', because these points are in the prolongations of lines drawn through α' *X'* and β' *X'*.

The simplicity of these principles, and the great range and variety of their applications, entitle the instrument of Coccius to the first place among ophthalmoscopes.

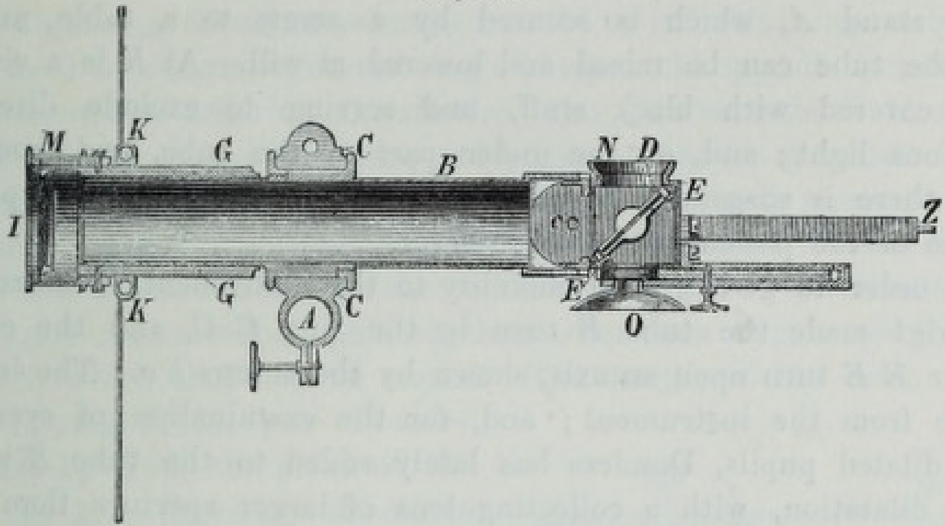
Fig. 36 exhibits in half-size an ophthalmo-microscope contrived by Coccius. It consists of a small microscope *A*, and of a plane mirror and lens *B*, suspended from the arms *c c* by the screw *d*, and sliding on to the body of the microscope by the ring *e*. The mirror will turn on the screws to any necessary inclination.

Fig. 36.



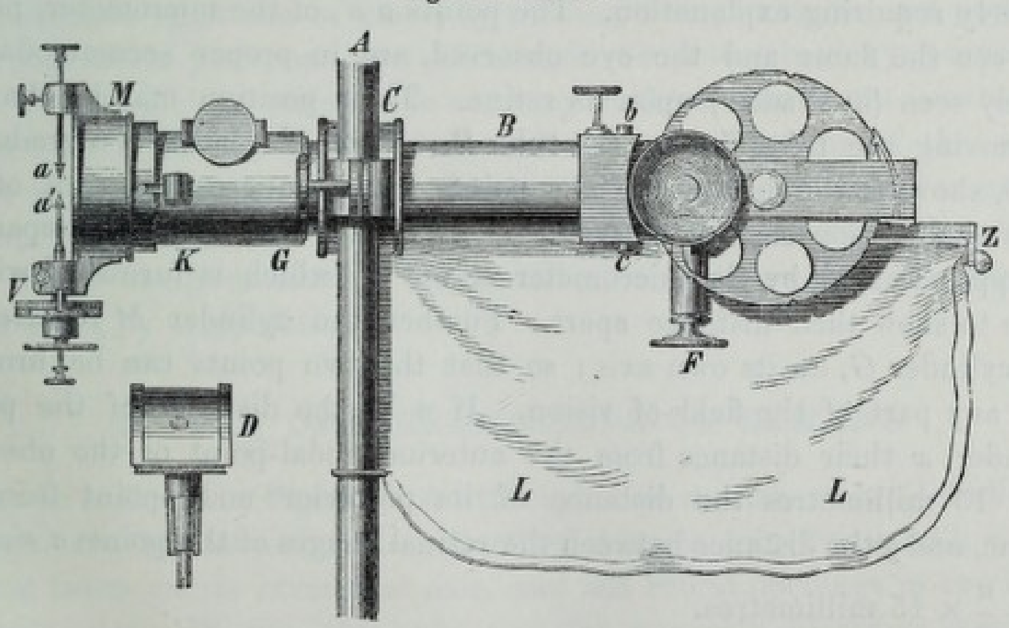
24. THE OPHTHALMOSCOPE OF EPKENS AND DONDERS is shown from above in section of half-size in Fig. 37, in a side view in half-size in Fig. 38, and its mirror alone in Fig. 39. A plane mirror,

Fig. 37.



perforated in the centre, is placed in the cubical chamber *E*, and turns by means of the milled head *F*. The opening *N*, in the side of the chamber, is turned towards the eye of the patient, and the observer looks through the opening *O*, which is furnished with the revolving disk of lenses, contrived by Rekoss for the instrument of Helmholtz. Donders places in this disk three positive lenses, of the respective focal lengths of 20, 3, and 4 centimetres (about 8″, $1\frac{1}{5}''$, and $1\frac{3}{5}''$), and three negative, of 16, 10, and 6 centimetres (about $6\frac{2}{5}''$, 4″,

Figs. 38 and 39.



and $2\frac{2}{5}''$). Epkens has united to the cubical chamber the cylindrical tube *B*, at the further end of which, where the micrometer *M* is attached, the lamp is placed. At this end of the tube, when necessary, a positive lens *I* can be inserted, the focus of which should be a short distance from the flame; so that a person looking into the mirror sees the whole lens illuminated, by which means a larger surface of the retina is lighted up. The whole apparatus is placed upon a stand *A*, which is secured by a screw to a table, and on which the tube can be raised and lowered at will. At *K* is a circular screen, covered with black stuff, and serving to exclude direct or superfluous light; and, on the under part of the tube, and from the bar *Z*, there is suspended a curtain of oiled silk *L L*, that separates the faces of the patient and the observer.

In order to give greater mobility to the instrument, Donders and Van Trigt made the tube *B* turn in the ring *C C*, and the cubical chamber *E E* turn upon an axis, shown by the screws *b c*. The lamp is separate from the instrument; and, for the examination of eyes with widely dilated pupils, Donders has lately added to the tube *B* a cup-shaped dilatation, with a collecting lens of larger aperture than *I*, in order to illuminate a larger portion of the fundus oculi.

The disadvantages of this instrument are that, from the number and complexity of its parts, its consequent costliness, its somewhat alarming size and appearance, and its want of portability, it is little suited to the wants of the practical surgeon. It is eminently fit for physiological research, and, for this purpose, especially as it admits of measuring the parts it exhibits, it cannot be too highly extolled.

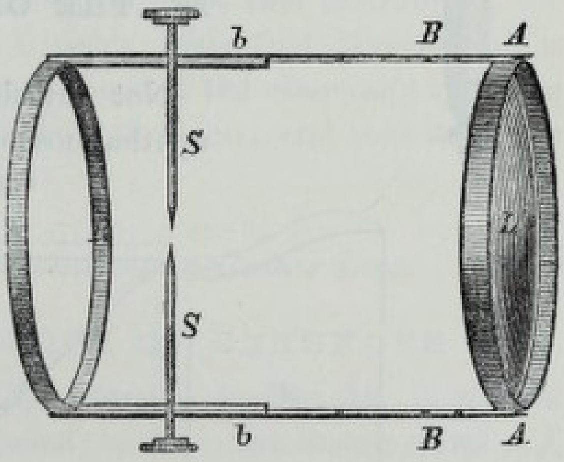
For the purpose of taking measurements, the instrument is furnished with a micrometer *M*, attached to the outer end of the cylinder *G*, and scarcely requiring explanation. The points a a', of the micrometer, placed between the flame and the eye observed, are, in proper accommodation, clearly seen (in shadow) upon its retina. Their position may be changed by moving the tube *G* upon the tube *B*. Upon the latter is a graduated scale, showing the distance of the points from the crossing-point of the lines of direction of the observed eye. The points a a', can be separated or approximated by the micrometer screw *V*, which is furnished with a scale to show their distance apart. Further, the cylinder *M* revolves on the cylinder *G*, on its own axis; so that the two points can be brought into any part of the field of vision. If n be the distance of the points asunder, x their distance from the anterior nodal-point of the observed eye, 15 millimetres the distance of its posterior nodal-point from its retina, and y the distance between the retinal images of the points a a', then

$$y = \frac{n}{x} \times 15 \text{ millimetres.}$$

By placing at the opening *O* a tracing apparatus, such as is used for a microscope, and marking the distance of the points across the vessels of the retina, it is possible to determine the exact size of these vessels, and of other structures of the fundus oculi.

In Fig. 40 is exhibited the micrometer of Schneller, which is applicable to all ophthalmoscopes, and is used to measure the inverted image. The lens *L*, which determines the distance of the inverted image from the retina (in change of accommodation from 5″ to 12″, this image only moves 4‴) is fixed in a narrow grooved ring of brass. At opposite points in the circumference of this ring are attached two slender rods, *B B*, at right angles with the plane of the lens, and becoming thicker at a little distance from it. Their thicker portions are pierced by female screws, carrying the male screws *S S*. These screws are exactly parallel to that diameter of the lens which would unite the points of attachment of the arms *B B*. Their inner ends are finely pointed, their outer ends surmounted by milled heads, by which they may be turned. The length of the arms *B B* is about $1\frac{3}{4}''$, and the first pair of screw-holes are $1\frac{1}{8}''$ from the plane of the lens. To give necessary steadiness to the whole, the other ends of the arms *B B* are fixed to the ring *R*, which resembles the one carrying the lens. The screws are of steel, and the rest of the apparatus is of brass. The points of the screws serve to measure the image (they might perhaps be replaced by a plate of polished glass, ruled with parallel lines), as their distance apart can be made, by turning them, to correspond perfectly with any of its parts, and can afterwards be determined by comparison with a finely divided scale. The accuracy of the measurement is enhanced when it is in the first place taken, and when the distance of the points apart is afterwards determined, by the aid of a magnifier. For greater accuracy, the apparatus may be fixed upon a firm stand; and the size of the image being measured, the actual size of the structures must be determined by computation.

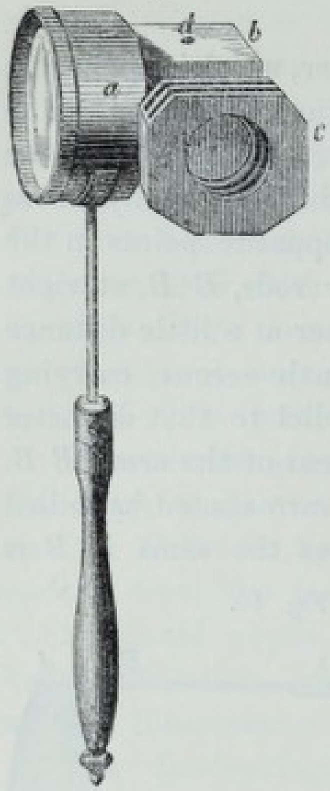
Fig. 40.



25. THE OPHTHALMOSCOPE OF SÄMANN

is shown half-size in Fig. 41. A little cylinder *a*, that, as in Helmholtz's instruments, carries a convex (collecting) lens, is joined to a hollow cube *b*, that turns on its horizontal axis, and has round openings in two of its opposite sides. Within, this cube contains a mirror, placed on a vertical axis *d*. This mirror consists of a plate of silvered glass, the foil being removed from a small elliptical portion in the centre. In front of one of

Fig. 41.



the openings of the cube is a little frame *c*, open above, in which necessary lenses can be placed, and from which they may be readily removed.

Like Burow, Sämann has found the revolving Rekoss's disks, to carry lenses, very convenient to handle. But a combination of two concaves, on account of the stratum of air between them, does not give a perfectly exact image; and, if twelve concaves were inserted in a single disk, this would be too large, especially as it would be required to carry convex lenses also. Burow has, therefore, fixed his lenses in a straight slide, which, when their use is required, can be moved up and down in the frame *c*.

26. THE OPHTHALMOSCOPE OF MEYERSTEIN.

Not satisfied with the working of his first ophthalmoscope, which will be described hereafter

Fig. 42.

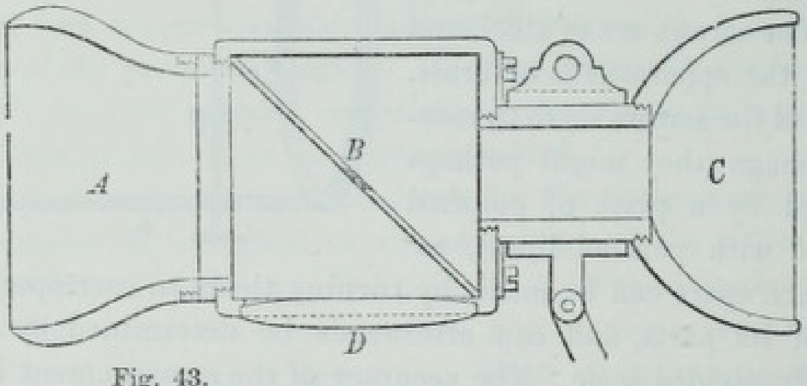
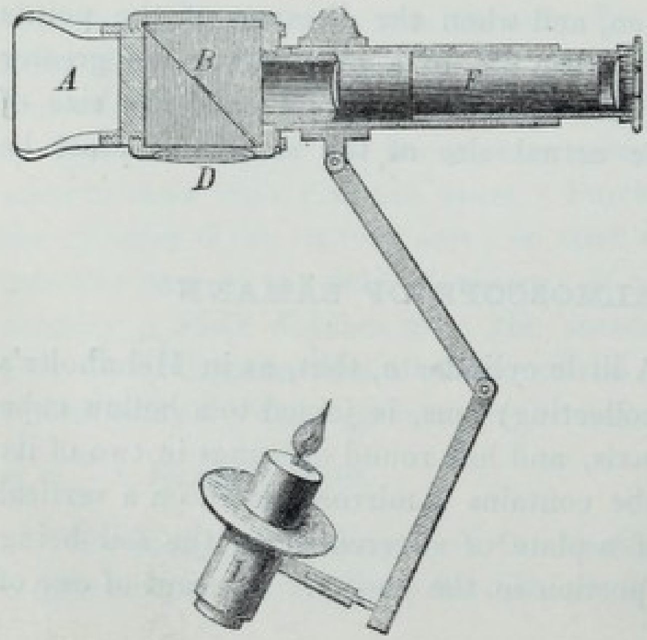


Fig. 43.



(see Fig. 51), Meyerstein constructed a second instrument, that is shown of natural size in Fig. 42, and of half-size in Fig. 43. It consists of a cup *A*, which serves to screen the patient's eye from light, so that this ophthalmoscope can be used in any room in the daytime. Immediately in front of the cup is a perforated plane mirror, inclosed in a rectangular box *B*, and fixed at an angle of 45° with the axis of the instrument. The side of the box opposite to the reflecting surface of the mirror contains a collecting lens *D*. On the opposite side of the box to the cup *A* is a second cup *C*, which receives the eye of the observer, and cuts off "false light," or the light of the lamp.

For more exact examination of the retina, the cup *C* may be unscrewed, and its place supplied by the small telescope *F*, Fig. 43. In a normal or emmetropic eye, parallel incident rays are brought to a focus upon the retina. If light be thrown into such an eye, the rays become parallel upon their exit from it; and the telescope must be adjusted as if for the inspection of an object in infinite distance, while for far or near sight the ocular must be more or less pushed in or withdrawn. For examination of the cornea, iris, or lens, the ocular tube must be drawn farther out, and the telescope used only as a magnifier. The way in which a light may be united with the instrument will be seen readily from the figures.

In comparing the merits and disadvantages of this instrument, the same may be said as in the case of Ulrich's; only that Meyerstein's is more difficult to handle; that the great distance of the observer's eye from the mirror considerably diminishes the field of vision; and that its power of illumination is altogether insufficient.

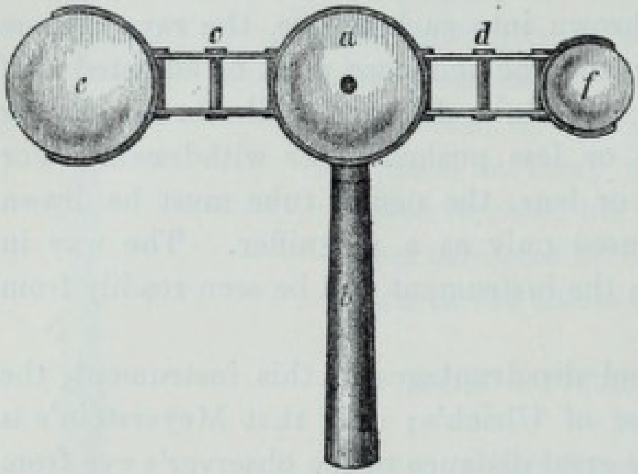
(*b*) *Convex Mirror in combination with a Convex Lens.*

27. THE OPHTHALMOSCOPE OF ZEHENDER

is shown in Fig. 44, in half-size. By referring to Fig. 34, it will be manifest that all the rays of light included between the lines *c e* and *d f*, could be made to pass through the space *i k* into the pupil of the eye *B*, if the mirror were so arranged, and held at such a distance, that a section of the cone of light, when it reached the eye, should not exceed *i k* in diameter. But then, on the one hand (from premature union and over-crossing of the rays), the dispersion circle on *B*'s retina would be too large, and the image, therefore, too dim; and on the other hand, the observer would be placed at too great a distance. If an endeavour be made to diminish the light cone *c d e f* to the size *i k*, by removing the collecting lens farther from the mirror, a sufficient quantity of light will not be obtained, and the lamp will also be required at a greater distance. Zehender met this difficulty by a means at once happy and sagacious. He used a stronger collecting lens, of 3″ focal length, distant from $\frac{3}{4}''$ to $\frac{1}{2}''$ from the mirror, and capable of being placed at any desired inclination; and he substituted a slightly convex metallic mirror for the plane mirror of glass. It followed that the strongly convergent rays falling upon the mirror were reflected from it slightly less convergent, that the whole of the light could be thrown through the narrow opening *i k*, and yet not united until it approached the retina. He thus collected the same quantity of light into a narrower section; and, on an equal base, made the light cone smaller, but neither shorter nor less luminous.

The ophthalmoscope of Zehender must therefore be considered a modification of that of Coccius, to which it bears a great external resemblance. It is shown in Fig. 44 as a small convex mirror *a*, placed on a short handle, and furnished with two lateral moveable arms *c* and *d*, one of which carries the collecting lens, and the other a spring clip for any ocular lens that may be needed.

Fig. 44.

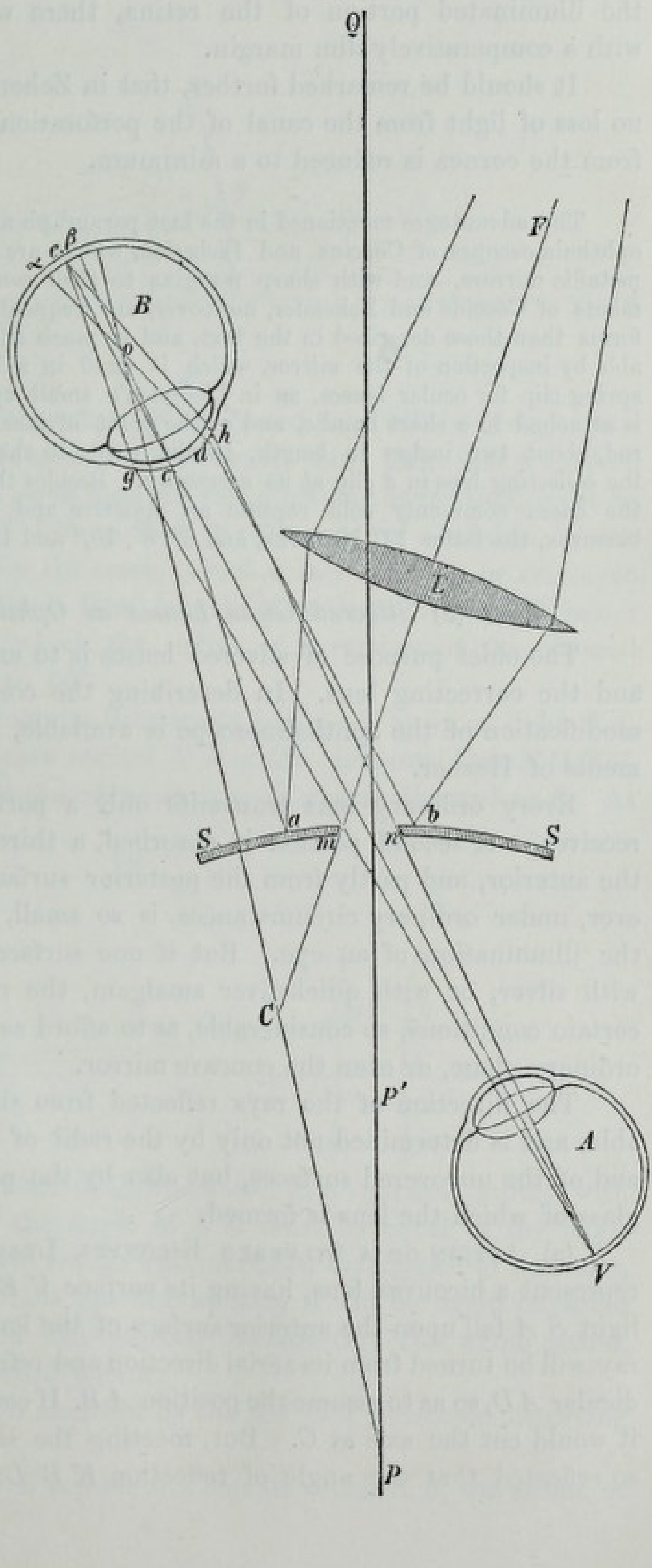


The handle is moveable, and can be screwed into the margin of the mirror at two opposite points, so as to turn the collecting lens to the right or the left at pleasure. The handle, acting as a lever, is apt to increase the very slight movements of the collecting lens that are often needed; and hence Arlt has dispensed with the handle entirely, and, perhaps with some advantage, holds the instrument by the joint *c*, on the arm that carries the collecting lens. By this the size of the case is conveniently diminished; and the instrument, with its six necessary lenses, is rendered extremely portable.

The mirror consists of a circular, highly-polished plate of metal, having a curvature of 6″ radius. It is pierced in the centre by an opening, funnel-shaped from behind forwards, with a sharp edge, and with a diameter on the reflecting surface of 1½‴. The focal length of the collecting lens may be from 1″, or 1½″, to 2″ or even 3″. If a concave or convex ocular lens be required in the examination, it may be placed in the second arm, which is furnished with a spring clip and two joints, so that it may be turned behind the opening of the mirror, and so close to it as to be almost in the same plane.

The optical principles on which this ophthalmoscope depends, are briefly as follows. Convergent rays of light, falling upon a convex mirror, are reflected parallel to the axis of the mirror, if their degree of convergence be such that they would unite, if prolonged, at the extremity of its radius of curvature, in the so-called imaginary focus of the mirror itself. But, if they would intersect, or unite in, the axis of the mirror, between it and its imaginary focus, they are reflected convergent; if beyond its imaginary focus, divergent: and consequently their convergence or divergence increases, the farther their point of intersection of the axis of the mirror is distant from the fixed extremity of its radius of curvature. In Fig. 45, let F be the flame, L the lens, S the mirror, having the axis $P\ Q$, and the imaginary focus P'; A the eye of the observer, B the eye of the patient. If now the collecting lens L be at such a distance from the mirror that the rays transmitted by it have a convergence that would unite them at C, in front of P', these rays will be reflected convergent from the mirror, and will strike the eye B within the limits $c\ d$. They will then, by the dioptric apparatus of B, be brought to a focus in front of the retina, at o, and will overcross and illuminate the fundus in a circle of dispersion. From a single point, for example e, in the illuminated part $a\,\beta$, a cone of rays $g\ e\ h$ will return towards the mirror, and a portion of this cone will pass through the opening $m\ n$, and enter the eye A; by which the point e will be seen clearly defined and brilliantly illuminated, if the cone $g\ e\ h$ be made to unite upon A's retina at V, either by the refracting power of A itself, or by the interposition of any lens that may be needed.

Fig. 45.



The strong curvature

of the collecting lens is sufficient to produce considerable spherical aberration, so that the image of the flame reflected from the mirror will not be formed in a single plane, but in several, on which account, in the illuminated portion of the retina, there will be a bright nucleus with a comparatively dim margin.

It should be remarked further, that in Zehender's instrument there is no loss of light from the canal of the perforation; and also that reflection from the cornea is reduced to a minimum.

The advantages mentioned in the last paragraph are obtained equally from the ophthalmoscopes of Coccius and Liebreich, which are now universally made with metallic mirrors, and with sharp margins to their central apertures. The instruments of Coccius and Zehender, moreover, are frequently seen in more convenient forms than those described in the text, and so much alike as to be only distinguishable by inspection of the mirror, which is fixed in a bronze setting, with a small spring clip for ocular lenses, as in Liebreich's small ophthalmoscope. The setting is attached to a short handle, and at the point of junction there is a double-jointed rod, about two inches in length, turning either to the right or left, and carrying the collecting lens in a clip at its extremity. Besides the mirror and collecting lens, the cases commonly sold contain an objective and five oculars; the former $1\frac{1}{2}''$ biconvex, the latter 12″ biconvex, and 6″, 8″, 10,″ and 12″ biconcave.

(c) *Silvered Glass Lenses as Ophthalmoscopes.*

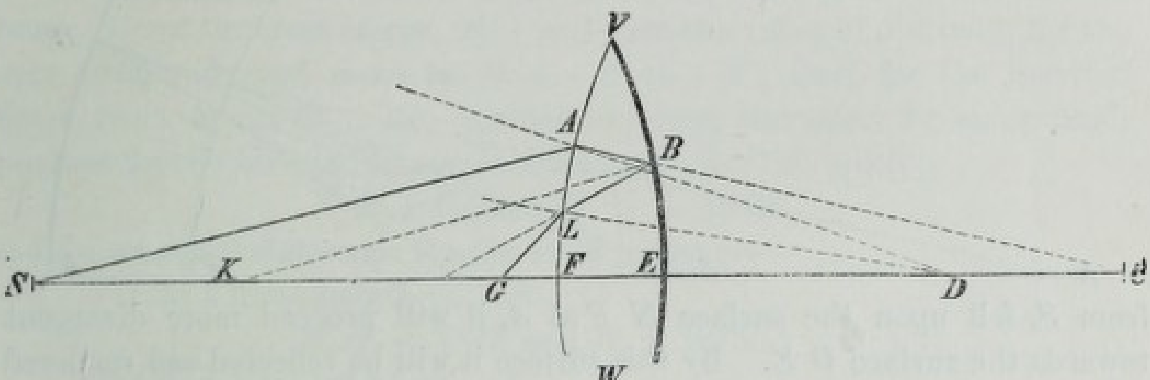
The chief purpose of silvered lenses is to unite together the reflector and the correcting lens. In describing the conditions under which this modification of the ophthalmoscope is available, I follow chiefly the statements of Hasner.

Every ordinary lens transmits only a portion of the light that it receives. A second portion is absorbed, a third is reflected, partly from the anterior, and partly from the posterior surface. The reflection, however, under ordinary circumstances, is so small, that it is insufficient for the illumination of an eye. But if one surface of the lens be covered with silver, or with quicksilver amalgam, the reflection becomes, under certain conditions, so considerable, as to afford as much illumination as the ordinary plane, or even the concave mirror.

The direction of the rays reflected from silvered lenses is very variable, and is determined not only by the radii of curvature of the covered and of the uncovered surfaces, but also by the power of refraction of the glass of which the lens is formed.

(a) Action of a Silvered Biconvex Lens.—Let *V W*, in Fig. 46, represent a biconvex lens, having its surface *V E W* silvered. If a ray of light *S A* fall upon the anterior surface of the lens, near the axis *S C*, the ray will be turned from its aërial direction and refracted towards the perpendicular *A D*, so as to assume the position *A B*. If continued in the same course it would cut the axis at *C*. But, meeting the silvered surface *B E*, it is so reflected that the angle of reflection *K B L* is equal to the angle of incidence *A B K*. Returning to the anterior surface at *L*, it passes out of the lens into the atmosphere, and is refracted from the perpendicular *L D*, so as to assume the direction *L G*, in which latter point it intersects

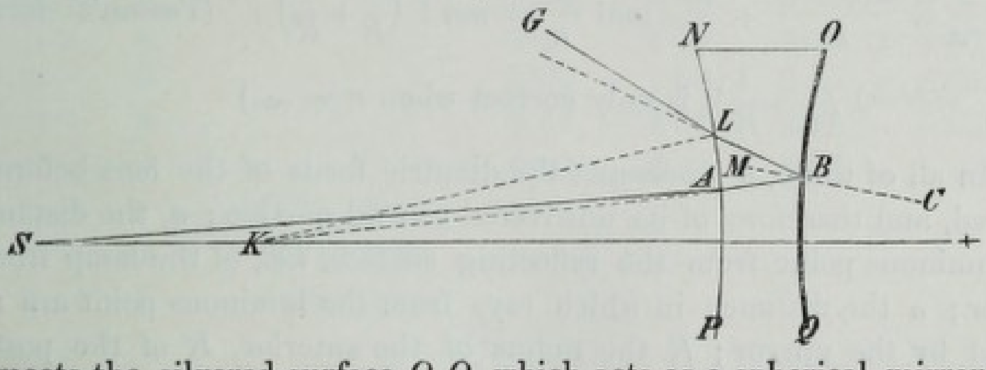
Fig. 46.



the axis. In this point, therefore, the reflected rays will be brought to a focus, and the lens will act as a concave mirror. It is plain that a silvered biconvex lens, in order to serve both for reflection and correction, must be used as an ocular; and it follows that it will only be available for the inverted image, and not for the erect. Such a lens can only be employed with advantage when it has a focal length of at least 6″, or still better of 8″ or 10″; to obtain which the radius of curvature of the silvered surface must be from 18″ to 30″.

(b) Action of a Silvered Biconcave Lens.—If a ray of light *S A*, Fig. 47, fall upon the concave surface *N P* of the biconcave lens *N O P Q*, it will be refracted towards the perpendicular *K A*, and diverted to *B*. At

Fig. 47.

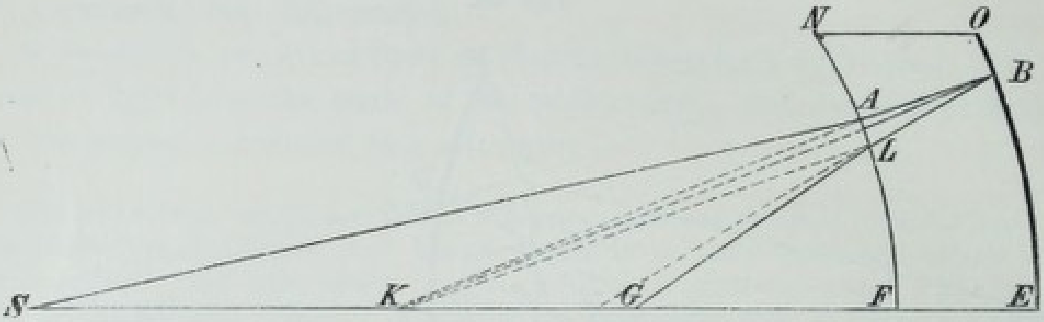


B it meets the silvered surface *O Q*, which acts as a spherical mirror with the radius *B C*. And as the angle *M B L* must be equal to the angle *A B M*, the reflected ray will return with increased divergence to *L*, where, on passing from the lens into the atmosphere, it will be again refracted from the perpendicular, and will proceed towards *G*. The whole action, therefore, is that of a spherical mirror.

These results are much modified by the use of a periscopic dispersing lens of determinate radii.

In Fig. 48, let *N O F E* represent a lens in which *K F*, the radius of the uncovered concave surface, is smaller than $K E$, the radius of the silvered convex surface, but is yet greater than $\frac{KE}{3}$. If a ray, coming

Fig. 48.



from S, fall upon the surface $N F$ at A, it will proceed more divergent towards the surface $O E$. By this surface it will be reflected and rendered convergent, so as to return to the point L. At this point it will re-enter the atmosphere, and undergo a final refraction, causing it to assume the direction $L G$, at which last point it will intersect the axis. The lens acts, therefore, as a concave mirror. It is obvious that dispersing lenses, according to the proportions of their surfaces, may act either as concave or as convex reflectors; but they will only serve for the illumination of the eye, and at the same time for the correction of the rays returning to the observer, when they are employed as ocular glasses for the examination of the erect image, and then only when the radius of the concave surface has some value between $\frac{1}{3}$ and the whole of the radius of the convex surface.

For calculating the radii of silvered lenses of this kind, Burow has given the following formulæ:—

$\frac{1}{a} + \frac{1}{\alpha} = \frac{2(n-1)}{-R} + \frac{2N}{R'}$ and $\frac{1}{b} = n-1 \left(\frac{1}{R} + \frac{1}{R'}\right)$; (Pastau's formula, $\frac{1}{a} + \frac{1}{b} = N-1 \left(\frac{1}{R} + \frac{1}{R'}\right)$, is only correct when $a = \infty$.)

In all of them, b represents the dioptric focus of the lens before it is silvered, and therefore of its unsilvered central portion; a, the distance of the luminous point from the reflecting surface, *i.e.*, of the lamp from the mirror; α the distance in which rays from the luminous point are again united by the mirror; R the radius of the anterior, R' of the posterior silvered surface; n the index of refraction of the glass. The values sought are in this case R' and R, while the values of b, a, and α, can be determined at the pleasure of the observer.

Since then, $\frac{1}{a} + \frac{1}{\alpha} - \frac{2}{b} = \frac{2}{R'}$, so is: $R' = \frac{2}{\frac{1}{a} + \frac{1}{\alpha} - \frac{2}{b}}$ and further, as:

$\frac{2}{(n-1)} b = \frac{2}{R} + \frac{2}{R'}$, so is $\frac{6}{b} - \frac{1}{a} - \frac{1}{\alpha} = \frac{2}{R}$ or $R = \frac{2}{\frac{6}{b} - \frac{1}{a} - \frac{1}{\alpha}}$

Burow found experimentally that the best values for a, b and α, and the most advantageous in practice, were:—a medium distance of the lamp from the mirror (a) of 12″; that the best illumination of the fundus was afforded when the focal length of the concave mirror nearly coincided with its distance from the examined eye; namely, in observation of the inverted image, 6″: of the erect image, $2\frac{1}{2}$″; and that the value of b should, for the erect image, in most cases be from $-8''$ to $-4''$; and, for the inverted image, from $4\frac{1}{2}''$ to $5''$. The calculation gives, therefore, for an ophthalmoscope for the inverted image (when $b=4\frac{1}{2}''$, $a=12''$, $\alpha=6''$),

$$R = 1{\cdot}84, \text{ and } R' = -10{\cdot}28,$$

and for an ophthalmoscope for the erect image:—

(1) in a focal length of $-8''$.

$$R = -1{\cdot}62, \text{ and } R' = 2{\cdot}73;$$

(2) in a focal length of $-4''$.

$$R = -1, \text{ and } R' = 2.$$

The annexed tables give the values of the radii for all possible heterocentric ophthalmoscopes, both for the erect and the inverted image.

The first table is computed for a lamp distant 12″, the second for a lamp distant 18″ from the mirror. The values of R and R' with a reflector of focal length $= 6''$ are not required in practice, nor the positive mirrors in a focal length of 4″ and $2\frac{1}{2}$″; so that these are not computed. The figures express inches.

I.

a (Distance of Lamp) $=12''$.

	$\alpha = 6''$.		$\alpha = 4''$.		$\alpha = 2\frac{1}{2}''$.	
	R'	R	R'	R	R'	R
$b = -\ 2$			1·50	− 0·60	1·35	− 0·57
$b = -\ 4$			2·40	− 1·09	2·03	− 1·01
$b = -\ 6$			3·00	− 1·50	2·45	− 1·35
$b = -\ 8$			3·43	− 1·85	2·73	− 1·62
$b = -\ 12$			4·00	− 2·40	3·08	− 2·03
$b = +\ 5$	− 13·33	2·11				
$b = +\ 4$	− 8·00	1·60				
$b = +\ 3$	− 4·80	1·14				

II.

a (Distance of Lamp) $=18''$.

	$\alpha = 6''$.		$\alpha = 4''$.		$\alpha = 2\frac{1}{2}''$.	
	R'	R	R'	R	R'	R
$b = -\ 2$			1·53	− 0·61	1·37	− 0·58
$b = -\ 4$			2·48	− 1·11	2·09	− 1·02
$b = -\ 6$			3·13	− 1·53	2·54	− 1·37
$b = -\ 8$			3·60	− 1·89	2·83	− 1·66
$b = -\ 12$			4·24	− 2·48	3·21	− 2·09
$b = +\ 5$	− 11·25	2·05				
$b = +\ 4$	− 7·20	1·56				
$b = +\ 3$	− 4·50	1·12				

The focal length of $-8''$ will give the most perfect images, in cases where the eyes of both observer and patient are emmetropic; and only in the higher degrees of myopia will it be required to place a concave lens between the mirror and the observed eye, or between the mirror and the observer; so that with the concaves 2, 4, 8, and 20, the instrument will be sufficiently provided for all cases.

28. THE OPHTHALMOSCOPE OF JÄGER.

As a simple ophthalmoscope, Jäger recommends a lens, the silvered and the anterior surfaces of which possess different curvatures; so that, according as the centres of curvature lie upon the same or on different sides of the lens, the reflected rays that pass through its unsilvered central portion are refracted at their exit by the necessary concave or convex surface. This mirror is either furnished with trunnions, to be placed in Jäger's instrument already described, or with a simple handle, so that it may be used as a lorgnette.

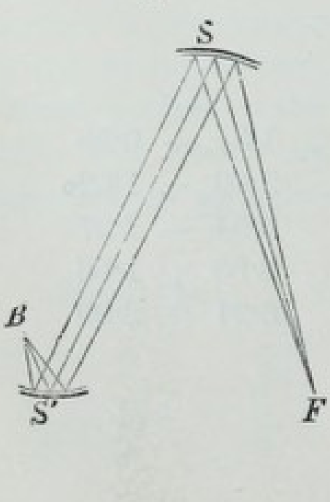
29. THE OPHTHALMOSCOPE OF KLAUNIG.

This consists of a double convex glass of 14″ focal length, having a diameter of 35 millimetres, and a central blackened perforation with a diameter of $4\frac{1}{2}$ millimetres. On one side this glass is silvered as a mirror, and it is set in a blackened brass capsule. A handle, which screws into one side of this capsule, may by practice be easily dispensed with.

As, in perforating the lens, the canal is often made too large, and the examination, therefore, rendered difficult, Klaunig has, recently, only perforated the cover; and has replaced the opening by a concave lens of 12″ focal length, placed behind the silvering, and united with the convex lens in a horn mounting.

The same rules apply to the use of these mirrors as to the examination in general. To make the observation less fatiguing, and the images perceptible by an inexperienced observer, Klaunig uses a second mirror in the manner following. The mirror for the reception of the image is placed as near as possible to the eye of the patient, or about $1\frac{1}{2}''$ distant from it, and at the same height. The eye of the observer being now placed in the proper direction, about 9″ or 10″ from this first mirror, a second concave perforated mirror of about 6″ focal length is held before the observer's eye. Upon this second mirror the light of a lamp is allowed to fall from a distance of 8″, and this light is reflected to the first mirror, and from that, in a concentrated cone, into the eye of the patient. In this way, the eye is thoroughly illuminated,

Fig. 49.



and the retinal image, reflected from the first mirror, is seen by looking through the perforation in the second.

In Fig. 49 *F* is the flame, 8″ from the mirror *S*. *S* is a concave mirror, made by a biconvex lens, of 24″ focal length, circular, 15‴ in diameter, and silvered upon one side. In the centre it has a blackened perforation 2‴ in diameter. The observer holds this mirror 9″ or 10″ distant from the mirror *S′*, and before his own eye, and gives it the necessary direction, that its light may fall convergent upon *S′*. *S′* is a concave mirror, made from a biconvex lens, circular, 15‴ in diameter, of 14″ focal length, also silvered upon one side, inclosed in a blackened brass capsule, and not perforated. It is placed perpendicularly upon a stand, and can be raised or lowered at pleasure. *B* is the position of the cornea of the examined eye, and the distance between *B* and *S′* is about 1½″.

30. THE OPHTHALMOSCOPE OF BUROW.

This consists of a simple lens, silvered upon one side, with the silvering removed in a central circle of 1½‴ in diameter, and fixed in a setting of blackened brass. It is so ground that its focal distance for transmitted light is 5″; but that its silvered surface, acting as a concave mirror, will bring rays, received from a flame 10″ distant, to a focus at 6″.

To examine the fundus oculi, a convex lens of from 1½″ to 1¾″ focus is held before the patient's eye, and the mirror moved further or nearer, according to the state of refraction, until the inverted image is seen in the focus of the lens.

Burow claims as the advantage of his instrument that it facilitates ophthalmoscopic study for beginners—that is, that unpractised persons, by its means, can learn to perceive the retinal image with great readiness.

31. THE OPHTHALMOSCOPE OF HASNER.

This form of instrument is extremely simple. It consists of a circular periscopic dispersing lens, an inch in diameter, the convex side of which is silvered. In the centre, a small portion of the silvering is removed for a sight-hole, and the whole is put into a simple metal casing. For ordinary examination of the erect image, the surgeon should have four such glasses, Nos. 4, 6, 8, and 12; but, for more exact examination, it is wise to have in reserve the almost superfluous and seldom-needed silvered concave glasses. Six or eight such glasses, fitted into a case, form the most complete and the most compendious apparatus for the examination of the direct image.

In use, these glasses are held by the margin between the thumb and index finger, and so turned obliquely towards the light, that a luminous disk is thrown upon the patient's eye. The eye of the observer is placed close behind the glass.

The simple application and easy exchange of the glasses, the compact form of the whole, the correction of reflections, the approximation of the observer's eye to the mirror, and of the mirror to the eye of the patient, are all reasons why this form of ophthalmoscope merits high commendation.

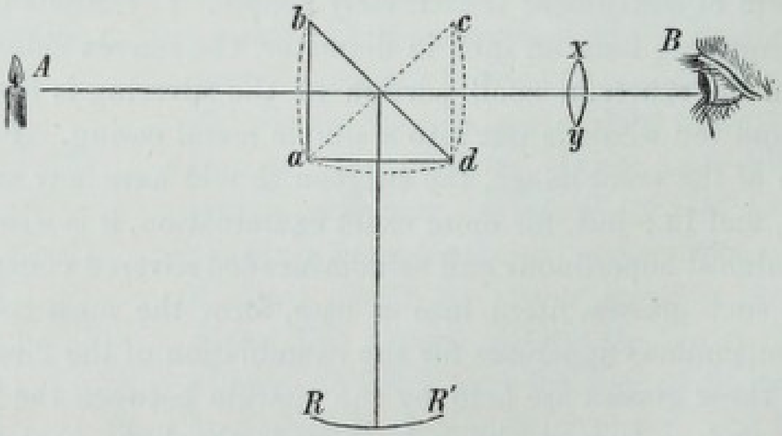
Furthermore, it is to be commended on the score of cheapness, as the operator may himself silver his lenses. For this, Hasner gives the following directions. A paste is to be made of fine plaster of Paris, and laid, 3‴ in thickness, 2″ in diameter, upon a piece of board. The side of the lens that is to be covered is pressed into this plaster, but not to such a depth as to reach the board. It remains until the mould is thoroughly hard and dry; is then taken out, and the mould lined with a double layer of tinfoil, spread as smoothly as possible. Upon the foil are suffered to fall a few drops of quicksilver, which are then allowed to come in contact, and to amalgamate, with the whole surface, upon which will form, in patches, a thin pellicle. This pellicle is to be removed by carefully rubbing the cleaned glass, that is to be silvered, over the surface until it reflects perfectly. The lens is then placed in the mould, pressed down firmly, and the pressure maintained by a weight. In two days the lens may be removed for use.*

(*d.*) *Prismatic Ophthalmoscopes.*

32. ULRICH'S PRISMS.

Professor Ulrich, of Göttingen, has the merit of having been the first to apply the complete reflection effected by prisms to the illumination of the background of the eye. He took two prisms of glass, Fig. 50, *a b d* and *a c d*, presenting in section the forms of right-angled triangles,

Fig. 50.



* I give Hasner's directions as I find them; but most amateurs will save themselves disappointment by buying their lenses ready silvered.—TRANSLATOR.

with equal containing sides, and so united them, that one containing side of the upper prism corresponded with one of the lower; and that the hypothenuse of one intersected that of the other at right angles.

It follows from the law of total reflection of light, that rays which come from a laterally-placed flame *A*, in a direction perpendicular to *b a*, a containing surface of the under prism *b a d*, will proceed to its hypothenuse *b d*, and will there be totally reflected, so as to pass out through the surface *a d*, and to reach the retina *R R'* of the examined eye, which is thus illuminated. The rays returning from the retina will be perpendicular to the surface *a d* of the upper prism, will reach its hypothenuse *a c*, and will there be totally reflected into the eye of the observer at *B*.

To concentrate the light, the containing surfaces *b a*, *a d*, and *c d* may be made convex; or a convex lens *x y* may be placed in the line of sight of the observer if required.

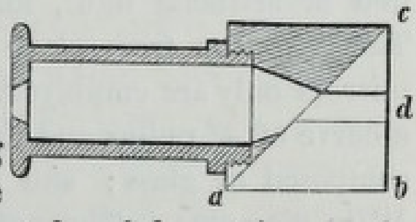
33. THE OPHTHALMOSCOPE OF FRÖBELIUS.

This instrument is a modification of the original ophthalmoscope of Helmholtz, suggested by the need of a brighter illumination, and consists in this, that, instead of the four plates of glass, Fröbelius fastened in front of the instrument a rectangular glass prism with plane sides, and drilled through from the hypothenuse to one side; so that rays from the flame, falling upon the hypothenuse, may be reflected into the patient's eye; and returning rays may be transmitted, without reflection, through the perforation of the prism and a concave lens, to the observer. For easy application of the concave lens, Fröbelius employs a Rekoss's disk, with glasses of Nos. 6, 8, 10, and 12.

34. THE OPHTHALMOSCOPE OF MEYERSTEIN

is shown in Fig. 51. This, the first instrument contrived by Meyerstein, is formed of a plane-sided right-angled glass prism, perforated from one side to the hypothenuse, and fixed in a setting. The rays of light falling upon the side of the prism *a b*, reach the hypothenuse *a c*, and are from thence reflected into the patient's eye. The rays returning from the eye pass in great part through the canal *d*, in the prism, and thence, through the tube of the setting, to the eye of the observer.

Fig. 51.



35. THE OPHTHALMOSCOPE OF COCCIUS

is shown in Fig. 52. It consists of a small rectangular unequal-sided glass prism, *a*; of which the hypothenuse is turned towards the source of light. The rays are refracted from the side next the observer, through the other side, to the eye of the patient. The prism rests on a short handle, which is screwed into the brass basis of the prism, and supports also the setting *b*, with its concave lens *c*. The setting is open on the side next the prism, so that different lenses may be inserted and placed close to the prism. At the lower angle of the setting is a simple hinge-joint *d*, by which the concave lens can be placed obliquely to the observer's line of sight, so as to obviate reflection.

Fig. 52.

The flame is placed near the head of the patient, and at the same level. The eye of the observer must be held close to the reflecting surface of the prism, and must be directed close to its angle.

For the sake of stronger illumination, Zehender employed prisms of which the sides containing the right angle were ground to be either concave or convex as required.

While, on account of their total reflection, the illumination by prisms is very good, yet still their application in practice has more disadvantages than benefits. They are high in price, their management is difficult, and in repeated or very careful examinations, they become fatiguing, because, in order to inspect the whole surface of the retina, the position of the flame requires frequent alteration. Moreover, the observer loses the focus that is afforded by a concave mirror, or by a plane mirror united with a convex lens.

(*e.*) *Solar Ophthalmoscopes.*

Under the expressive heading "a Sun Ophthalmoscope," Mr. Streatfield has published a communication received by him from Dr. Macdonald, of New York, who states that he has been in the habit of using solar, in lieu of artificial light, for the purpose of ophthalmoscopic investigation. The reflection from plane or concave mirrors being too dazzling, convex mirrors only are employed. Of these, Dr. Macdonald uses two,—one with a curve of 4″ radius and the other of 8″. They are about 1″ in diameter, composed of glass; and their silvering is removed from a central circle 1‴ in diameter. The patient is placed with his back towards the sun, and the examination is conducted in the usual manner.

IV.—BINOCULAR OPHTHALMOSCOPES.

36. THE BINOCULAR OPHTHALMOSCOPE OF GIRAUD-TEULON.

At a time when all optical instruments, spectacles, telescopes, microscopes, stereoscopes, and so forth, had been successfully constructed in accordance with the physiological principle of binocular vision, the ophthalmoscope was still left to stand alone. The law of its action, that the rays of light emerging from the eye return in the track of their incidence, seemed to present an insurmountable obstacle to the attainment of the conditions of binocular vision. Dr. Giraud-Teulon, however, in considering the position of the actual inverted aërial image formed between the ophthalmoscopic object-lens and the observer, was led to inquire why the rays diverging from this image should not be seen as readily with both eyes as with one. He found the difficulty to depend upon the distance to which it would be necessary for the observer to retire. If the centres of the observer's eyes were from 2″ to 2½″ apart, the focal length of the objective 2″, and the diameter of the pupil of the observed eye 3‴, the observer's eyes would require to be 20″ from the image. If the pupillary diameter were only 1‴, the other elements of the calculation remaining the same, the distance would have to be increased to five feet. It is apparent that, even in the former case, from loss of light and diminution of the visual angle, no details of the fundus oculi would be discernible.

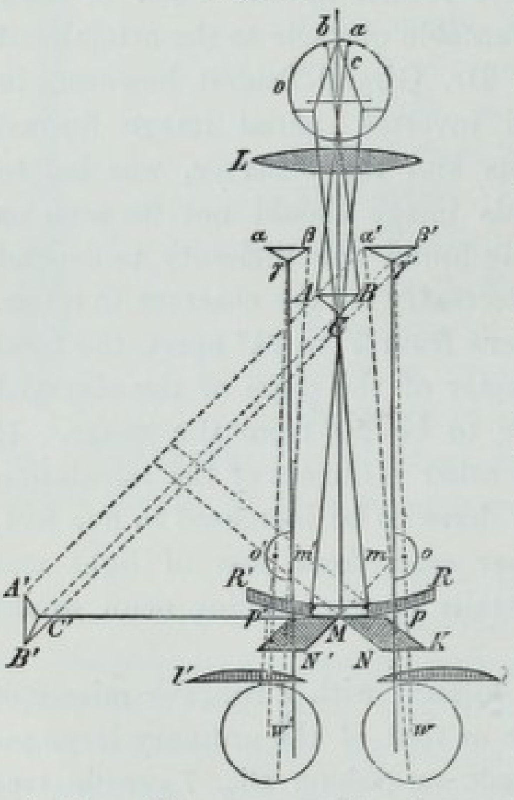
Dr. Giraud-Teulon next provided himself with a concave mirror of about 30 centimetres focus, and as large as that of the ordinary laryngoscope. In its horizontal diameter he made an oblong slit, 7 centimetres in length and 6 millimetres in breadth, through which both eyes could look at once. By placing a lamp above and behind the patient, in a vertical plane with the eye to be examined, the pupil of which must be fully dilated, an observer may see the optic disk, say with the right eye, in the ordinary way. After a while he will see it also with the left eye, the two images partly overlapping one another.

The two images thus obtained have a great tendency to separate and to vanish behind the pupillary margin. By great practice, and very extreme convergence of the ocular axes, it is sometimes possible to unite them, and to produce a stereoscopic effect.

Having thus theoretically solved the problem of binocular ophthalmoscopy, Dr. Giraud-Teulon sought to render his discovery available in practice. M. Nachet, jun., had long before constructed a microscope in such a manner that the actual image formed by its objective was divided by a system of prisms, and presented at once to both eyes of a spectator. Acting upon this principle, Dr. Giraud-Teulon placed behind the opening of a mirror two rhombs of glass, with their edges meeting on the vertical diameter of the opening, and their surfaces ground to afford a complete double refraction at angles of 45°. By this means the rays proceeding from the actual image of the fundus oculi were divided, and, like those of stereoscopic pictures, were easily so united by the aid of lenses or prisms as to afford an appearance of relief.

In Fig. 53, let *a b c* be an object on the background of the examined eye, *L* the convex lens, *R R'* the perforated concave mirror, *N N'* the two rhombs of glass, *l l'* the ocular lenses before the eyes of the observer, and *A B C* the actual image of the object; $\alpha\ \beta\ \gamma$, and $\alpha'\ \beta'\ \gamma'$ will then represent the two inverted images formed by the rhombs, and these will blend together. The retina will exhibit its real thickness; the vessels issuing from the papilla will appear as trunks, with twigs projecting forwards towards the retinal surface; and the papilla itself will be displayed in its actual condition, either concave, plane, or convex.

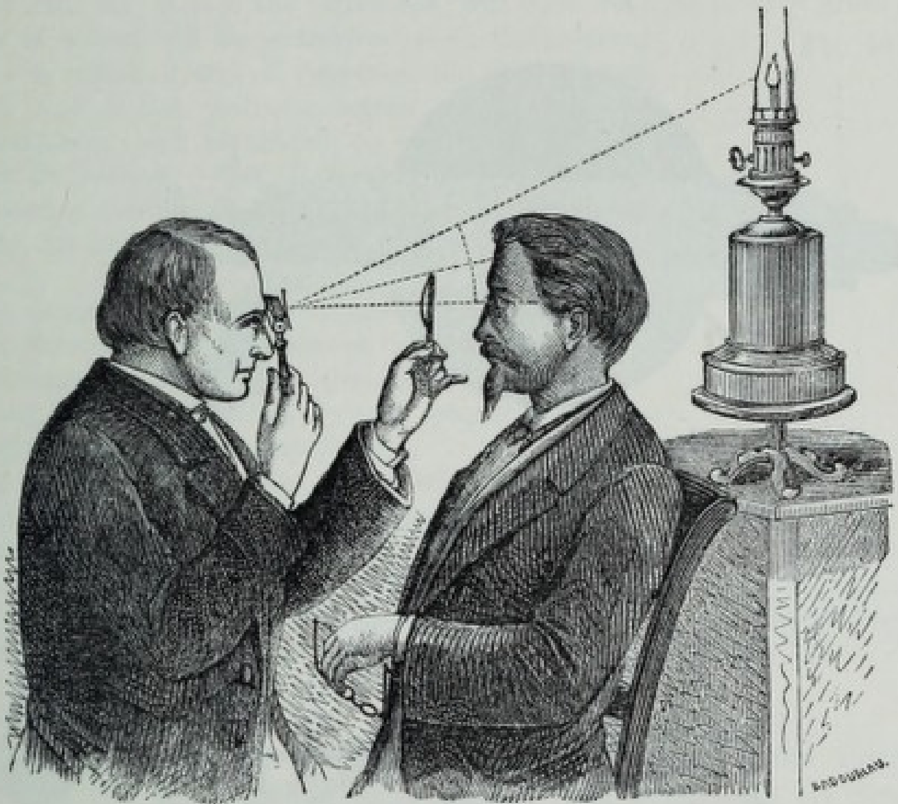
Fig. 53.



If the mirror and the observer's eyes are now brought nearer to the patient, and the instrument be fitted with prismatic decentred convex ocular glasses, as in the common stereoscope, the image assumes great magnitude. The eye under inspection disappears from view; and there only remains an aërial picture, relatively of immense size, "any description of which would be inadequate, and would appear exaggerated." From the extent of the image, and according to a well-known property of the convex glass required as an objective, the whole surface will present an appearance of anterior convexity.

As already mentioned, the lamp for this examination is placed above and behind the patient; so that the rays pass over his head. The mirror is attached to a horizontal bar turning on pivots upon the horizontal box that contains the rhombs, and no lateral movements are required for the necessary illumination. The rhombs must be kept perfectly horizontal, and the eyes of observer and patient must be upon the same level. The general arrangement is exhibited in Fig. 54.

Fig. 54.



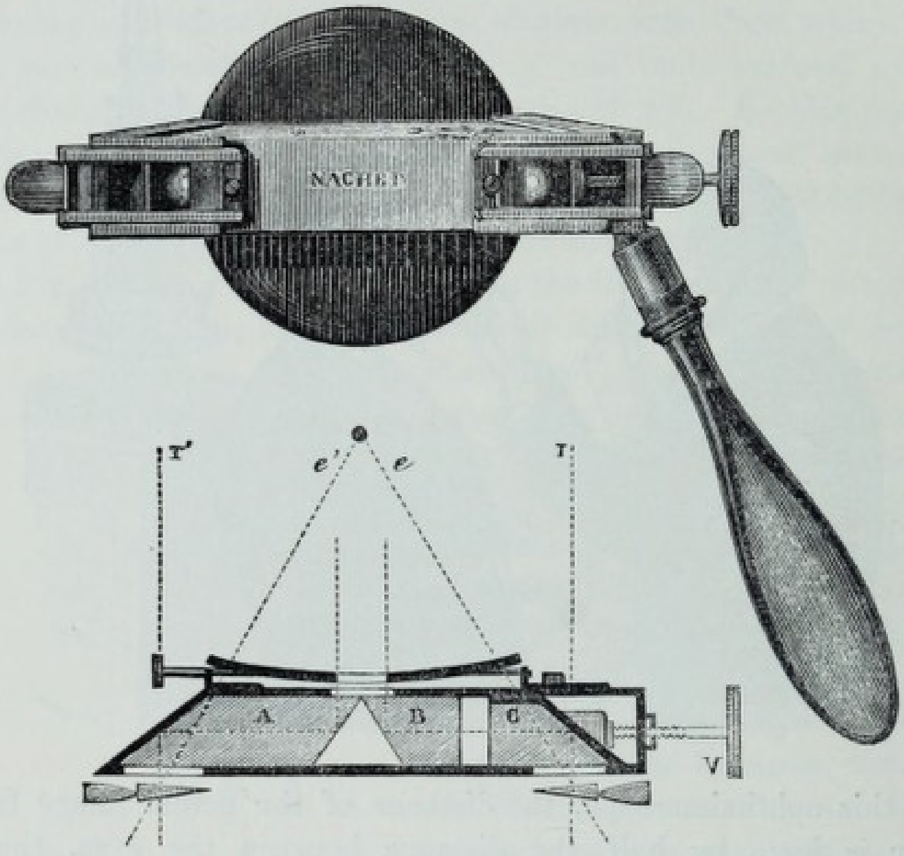
In this ophthalmoscope, the distance of the actual image from the observer is less, by half the distance between the eyes, than in a monocular instrument. The mirror may, therefore, have a shorter focal length than in the latter; and the examination may be made from a nearer point.

Myopic observers require simple ocular prisms of 7° or 8°. Hypermetropic, or presbyopic, require convex lenses, decentred by about 1 centimetre, which exert, moreover, a considerable magnifying power.

For the examination of the erect image, the mirror must be brought close to the eye, and the convex oculars replaced by concaves, of from 6″ to 10″ focal length. Both kinds are decentred, and are placed, the concaves with their thin edges inwards, the convex with their thin edges outwards.

In Dr. Giraud-Teulon's instrument, as made originally, there was no provision for altering the distance between the ocular openings. The instrument was altogether useless unless its width accurately corresponded to the distance between the eyes of the observer. A slight deviation from the proper width produced double images; and a larger deviation altogether excluded one eye from the visual act, and reduced the instrument to a monocular ophthalmoscope of inferior illuminating power. The exact fit required was not easily obtained; and, especially in this country, where there was little power of selecting from a stock, was sometimes altogether unattainable. It followed that many observers failed to realize any stereoscopic effects; and that many doubts were cast upon the value of Dr. Giraud-Teulon's beautiful and ingenious invention.

Fig. 55.



These doubts were, however, in a great degree set at rest by the improvement shown in Fig. 55, which exhibits the general appearance and the sectional arrangements of the instrument as at present made. The left-hand rhomb *A* is left entire; but the right-hand rhomb is divided into two portions *B* and *C*, the outer of which is moveable, and is governed by the screw *V*. The distance between the points *I I'*, the apparent positions of the two images formed by the rays *e e'* is thus placed perfectly under the command of the spectator; and any instrument may be adjusted to meet the wants of various observers.*

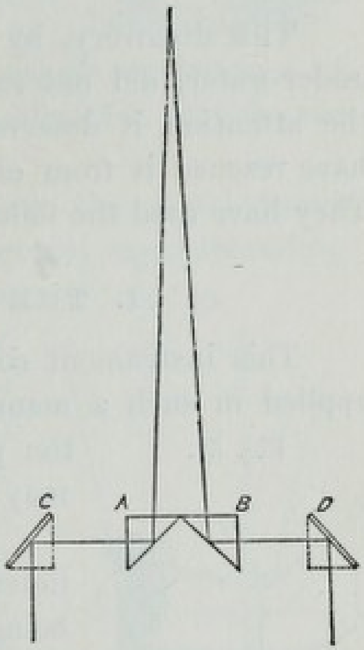
37. MURRAY AND HEATH'S ADJUSTING BINOCULAR OPHTHALMOSCOPE.

At the same time that Dr. Giraud-Teulon was employed in contriving the improved or adjusting form of his own instrument, it was most happily suggested by Mr. J. Zachariah Laurence that the division of the rays might be effected by four small mirrors, the two central ones arranged as in the original (Wheatstone's reflecting) stereoscope; and that the outside mirrors would admit of adjustment, not only of

* I cannot omit to mention the error of a recent writer, who refers to the binocular ophthalmoscope of Dr. Giraud-Teulon as "the invention of M. Nachet." The error is less excusable, since the writer in question has done me the honour to copy freely from an article of my

distance, but also of inclination. An instrument of this kind was manufactured under the superintendence of Mr. Heisch, of the firm of Murray and Heath, Piccadilly, and succeeded admirably in practice. It was found, however, that the mirrors, if made of metal, would be liable to tarnish, and difficult to clean; and, if made of silvered glass, they produced confusion by reflecting from two surfaces. Eventually, it was necessary to substitute prisms for the mirrors; and by the joint labours of Mr. Laurence and Mr. Heisch the instrument has been brought to very great excellence. Its mode of action will be understood from the annexed diagram, in which *A* and *B* represent the fixed central prisms, *C* and *D* the moveable lateral ones, which can be approximated and separated, as well as set at any necessary inclination. The former movement governs the distance of the points at which the pencils emerge; the latter, the angle of their divergence from the median line.

Fig. 56.



The power to vary the inclination of the ocular prisms makes this ophthalmoscope independent of the decentred lenses required for Dr. Giraud-Teulon's. Their places may therefore be filled by any spherical oculars that special circumstances may require.

The instrument consists of a horizontal metallic plate $1\frac{1}{2}$ centimetres wide and 10 centimetres long, with a central perforation. Behind this plate the central prisms are fixed, and the lateral ones slide in moveable settings, furnished with an index and graduated scale, by which their distance apart can be read off at a glance. Their inclination is regulated by a screw that acts upon both of them at once. The mirror turns upon a pin on the upper part of the plate, and the instrument is completed by a moveable wooden handle. The metallic portions are constructed of aluminium bronze; and the total weight is thus reduced to 2 ounces and 50 grains. The case, as fitted up by Messrs. Murray and Heath, contains also an object-lens and two pairs of oculars, and is made of a shape and size convenient for the pocket.

I have found by careful experiments that the binocular ophthalmoscope may be constructed for lateral as well as for vertical illumination; and that it may be fitted with the mirror and collecting-lens of Coccius's or Zehender's instrument. In this way it becomes much more convenient for the direct image. It may also be fixed to a stand, and rendered available for clinical demonstration.

As regards the difference between Dr. Giraud-Teulon's instrument and that of Messrs. Murray and Heath, any comparison is greatly in favour of the latter. The power to alter the inclination of the reflecting surfaces is most valuable. It gives perfect rest to the ocular muscles of the observer, which have no longer to adapt themselves to pencils of a given divergence, but receive exactly what they require. It allows of the ready displacement of reflected images of the mirror, and thus greatly clears the field of vision. It also allows, by the removal of the ocular prisms, amplifying lenses of higher power than these prisms to occupy their positions, and thus affords more enlargement of the image. The English instrument is, moreover, much less heavy than the French one, which weighs four ounces; and which is, therefore, less convenient both for the hand and the pocket.

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own, published in the *Lancet*, in which full justice was done to Dr. Giraud-Teulon's merits. The claims of this gentleman to be the originator of binocular ophthalmoscopy, and the inventor of the first instrument used for the purpose, are perfectly unquestionable; and indeed, have never been disputed.

V.—ORTHOSCOPES.

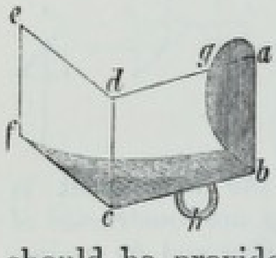
For the Examination of the Eye under Water.

The discovery, by De la Hire, of a method of examining the eye under water, did not receive in his own time, or immediately afterwards, the attention it deserved; but, in modern days, Czermak and Coccius have rescued it from oblivion, and have exactly studied its advantages. They have used the following contrivances :—

1. THE ORTHOSCOPE OF CZERMAK.

This instrument consists essentially of a little vessel with glass sides, applied in such a manner to the face of the patient that the eye forms the posterior side, and completes the vessel, which may then be filled with water.

Fig. 57.



As shown in Fig. 57, the under side *f c b*, and the inner or nasal side *g a b*, are of metal; the former being provided with a ring *h*, for more convenient handling. Their free edges are cut into such a shape that they will fit accurately against the face; and should be provided with a border of vulcanized tubing, so as to prevent leakage without painful pressure. The anterior and lateral sides, *a b c d* and *c d e f*, are formed of slips of polished plane glass. The eye being closed, the orthoscope should be filled with water at from 23° to 26° R. and the eye then opened.

In an orthoscope contrived by Professor Arlt, the vessel is formed of gutta-percha, and has only one glass side, which is inclined, from forwards and inwards, backwards and outwards. The margins lie very accurately upon the face with gentle pressure, and prevent the escape of water. The observer easily avoids the reflection from the inclined glass plate, by giving the necessary direction to the incident rays of light. This instrument, the price of which does not exceed a florin, is extremely convenient for surgical purposes.

The cornea, viewed from the side, appears as a transparent arched bladder; the iris appears as an almost plane curtain behind it.

2. THE BASIN OF COCCIUS.

This instrument, shown in Fig. 58, consists of a little glass bowl, the opening of which is adapted to the soft parts covering the orbital ridge, while the bottom is formed of a smooth polished plate. The cup is filled with lukewarm water, and is applied to the closed eye, while the patient bends forwards.

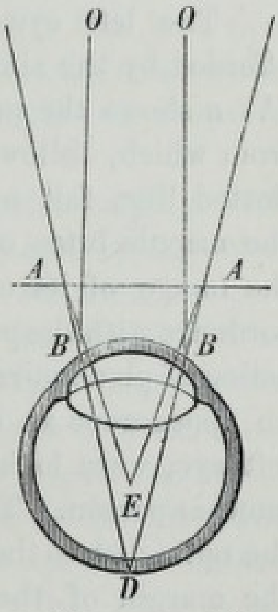
Fig. 58.

For the same purpose can be used the common eye-bath, the lower third being cut off and replaced by a cemented glass plate. Coccius found the best method of examination to be by artificial light from a perforated concave mirror.

Still more simple, but more fatiguing, is Coccius's contrivance of putting into the eye a drop of water, and pressing a film of it between the cornea and a thin glass plate.

The explanation by De la Hire, of the visibility of the retinal vessels under water, is as follows:—If *D B O*, Fig. 59, represent rays proceeding from a point *D*, in the retina of an eye, when the same eye is immersed in water, the refractive power of the water and of the aqueous humour is so nearly identical, that the rays will undergo no change of direction on leaving the cornea, but will reach *A*, the surface of the water, in the direction *D A*. At their exit from this surface they will be rendered more divergent, as if they came from *E*; and therefore an observer will perceive, as if at *E*, an erect, virtual, and diminished image of the point *D*.

Fig. 59.



Notwithstanding that the examination of the eye under water is not equal in its results to those given by the ophthalmoscope, and is more fatiguing to the patient, it is yet not to be lightly esteemed as an aid to diagnosis. Not to mention that the use of the orthoscope, either by daylight or lamplight, is attended by fewer difficulties and requires far less practice, than the application of the different ophthalmoscopes; and also that in unskilful hands it is safer than these; it is especially valuable as a means of examination in cases of opacity of the cornea or irregularity of its surface. In opacity, the levelling of the surface by water permits a more complete inspection of the whole; but the advantage is more important when it is desired to examine the interior of the eyeball, and especially the membranes of the fundus, through a cornea the surface of which is entirely or in great part irregular, since the levelling of all inequalities of the surface permits the formation of a clear image of the retina. In posterior synechiæ, also, an examination under water affords the most exact information; because otherwise the corneal meniscus and the aqueous humour prevent the iris from appearing precisely in its true anatomical position, shape, and size.

For the inspection of other conditions of the eye, the ophthalmoscope generally deserves the preference; but still it is well, in many cases, to combine both methods; especially for a better survey of the diseases of very myopic eyes, in cases of moderately large exudations under the retina, separation of the retina from the choroid, and other conditions.

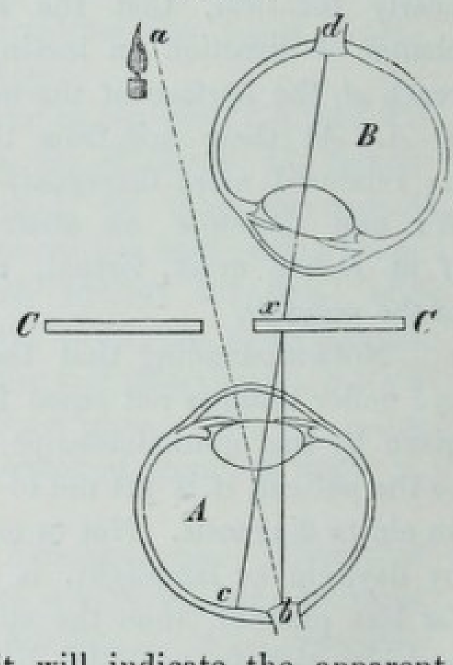
VI.—AUT-OPHTHALMOSCOPES.

1. THE AUT-OPHTHALMOSCOPE OF COCCIUS.

The first complete instructions for self-examination with the ophthalmoscope were given by Professor Coccius, whose statements are here followed. He used for this purpose his plane mirror, in the manner shown in Fig. 60.

The left eye *A* here sees its own optic nerve in the image *B*, afforded by the almost perpendicular mirror *C*. *a* shows the position of the light, rays from which, following the direction of the dotted line, fall upon the optic disk. *c* is the macula lutea of the left eye, which sees the image of its optic nerve at *d*. In accordance with the principles which govern the action of plane mirrors, the image *B* presents an appearance as if the observer, with his left eye, were looking at the right eye of another person. The ray *b*, proceeding from the optic disk to the mirror, is reflected, near the margin of the central perforation, at an angle equal to that of its incidence, and returns to the macula lutea at *c*. If the line *c x* be prolonged to *d*, a point as much behind the mirror as *c* is in front of it, it will indicate the apparent position of the reflected image.

Fig. 60.



In commencing the examination, the mirror is held perpendicularly before the eye, close to it, and in such a position that the optic axis is directed to the inner edge of the central perforation. A wax-light should then be placed behind the mirror, in the continuation of the optic axis, so that the inner edge of the mirror, the flame and the optic axis, are all in one line; the mirror is then inclined at a small angle from the eye (from the temporal side), upon which an image of the flame becomes visible in the mirror, close to the actual flame itself, and deviates inwards from the latter (towards the nose) as the inclination of the mirror is increased. A slight movement, which allows the image of the flame to deviate somewhat upwards and inwards, will then bring the reflection of the optic disk and vessels into view. In order to follow the course of the central trunks, which mostly proceed upwards and downwards, it is necessary to guide the image of the flame upon them,—after having first diminished the light by the interposition of a strong concave lens, or of a diaphragm with a small perforation.

For complete and thorough self-examination, with the ophthalmoscope, of the optic nerve, retina and choroid, it is necessary to dilate the pupil, to use a lamp for illumination, and to place a convex collecting lens behind the mirror. Coccius employs a steel plane mirror with a sharp-edged central perforation, and recommends, according as the observer can bear more or less dazzling (which cannot be entirely obviated), a collecting lens of from 2″ to 3″ focal length. The dazzling will then not be greater than that which is experienced in being examined by another person, with an object lens of 2″, for the inverted image. The best view of one's own fundus is obtained by holding, with the free hand, a convex lens of 2″ or 3″ focal length at from 1″ to 2″ behind the mirror; or a weaker lens, of from 4″ to 6″ focal length, close to the lamp.

For self-examination of the refracting media, Coccius employs with greater success two mirrors, in the manner first proposed by Seydeler. After having dilated the pupil of the eye to be examined, a perforated plane mirror is placed before the other, and so inclined, that its image of the flame is reflected, by the second, large, plane mirror upon the eye under examination, an illuminated image of which will then be seen in the second mirror. If it be desired to inspect the media of the left eye, the perforated mirror is therefore placed before the right eye, and so directed that its image of the flame falls upon the second mirror at a proper angle to be reflected into the left eye. As soon as this is the case, the right eye, through the opening in its mirror, will see the illuminated image of the left eye in the second mirror. In order to test accurately the transparency of one's own crystalline lens, Coccius employs as his second mirror a concave of 4″ or 5″ diameter, and 20″ or 24″ focal length. The lamp is best placed laterally in front of the eye to be examined, which must be screened from its direct light.

As advantages of autoscopy, Coccius points out that the examination affords proof, by allowing the red vessels to be seen when either no part, or only a part, of the flame itself is visible, that the fibrous layer (of the retina) is insensitive to light, and that the bacillary layer is not a simple catoptric apparatus; since, if it were so, the experiment would not succeed. It allows, moreover, of simultaneous subjective and objective examination, since the light from the optic nerve and its vessels is partly distributed upon the contiguous portions of the retina; and, being perceived by them, is, by our imagination, transferred to the blind spot. Further, it may be observed that, near the borders of the optic disk, the light of the candle flame begins to be more white, in consequence of the deficient choroid no longer returning red rays. Lastly, it is of great interest to observe precisely the boundary between the bacillary bodies and the optic nerve. A small ring at the margin of the optic disk is well known to be sensitive, and it certainly is so, as far as the bacillary bodies extend. The auto-scopic examination teaches the observer that the subjective image of the candle-flame is abruptly cut off where the clear objective image ceases. The knowledge of these circumstances, and an exact acquaintance with the optic disk of one's own eye, the difference between veins and arteries, the form of the nerve and its physiological boundaries, are all of great assistance in the recognition of disease, and afford a standard of the natural appearance of the disk in respect of colour, condition of surface, and other particulars. The discovery of the nerve in the eye of another person is also facilitated by the practical knowledge gained upon oneself, that its position is not central, but somewhat below the horizontal meridian of the eye.

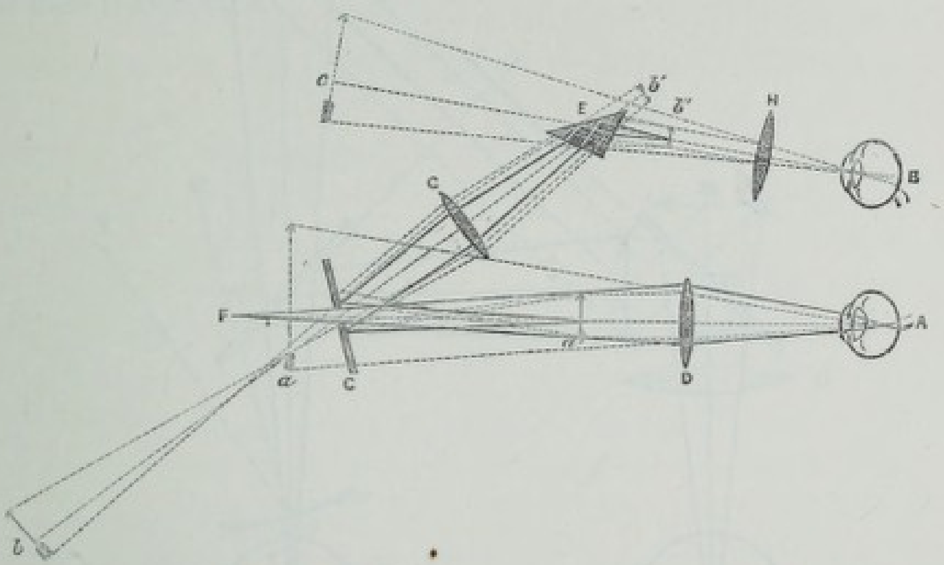
The aut-ophthalmoscope of Coccius is now sold in a very simple form. It consists of a brass tube $5\frac{1}{2}$ centimetres in length, and 3 centimetres in diameter, closed at one end by a plate perpendicular to the axis of the tube, in which is set a plane mirror of highly-polished steel, 2 centimetres in diameter, with its reflecting surface turned outwards, and with a central perforation 3 millimetres in diameter. The tube is blackened within, and carries at its other extremity a 3″ biconvex lens, covered by a metal plate having a circular excentric perforation, with a diameter of 12 millimetres, that extends from the centre of the lens to its circumference. With a very little practice and knack, the optic disk can be readily brought into view; but an examination of the whole fundus oculi is difficult and tedious. The field of vision is very limited indeed, and the eye has to be turned in all directions, and examined bit by bit, in order to see as large a portion of the retinal surface as can be scanned at one glance in the eye of another person. Moreover, the principle of the apparatus renders it impossible to see the macula lutea. Many of these disadvantages have been obviated by the invention of the instrument next to be described.

2. THE AUT-OPHTHALMOSCOPE OF HEYMANN

affords to one eye a vertically-inverted image of the fundus of the other. Its operation will be readily understood by the annexed figure, which displays the arrangement necessary in order to examine the left eye with the right.

In front of the left eye, the flame of a lamp is placed at the point *F*, and between them a plane mirror, centrally perforated, with its reflecting surface turned towards the eye. From the point *F* the rays pass through the opening of the mirror, and proceed, divergent, until they are intercepted by the lens *D*, which renders them convergent. Entering *A*'s pupil, they meet, overcross, and form a dispersion circle on the retina. Returning, they would (*A* being accommodated for the flame *F*) be brought to their focus *a*, and would there form an inverted aërial image. By the influence of the lens *D*, however, this image is formed earlier, in front of the mirror at *a*′. From it rays diverge to the mirror, and are reflected by it, still divergent, in a direction as if they came from an image at *b*. Passing through the lens *G*, the rays again become convergent, and would unite in an image at b'. They are, however, intercepted by the hypothenuse of a right-angled prism of flint-glass E; and are so refracted by it that their image is formed at b'', in front of the right eye B. By the interposition of a lens H this image is magnified; that is to say, the rays diverging from it to the eye B are refracted as if they came from c, in which position, therefore, B sees an enlarged actual image of A's retina. The manner in which this image is inverted will be explained in the next section, in which the different methods of ophthalmoscopic examination are described.

Fig. 61.



By the arrangement shown in the diagram, it is manifest that only the inner or nasal side of A's retina could be brought into view. To see the outer side, it is necessary to place a prism between A and D, with its base outwards, and with such an obliquity and refracting power as may bring rays from the parts desired to be seen into the line of direction between A and F.

The various parts of Dr. Heymann's very ingenious apparatus are inclosed in a box, supported on a stand, and furnished with two ocular openings like those of a common stereoscope, and with the various screws and milled heads necessary for the purpose of adjusting the mirror, lenses, and prism. The side of the box that is undermost in examining the right eye must be turned uppermost in examining the left, by which means the necessary reversal of the whole instrument is effected. It would be useless to describe here in detail the several mechanical arrangements, the purposes of which will at once become apparent when the instrument is taken in the hand.

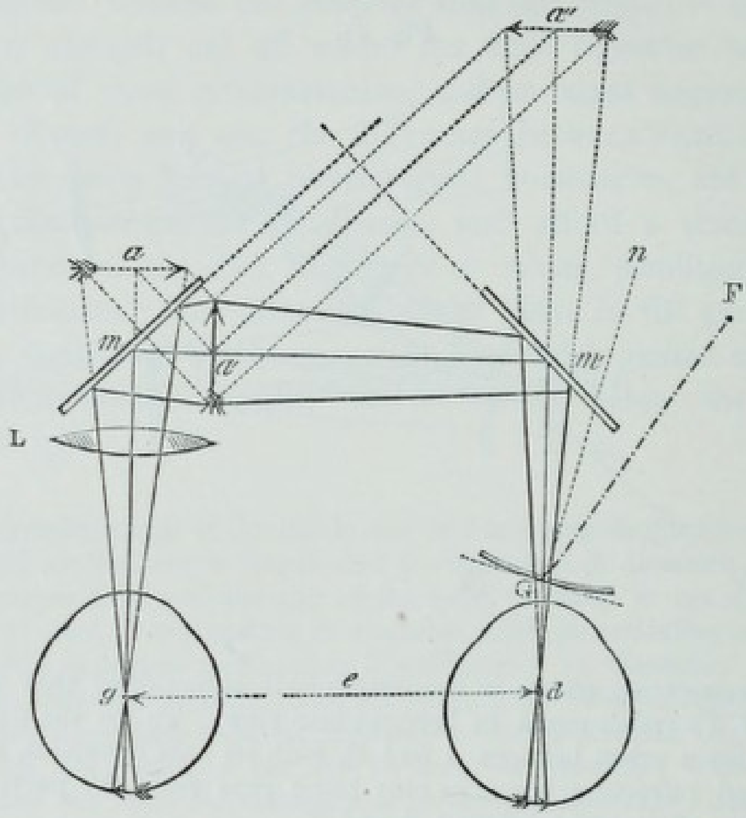
For use, it is necessary, in the first place, to adjust the distance between the ocular openings to suit the spectator, and then to place a brightly-burning lamp behind the mirror. On looking into the apparatus, if the illuminated fundus be not in view, it must be sought by very gentle movements of the mirror and prism; and, as soon as a trace of it is perceived, it will be easy to guide it into the centre of the field of vision. This done, the lenses should next be so moved as to bring out the details of the picture.

3. THE AUT-OPHTHALMOSCOPE OF GIRAUD-TEULON.

In this instrument, by a contrivance equally simple and ingenious, the whole of the fundus of either eye can be rendered an object of vision to the other, either in the inverted image or the erect. As shown in the diagram, Fig. 62, the left eye is the one inspected.

The apparatus consists of two plane mirrors, *m′ m*, inclined to one another at a right angle, and placed in front of the observer. The ordinary object-lens *L* is placed between the left eye *g* and the mirror *m*; and the ordinary ophthalmoscopic mirror *G* is placed in front of the right eye *d* in such a manner as to receive rays from a flame at *F*, and to reflect them directly upon the mirror *m′*. The practical effect is, that the rays leaving *g*, instead of proceeding straight forward to

Fig. 62.



an observer in front, are twice bent at a right angle, and brought back to *d*, without any change in their relative positions.

In the diagram, the divergent rays *F G* are reflected towards *a″* at an angle of reflection *n G a″*, equal to the angle of incidence *F G n*. They are intercepted by the mirrors *m* and *m′*, twice totally reflected by them, and brought to the lens *L*. Rendered convergent, they pass through the pupil of *g*, meet, overcross, and form a dispersion circle on *g*'s retina. The emerging rays would be united by *L* into an actual inverted image at *a*, but intercepted and reflected by *m* they form their image at *a′*. The rays proceeding from this image to *m′* are again reflected, and become visible to the eye *d*, through the central perforation of *G*, as if they came from *a″*; at which point, therefore, an inverted image of *g*'s retina will be seen. By removing the lens *L*, approximating the eyes to the mirrors, and using, if necessary, a concave ocular, the erect image may be seen instead of the inverted.

4. THE AUT-OPHTHALMOSCOPE OF ZEHENDER,

which was contrived in order to facilitate self-inspection of the excentric portions of the retina, is essentially the same as that of Dr. Giraud-Teulon.

It consists of two plane mirrors, so arranged that they can be inclined towards one another at any necessary angle. A lamp is placed at the side of the observer, facing one of the mirrors. This first, or illuminating mirror, reflects rays from the flame into the eye, and also reflects a portion of the returning rays towards the second mirror, by which they are again reflected in the visual axis of the observer. If the eye be emmetropic, and the emergent rays parallel, they will be united into an erect virtual image of the parts from which they come. If the emergent rays be convergent, they may be rendered parallel or divergent by substituting for the second plane mirror a convex one, of which the radius of curvature should be double the negative focal length of the concave lens that would produce the desired correction. If the illumination be otherwise insufficient, a concave mirror may be used instead of the first one; but, if this be done, the second mirror must in any case be convex. For parallel rays, its radius must be equal to, or somewhat less than, that of the first; and, for convergent rays, its radius must be still further diminished, according to the degree of their convergence.

SECTION THE SECOND.

THE EXAMINATION WITH THE OPHTHALMOSCOPE.

SINCE special directions for the use of each variety of ophthalmoscope have already been given in the first section, in the description of the varieties themselves, I may here confine myself to the enunciation of those practical rules and optical principles that are required for the application of all.

With regard to the choice of an instrument,—a matter that may well be a source of embarrassment to many persons,—it may not be superfluous to call attention to the points that deserve consideration in selecting either this or that. Generally speaking, it may be said that all the instruments already described are available for the examination of the eye; and that it depends only upon the skill and management of the observer whether they give clear images of the retina or not. It must be observed, however, that the capabilities of the different instruments vary; and that one, for example, may be commended on account of its superior illuminating power; another, because it is easy of management. I will, therefore, consider the performances of the different ophthalmoscopes: first, as a question between stationary and moveable instruments; and, secondly, with regard to the quality of their illumination.

(1) "It is evident that, if it be desired to inspect carefully some single point of the fundus oculi, a fixed instrument will be found the most desirable, but that it will be far less adapted for a more extended survey. With the fixed instrument, the observer sees only from a distance; that is to say, he has before him an image of the retina at his distance for clear vision. While, by this, he is spared all exertion of his eye, it must not be forgotten that he loses that sharpness of perception which we obtain, as if from a magnifier, by the close examination of objects. With fixed instruments, moreover, a careful inspection of the periphery of the ocular fundus becomes very difficult; since, for this purpose, the patient must turn his eye in all directions, and will often be required to give it a degree of obliquity that he will be unable, with any steadiness, to maintain.

"The moveable mirrors are free from the above-named defects, and can be so managed as to display all parts, behind the equator of the eye, without any considerable changes in the direction of the organ. They require, however, if used for the examination of the erect image, far more practice and dexterity than the fixed instruments; since it is necessary for the observer, in spite of his proximity to his object, to maintain accommodation of his eye for distant vision; and also to hold the mirror with great steadiness, partly in order to keep the image in his field of sight, and partly in order not to dazzle the patient by to-and-fro movements of the reflecting surface, such being among the greatest disadvantages of ophthalmoscopic examination." (Heymann.)

For clinical demonstration, or for observation with little study or practice, or for purposes of exact drawing or measurement, the large instruments must be preferred, in which the different parts of the ophthalmoscope, and the eye examined, are all fixed as steadily as possible. Among these, the best are those of Liebreich, Follin, Epkens and Donders, and the larger one of Ruete; while for hand use, the small, cheap, and portable forms, and especially those of Coccius, Zehender, and Hasner, deserve the preference.

In most cases, too, a simple concave mirror (the ophthalmoscope of Anagnostakis) will suffice, if the following proportions be observed:—Its focal length should not be less than 5″ nor more than 10″, its diameter about 5 centimetres, and the diameter of its central perforation not more than 3 to 4 millimetres. Glass mirrors with a central perforation are preferable to those from which only the metal is removed, and metallic mirrors are better than either, as in these the canal of the perforation can be reduced to a minimum. When ocular lenses are required, they must turn easily upon their axes, so as to be applied closely to the back of the mirror.

(2) With regard to the illuminating powers of different ophthalmoscopes, the following observations are made by Zehender:—

The faintest light is that which is reflected from a plate of unsilvered glass, when the angles of incidence and reflection are = 70°. It is necessary, however, to take into account the distance of the reflecting surface from the eye under inspection; because there is, for every eye, one determinate distance at which it will receive more light than at any other, and within or beyond which the degree of its illumination diminishes. Simple concave mirrors direct upon the examined eye a cone of light, having the reflecting superficies for its base; and of greater intensity, the shorter the focal distance of the mirror. Experience teaches, however, that only mirrors of considerable focal length are available for ophthalmoscopic examination, and that, if their focus be nearer than 6″, they are wholly useless. If a cone of light be thrown upon the eye, from a distance, by a concave mirror of considerable surface, only those rays will penetrate the organ that strike the cornea within the limits of a circle the size of the pupil. If the mirror be brought nearer to the eye, there will be found a position at which all the rays reflected from it enter the pupil; but this will be at too great a distance to allow of examination of the erect image of the retina. If the observer bring the mirror near enough for this purpose, by far the greatest part of the light will fall upon the iris, and the pupil will receive only those rays that are reflected from the immediate border of the central perforation, and that do not afford an illumination stronger than that of a plane mirror. Simple concave reflectors, therefore, do not give sufficient light for close observation; although their action is extraordinarily good in the examination of the inverted image.

The light reflected from a plate of silvered glass is the incident light in undiminished quantity. Coccius first used such a mirror, and obtained with it about the same illumination as with Helmholtz's instrument. He, however, increased its action by employing a convex lens, to cast an enlarged image of the flame upon the mirror. In respect of illumination, the improvement thus gained was as if the plane mirror were exchanged for a concave of a focal length equal to that of the lens, with the additional advantage that, by changing the lens, this focal length could be varied to meet the requirements of any particular case. For the purposes of examination, this arrangement possessed a still greater advantage over the concave mirror, since the eye of the observer is, with the former, brought actually within the cone of reflected light, instead of being placed behind its base, as with the latter. It is obvious that, with the plane mirror and lens, the virtual base of the light cone will be as much behind the mirror as the actual source of light is in front of it, after allowing for the virtual approximation of the flame to the mirror that is effected by the lens. But, in such a combination, the focal length, and the size of the image of the flame, increase and diminish in the same ratio, and in such a degree that, in concentrating the light upon a portion of the mirror not much larger than the pupillary diameter (in which case alone no light is wasted), the marginal rays undergo a considerable spherical aberration, which renders them almost useless for the purpose of illumination. In Zehender's convex mirror, however, this spherical aberration of the marginal rays is much diminished, and interferes much less with their illuminating power; since both axial and marginal rays, when reflected from a convex mirror, have a considerably greater focal distance than when reflected from one that is either plane or concave. It follows from these considerations that it is best to use a concave mirror for the inverted image; and, for the erect image, the mirror of Zehender or Coccius. The merits of Hasner's silvered lenses have been already pointed out and explained. (*See* page 54.)

Since the above was published, the question of the choice of an ophthalmoscope has become more complicated. The beginner must consider it (1st) as between English and foreign instruments; (2nd) as between the binocular and the monocular; (3rd) as between the varieties of either class.

The observers who require a fixed instrument must always be a minority, and will be almost limited to surgeons in consulting ophthalmic practice, to those who have to instruct students, and to those who have opportunities and leisure to make careful drawings of the appearances they observe. For all these purposes, the large ophthalmoscope of Liebreich answers admirably; but I should think the modification of it contrived by Follin (*see* page 33) would be in many respects more convenient. The mobility of the object-lens itself, as well as the power to draw the patient gently towards it, or to make him recede from it, without altering the field of vision, and without moving the eye of the observer, would often be highly valuable.

Such instruments should be obtained only from English makers. The foreign ones that I have seen have been at once dear and bad. The threads of their screws are always defective; the parts that should be steady quiver and shake, the parts that should glide easily stick fast, the parts that should be immovable slide downwards, in tardy and reluctant obedience to the law of gravitation. By the time that all the faulty portions have been replaced in this country, the instrument will be far more costly than one originally of English construction, made to work as smoothly and easily as a microscope from the first. I trust my readers will take warning from experience.

I have found that the most convenient method of using a stationary ophthalmoscope is to attach it to a small table, constructed for the purpose. My own has a surface about a foot square, and is supported by a strong central column, heavily weighted at the base. In practice, this arrangement possesses many advantages over the corner of a larger table.

The smaller foreign instruments are generally cheaper than the English, often much cheaper; and, if of simple construction, are fully equal to them. The hand-ophthalmoscopes of Liebreich, Coccius, and Zehender, are largely imported from Berlin, and may be obtained of excellent quality from any instrument-maker or optician. The binocular instrument of Dr. Giraud-Teulon is made chiefly by MM. Nachet & fils; and, in consequence of the number they manufacture, certainly cheaper than elsewhere. Messrs. Murray & Heath's instrument has been made only by themselves.

The difference between the effects produced by binocular and monocular ophthalmoscopes is very considerable; and, for a beginner or an inexperienced observer, is very important. In order to estimate this difference correctly, it must be remembered that the difficulties of ophthalmoscopy are twofold. There is, first, the difficulty of seeing; and then there is the difficulty of interpreting what is seen. Of these, the first is much the same with all instruments; but the binoculars reduce the second to a minimum.

In using the monocular ophthalmoscope of Coccius or Liebreich for the inverted image, in spite of abundant light and perfect definition, the details of the picture appear to be all in the same plane. The vessels of the retina can be distinguished from those of the choroid by colour and direction, but not by any appreciable difference in their position. The depressions formed by choroidal atrophy or posterior staphyloma, and the elevations from sub-retinal hæmorrhage or effusion, present colours which contrast with those of the general field, but scarcely any appearances by which, prior to reflection, their sunken or raised position can be positively determined. Even the cupped optic disk, the most marked of the surface changes of the fundus oculi, betrays itself chiefly by the bending of the vessels at its margin, and, by inexperienced observers, is often mistaken for an elevation. It may fairly be said, I think, that the limited power of one eye, to furnish data for correctly estimating relief, is the chief source of difficulty in the interpretation of ophthalmoscopic appearances.

With a good binocular ophthalmoscope, this difficulty vanishes. The difference between the appearances presented by the two methods is like the difference between the appearance of a tree growing in a field and a tree painted in a picture. Not only is the depressed optic-nerve immediately recognized as an unmistakable cup or cavity, but even small effusions of blood, or lymph, or serum, on the one hand, or patches of atrophy on the other, present aspects that are conclusive with regard to their relations to the general level of the field. The vessels of the retina, too, are seen to stand out from, and to be distinctly on a plane anterior to, those of the choroid; which again, in young light eyes, with good illumination, may be distinctly traced to different strata of the membrane.

For those surgeons who have obtained a thorough mastery of the older forms of the instrument, and with whom the process of eliminating optical illusions, or of using the data by which relative position can be determined, has become almost instinctive, the binocular ophthalmoscope is only so far advantageous, as the picture it presents is more beautiful. But for less skilful observers, it is of high practical value.

There are few ophthalmoscopic questions more important, or having a greater bearing upon diagnosis and prognosis, than to determine whether a given mass of pigment be infiltrated among the retinal tissues, or deposited beneath the retina, in the choroid. It is of equal importance to be able to recognize, with certainty, the commencement of serous sub-retinal effusion. By binocular vision, all these conditions can be determined at a glance; by monocular, if at all, only after protracted and possibly hurtful examination. It follows, I think, that by observers who desire to learn the use of the ophthalmoscope quickly, and to avoid errors of interpretation after having had but small experience, the binocular instrument should be unhesitatingly preferred.

For the erect image, the binocular ophthalmoscope possesses little advantage over the older forms; and, even when adapted for lateral illumination, it is not so easy of use. For this purpose, therefore, it is not calculated to supersede the ophthalmoscope of Zehender; but it is still quite available in the hands of an observer who will take the trouble to master the difficulties of manipulation. For the erect image, it will generally be needful slightly to approximate the prisms. The respective merits of the different binoculars have been sufficiently noticed in the former section.

Before purchasing a binocular ophthalmoscope, it is prudent to make certain of the possession of binocular vision. This is not universal, and those in whom it is wanting are often unconscious of their deficiency. The test is very simple. The eyes should be directed towards a candle-flame, or other convenient small object, at a distance of eight or ten feet; and a prism of 16° or 20°, with its angle towards the nasal side, should be held before one eye. With binocular vision, the result will be either two images of the object, or an internal strabismus very manifest to a bystander. If neither of these consequences follow, a binocular ophthalmoscope will be wholly useless.

With regard to the choice of a monocular instrument, I find myself compelled to differ from Dr. Zander in two particulars:—first, with regard to the utility of the simple mirror; and, secondly, with regard to the superiority of a concave mirror for the inverted image.

My own earliest attempts at ophthalmoscopic investigation were made with the simple mirror, the so-called instrument of Anagnostakis. I have long since wholly discarded it, not because it will not suffice for many cases, but because it will not suffice for all. I am convinced that difficult investigations will be most successfully conducted with an instrument that is, from daily use, perfectly familar to the observer; and for this reason I confine myself to a mirror that carries a magnifying lens behind it.

With regard to the concave mirror, I should, until very recently, have echoed Dr. Zander's statement; and should have agreed with the opinion of Mr. Hulke, that Liebreich's small ophthalmoscope is the best and most convenient for the inverted image. Lately, however, the contrary testimony of very skilled observers has induced me to investigate the question with some care, and to compare the performance of different ophthalmoscopes upon eyes well adapted for testing them. I have come to the conclusion that my former preference was the result of habit, and that the best ophthalmoscope for the inverted image is, beyond all question, that of Coccius. It illuminates the fundus somewhat less brilliantly than Liebreich's, but more uniformly; it is less interfered with by reflections of the mirror from the cornea, and by images of the flame upon the retina of the eye examined; it affords better definition, and permits the use of a higher magnifying power. Lastly, though inferior to Zehender's for the erect image, it yet shows it very fairly, and in a manner far superior to Liebreich's.

Preparations for the Examination.—Among the various forms of ophthalmoscope already described, only those of Ulrich, Meyerstein, and Galenzowski, and the large instrument of Liebreich, are adapted for use in the daytime, without any disturbing influence from daylight. For all others, the first essential is a moderately darkened chamber.

The second essential is a good light. It is possible to use the sun's rays, admitted through a small opening in a closed shutter; but, on account of the great uncertainty of this light, of the dazzling that it produces, and of its inequality from the passage of clouds, it is not to be recommended. Practically, the best light is that of an oil-lamp, burning with a clear and steady flame, covered only by a chimney-glass, and so arranged as to be raised or lowered at pleasure. A naked candle-flame may be used for very susceptible patients, to reduce the dazzling to a minimum. With regard to the position of the light, it should be the rule of a beginner to place it near the head of the patient, on the same side as the eye to be examined, and so far back as to leave the cornea in shadow. It is also important that the flame, the eye of the patient, and the eye of the observer, should be all at the same level.

For binocular ophthalmoscopes, as already mentioned, it is necessary to have a vertical instead of a lateral illumination. Partly from the ready mobility of the burner, and partly because the intensity and size of the flame can be regulated at will, I am disposed to think that gas affords the *best* light for all ophthalmoscopic purposes. The most convenient bracket is one that may be seen at the Royal London Ophthalmic Hospital, Moorfields, and that possesses an universal movement, upwards, downwards, and to either side, while the chimney of its argand burner remains always perpendicular. The burner itself may be either of metal or porcelain, but should be closed underneath by fine wire gauze, to subdivide and regulate the draught. There should be two taps, or, if only one, it should be remote from the flame, so as to check the pressure from the meter, and to prevent noise in combustion. These arrangements not only afford, above the blue part of the flame, a perfectly steady and motionless cylinder of white light, but they give the power of regulating the height of this cylinder at pleasure, and of placing it exactly in any desired position, for any kind of examination. The next best arrangement is an upright moveable burner, made to stand upon a table, and connected with the gas pipe by an elastic tube. The bracket with universal movement is, however, of such great general utility, that it cannot be too strongly recommended as an essential part of the fittings of the consulting-room. It will be found invaluable for laryngoscopy, especially for the application of instruments to the larynx; and it will greatly facilitate many procedures about the mouth, nostrils, and ears. There are probably few practitioners who have not experienced the difficulty of getting any assistant to hold a light in the exact place where it is wanted.

"Since," as Hasner has very forcibly remarked, "it is perfectly intelligible that the laity should be alarmed by being brought into a darkened chamber, by the use of artificial light in the daytime, and by the application of mysterious lenses and reflectors, it is proper, even if fear be not expressed, in every case to avoid making a mystery of the ophthalmoscope. More especially to timid patients, the nature and objects of the examination should be first carefully explained."

The position of the lamp and of the patient being arranged, the latter must next be shown a point in the distance, behind the observer, at which he must look fixedly. As the anterior pole of the axis of the optic nerve corresponds to the outer third of the cornea, the fixing-point for vision must be to the left side of the head of the observer when the left eye is examined, and *vice-versâ*. If the patient, as, for example, in total blindness, be unable to direct his eye by the sense of vision, he may still often do so by muscular sense, if his own finger be placed in the position or direction towards which his eye should be turned.

It is desirable to keep the patient as still as possible, and at the same distance from the lamp; and it is best when the eye can be widely opened without assistance. When it is necessary to hold the lids asunder, the irritation often produces a considerable flow of tears, and makes the patient restless and unsteady.

Special attention must be paid to the condition of the pupil of the eye examined. If this be much contracted, which, from the sudden influx of light, would usually be the case at the beginning of the examination, only a small cone of rays will be admitted, and only a small portion of the retinal surface will be illuminated. In such cases the pupil must be dilated, either by covering the other eye, or by directing the patient to accommodate for his far point; or, lastly, by the use of a mydriatic.

Two grains of extract of belladonna, dissolved in a drachm of distilled water, will produce sufficient dilatation; but the best mydriatic agent is the sulphate of atropia, for applying which Professor Donders recommends the following solutions:—

1. Gr. iv. in ℥ j aq. distillat. (gr. j—ʒij) as a preparation for operations; to avert threatened synechiæ, closed pupil, or prolapsus iridis; and to restore vision in cases of central cataract, or central opacity of the cornea.

2. The first solution diluted with 15 parts of water (gr. j—℥iv),

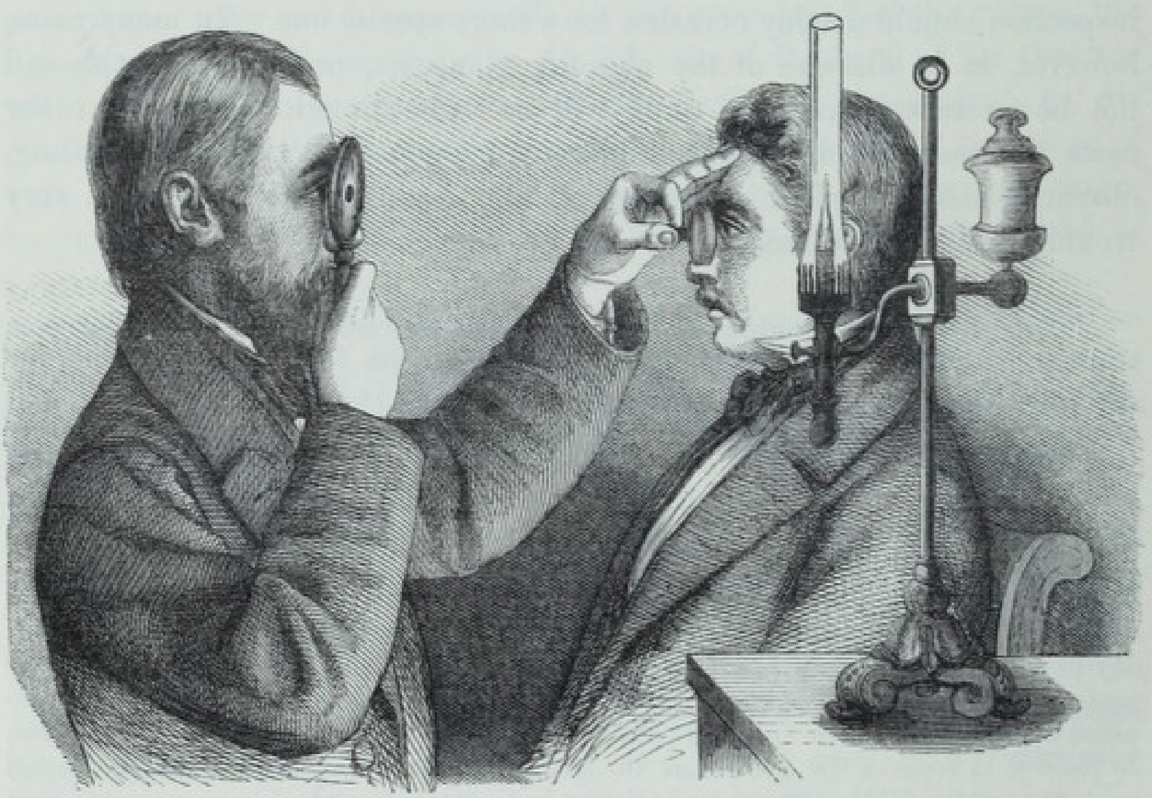
to produce complete dilatation and immobility of the pupil, so as to allow of examination of the interior of the eye in all directions. The dilatation is produced in from 30 to 45 minutes, and the sight is commonly disturbed only for about 24 hours.

3. The first solution diluted with 80 parts of water (gr. j—℥xx) 1 in 9,600, for common use. One or two drops of this solution, retained for a few seconds between the lids, will give, in from 30 to 60 minutes, a sufficient dilatation to examine the eye in most cases. The dilatation will continue from 8 to 36 hours. By some practice it is possible, however, in the great majority of cases, to see the details of the fundus oculi, and to form a diagnosis, through a moderately narrow pupil, without artificial dilatation. The attempt should generally be made, since there will always be opportunity to dilate the pupil afterwards, if the general inspection should display occasion for a more special one. In many cases, however, as in diseases of the choroid, glaucoma, and so forth, this will not be necessary, and the pupil will be wide enough. In many other cases the morbid phenomena consequent upon mydriasis, the dazzling, obscured vision, and disturbance of the accommodation, will be very troublesome, or even hurtful.

The necessity for a mydriatic may frequently be obviated, and the contraction of the pupil diminished, by making the examination with blue light, which has the additional advantage of being more pleasant to the observer. The merit of this suggestion is due, I believe, to Dr. F. Argilagas, of Cuba, who employed a mirror of blue glass, silvered at the back, and with only the silvering removed from the sight-hole. After this, a blue chimney-glass came into very general use; and a screen has lately been recommended by Mr. Ernest Hart and others. This may be of cobalt blue glass; or, if it were desired to transmit blue rays only, it might be made of two plates of white glass, cemented together, and inclosing, as in Dr. Boehm's tinted lenses, a film of a solution of ammonio-sulphate of copper, or of prussian blue. My own practice, formerly, was to use the blue chimney-glass; but, latterly, I have preferred a blue object-lens, made by cementing a plane glass of the A tint between two plano-convex lenses of the required power. With such a lens, it is necessary, of course, to place it in front of the eye, before the reflection from the mirror is allowed to fall upon the pupil. MM. Janssen and Follin have lately contrived an apparatus that can be fitted to any lamp, and that carries a screen of any desired tint. It is well adapted for the consulting-room, but the blue lens has the advantage of ready portability. The same advantage attaches to the atropinised gelatine, recently introduced as a substitute for mydriatic solutions.

Conduct of the Examination.—All preparations being made, the observer takes the concave mirror in the hand that is on the side towards the lamp, places its upper edge against the superior margin of his orbit, and looks through the perforation at the eye to be examined; he then causes the mirror to turn a little on its vertical axis, until the inverted image of the flame is cast upon the eye under examination, the pupil of which will then return a more or less intense reddish or whitish glow. For a general inspection of the refracting media, it will be sufficient to look at the eye from different distances, and to cause it to make slight movements, upwards, downwards, and to either side. If no diseased conditions be apparent, the observer proceeds to examine the inverted image of the fundus. For this purpose, he takes a biconvex lens, of 2″ or 3″ focal length, in the thumb and index of his free hand, rests his little finger upon the forehead of the patient, and brings the lens in front of the examined eye, so that the light from the mirror, passing through this lens,

Fig. 63.



will be concentrated upon the pupil. The actual inverted image of the fundus will now be formed betwixt the lens and the observer, in the focus of the former; and, to render it visible, the observer must usually move his head somewhat farther back. This movement requires considerable practice; since it is especially necessary, in executing it, to maintain the mirror in unchanged direction. Even for a sound eye, and far more for a diseased one, unexpected to-and-fro movements of the cone of light will soon become unbearable. The distance of the lens from the examined eye should be such as to make the focus coincide exactly with the pupil. For this purpose, the pupil itself affords the best standard. While the pupillary margin limits the visual field, the lens is too near the eye. As the distance between them is increased, the pupil enlarges, and finally, in the focus of the lens, its margin disappears. The distance of the mirror from the lens must be the focal length of the latter, added to the distance for clear vision of the observer.

The first object to be sought within the eye is the entrance of the optic nerve. Sometimes, before its white surface becomes visible, darker streaks may be seen traversing a bright red ground. These will be the vessels that proceed from the entrance itself, and by following one of them, in the direction of its increasing thickness, towards the inner and inferior part of the eye, by movements of the observer and mirror in the opposite direction, the white surface of the optic-disk will presently be perceived.

At the beginning of the examination, as soon as the nerve surface is found, it is desirable,—since the eye of the observer has then a distinct object of sight, and the eye of the patient is accommodated for its far point,—to form, by the clearness of the central vessels, a judgment of the state of refraction of the eye, by which the selection of a concave lens for the erect image may be assisted. The fine arterial twigs, passing over the nerve surface, serve as test-objects for more accurate determination.

After inspection of the nerve surface, attention should next be directed to the vessels, to observe whether they present a normal condition at their place of entrance, to note their course over the white disk, and their conduct at and after passing to the red background. After the vessels, should be observed the transparency of the retina, its relations to the choroid and to the nerve entrance; next, the pigment-layer of the choroid; and then the observer should return to a more careful and accurate study of the entrance of the nerve. Lastly, follows the inspection of the refracting media, the vitreous body, the crystalline lens, the cornea, and then that of the iris.

When the habit is once acquired of commencing at the nerve entrance, and studying the topography of the inner eye from behind forwards, so to speak, it will be easy to examine cases in which the crystalline is impaired, or the retina detached, or in which one side of the globe is obscured.

Difficulties of the Examination.—Every honest observer will have to acknowledge, at the commencement of his investigations, that he has only succeeded in seeing a luminous reddish disk, and will find that he requires continued practice in order to learn the use of the ophthalmoscope; and, what is even more important, to understand the appearances it reveals:—precisely as practice is needed in order to obtain skill in auscultation, or in tactile examination. Difficulties arising from this cause cannot, of course, be entirely obviated; but still there are certain sources of trouble to the learner about which information may be given, and which are briefly referred to in the following paragraphs.

The first of these difficulties depends upon the presence of the object-lens, and upon the reflection of its image of the mirror by the cornea of the examined eye,—a reflection that may prevent the possibility of accurate examination. In order to displace it, the eye under examination should be slightly moved, and the object-lens somewhat rotated upon either its vertical or its horizontal axis; it may also be necessary to alter the position of the flame.

The small, bright, round image of the mirror may, by an inexperienced observer, be mistaken for the optic disk itself. The presence of a dark spot in the image, corresponding to the central perforation, and the absence of vessels, are the indications by which this error may be avoided.

It is not, at first, easy to obtain the proper relative distances between the eyes of patient and surgeon, and between the mirror and the lens, that are necessary for clear images. On this subject, however, directions have already been given.

Another difficulty may be that the examiner, in spite of brilliant illumination, obtains no clear definition; and this may arise from a mistaken endeavour to use the greatest possible amount of light. Many objects are best shown by moderate illumination, and a very brilliant light may itself be a source of erroneous diagnosis. Experience shows this to be the case in opacities of the media, which are more clearly seen in front of a dimly-lighted fundus than against a strong illumination; it is therefore prudent to use a moderate degree of light for studying the topography of the eye, and especially for the determination of the relative depths of objects; and to advance to further illumination only when the localities are known, and for any object that may specially require it.

A final difficulty, especially in the erect image, is the proper accommodation of the eyes of the observer. The short-sighted, and persons generally who are unaccustomed to the use of optical instruments, experience this difficulty—that they involuntarily accommodate the eye for its near point, when the object of vision is close to them; on account of this, their eyes are readily fatigued, and soon suffer from congestion and lachrymation. With the ophthalmoscope, as with all optical instruments admitting of adjustment, it is necessary to accommodate the eye for its far point, and to arrange the apparatus accordingly.

Heymann advises the use of concave glasses in ophthalmoscopic examination, as an exercise of accommodation; since, in using a stronger concave than is necessary for correction, although the image will appear smaller, the greater the difference between the refraction of the media and the compensation of the lens, yet this small image is exceedingly clear and sharp. Then, by degrees using weaker glasses, with continually nearer approach to the eye examined, and, at the same time, with continual endeavours to accommodate for greater distance, the image of the retina may be seen, at last, without optical assistance.

I proceed now to the consideration of certain physical conditions, in order to explain the means by which a clear image of the fundus oculi can be obtained.

The human eye, in respect of its refraction, resembles a strong combination of positive lenses. If such a combination be placed between our own eye and any object, the object is rendered visible, under certain definite circumstances, as an erect, or as an inverted image; and, under other circumstances, it becomes invisible. The visibility of the object is chiefly determined by its relation to the focal point of the combination of lenses, partly by the distance between the lenses and the eye, and also by the greater or smaller range of accommodation of the observer. If the object be either at the focus of the lens, or a little within it, the observer receives either parallel or slightly-divergent rays, and unites them into an image upon his retina; but, at the same time, as the object is seen under an increased visual angle, it appears erect and magnified. This statement, however, of the visibility of an object situated in the focus of the lens, only applies to observers who possess normal power of accommodation; for, if the observer's eye be so constituted that it can only accommodate for near objects, the object in the focus will not be visible, and the object and the lens must be brought nearer together, in order to obtain an erect image. The object continues visible, however, whether the eye of the observer be close to the lens or distant from it; only the greater the distance, the smaller will be the field of vision, from the loss of the marginal rays of light.

If an object be placed beyond the focal point of the lenses, then the divergent rays proceeding from the object are so refracted in their passage that they become convergent, and unite to form an inverted image on the other side. This image is larger, the farther it is from the lenses, and the nearer the object is to the focus. It is only clearly visible when intercepted at the common focus of all the pencils of light entering into its formation; but, if this common focus be very far distant, the image, on account of imperfect definition and illumination, again becomes imperceptible, and cannot be seen either upright or inverted.

When we come to apply these laws to the system of refraction of the eye, and to the retina as an object of vision, the next question is,—where is the retina? Does it lie within, in, or beyond the focal point of its own refracting media? The reply is, that it may be found to occupy any of these positions; but we can seldom ascertain which, prior to examination, particularly in cases of blindness. If vision remain, the point can be certainly determined by the distance, farther or nearer, at which objects can be clearly seen. If, without the help of a lens, the patient cannot clearly see either near or distant objects, the retina lies within the focus, since no rays are united into clear images (*hypermetropia*). If there be good vision at long distance, then the retina is in the focus, since parallel rays are united upon it (*emmetropia*). And if it be necessary to bring objects very near the eye, then the retina lies beyond the focus, and receives images only from divergent rays (*myopia*).

When we know the relation of the retina to the focal point of the eye, and see it with good illumination, it is easy to deduce whether in any particular case it will be visible in erect or inverted image or not; and it can be deduced further, as we shall proceed to show, in what manner a clear image can be obtained.

I. THE EXAMINATION OF THE VIRTUAL, ERECT IMAGE.

If we assume that an eye to be examined is thoroughly illuminated, its pupil widely dilated, and that its fundus is observed by a person of normal or far-sighted vision, the retina may be clearly seen in the absence of a lens, without accommodation for the far point; but if the eye to be examined is accommodated for its near point, or if it be unable, as in myopia, to accommodate for a distance, its retina will be invisible in the erect image, because situate behind the focus of its refracting apparatus. In such a case, the patient, if normal-sighted (emmetropic), must accommodate for distance, but, if short-sighted, and unable so to accommodate, the focal length of his refracting media must be increased artificially, so that the retina may come to lie in, or in front of, the focus. This object is attained by the interposition of a negative lens. In general, the glass selected must be one or more degrees stronger than that habitually used by the myope; so as to place his eye in a state equivalent to one accommodated for infinite distance; and for this purpose the dispersing lenses of 2″, 4″, 6″, and 8″ negative focal length are chiefly used.

If the eye examined be blind, there is no means of ascertaining beforehand which place the retina occupies in relation to the focal point, and therefore what glass will be required to render it visible. The question can only be determined by experiment.

If the observer be himself short-sighted, he must make his eye equivalent to one that is emmetropic, by the use of a negative lens of shorter focal length than that which he uses habitually. In examination of an emmetropic eye, he will therefore require a weak negative lens; and, in examination of a myopic eye, a stronger one than would be required by an emmetropic observer.

Ryba gives the following rule, by which in every individual case to find the strength of the concave lens necessary to give a clear image of the retina :—

"Measure the distance of clear vision both of the observed and the observing eye, and the distance of each eye from the intervening concave lens; subtract the distance of each eye from the lens, from its distance of clear vision; multiply the remainders together, and divide their product by their sum."

The Table given on the next page, in which A represents the visual distance of the observing, B of the observed eye, and p the focal length of the proper concave lens, is calculated on the assumption that the lens should always be $\frac{1}{2}''$ distant from the eye of the observer, and $3\frac{1}{2}''$ from the eye of the patient.

The concave lenses given in the Table are adapted to render the retina and choroid clearly visible, while, for parts anterior to the retina, weaker glasses would, *cæteris paribus,* be required.

In practice, it is often desired to render such parts visible; so that the value of p given in the Table must be regarded as the shortest focal length applicable to each of the cases specified.

The Table was published by Dr. Zander with the columns p computed in vulgar fractions, of two and even three figures in both numerator and denominator. I have converted all these fractions into decimals, calculated to two places only, but with the second place increased by one, whenever the third would have exceeded 5.

Since, however, the numerous fractional gradations of concave lenses, expressed in the Table, cannot be procured in practice, it is necessary in every case to select the actual lens that approaches most nearly to the ideal one required, and, by preference, that which deviates from it in the direction of being weaker. Since such an actual lens will not give perfect vision at the precise distance for which the ideal one is computed, the observer must compensate for the incorrectness of the lens by corresponding changes in his own position. If the lens be somewhat too strong, the observer must bring his eye nearer to, and if the lens be too weak he must withdraw it farther from, the eye of the patient.

In cases where the two eyes, examiner and examinee, are of different powers, the action of one and the same concave lens varies with its position between them. If the lens be placed, as usual, near the eye of the examiner, it must be stronger when this is farther-sighted than the eye examined, and weaker when the examining eye is more short-sighted than that of the examinee. If the lens be nearer to the eye of the examinee, it

A.	B.	p.	A.	B.	p.	A.	B.	p.	A.	B.	p.	A.	B.	p.	A.	B.	p.	A.	B.	p.	A.	B.	p.
″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″
5	5	1·12	7	5	1·22	9	5	1·27	11	5	1·31	13	5	1·18	15	5	1·36	17	5	1·38	19	5	1·39
5	6	1·60	7	6	1·81	9	6	1·93	11	6	2 02	13	6	2·08	15	6	2·13	17	6	2·17	19	6	2·20
5	7	1·97	7	7	2·27	9	7	2·48	11	7	2·62	13	7	2·73	15	7	2·82	17	7	2·89	19	7	2·94
5	8	2·25	7	8	2·66	9	8	2·36	11	8	3·60	13	8	3·31	15	8	3·43	17	8	3·54	19	8	3·62
5	9	2·48	7	9	2·98	9	9	3·34	11	9	3·61	13	9	3·82	15	9	3·98	17	9	4·12	19	9	4·24
5	10	2·66	7	10	3·25	9	10	3·68	11	10	4·02	13	10	4·28	15	10	4·49	17	10	4·66	19	10	4·81
5	11	2·81	7	11	3·48	9	11	3·98	11	11	4·37	13	11	4·69	15	11	4·94	17	11	5·16	19	11	5·34
5	12	2·94	7	12	3·68	9	12	4.25	11	12	4·69	13	12	5·06	15	12	5·36	17	12	5·61	19	12	5·82
5	13	3·05	7	13	3·84	9	13	4·48	11	13	4·99	13	13	5·39	15	13	5·74	17	13	6·03	19	13	6·28
5	14	3·15	7	14	4·01	9	14	4·69	11	14	5·25	13	14	5·70	15	14	6·09	17	14	6·42	19	14	6·69
5	15	3·08	7	15	4·15	9	15	4·89	11	15	5·49	13	15	5·97	15	15	6·50	17	15	6·77	19	15	7·09
5	16	3·30	7	16	4·28	9	16	5·06	11	16	5·70	13	16	6·25	15	16	6·75	17	16	7·11	19	16	7·46
5	17	3·37	7	17	4·39	9	17	5·21	11	17	5·91	13	17	6·50	15	17	6·99	17	17	7·42	19	17	7·80
5	18	3·43	7	18	4·17	9	18	5·36	11	18	6·09	13	18	6·71	15	18	7·25	17	18	7·69	19	18	8·13
5	19	3·49	7	19	4·58	9	19	5·49	11	19	6·27	13	19	6·92	15	19	7·50	17	19	7·72	19	19	8·43
5	20	3·53	7	20	4·66	9	20	5·61	11	20	6·42	13	20	7·11	15	20	7·72	17	20	8·25	19	20	8·72
6	5	1·18	8	5	1·25	10	5	1·29	12	5	1·32	14	5	1·35	16	5	1·37	18	5	1·38	20	5	1·39
6	6	1·72	8	6	1·87	10	6	1·98	12	6	2·05	14	6	2·11	16	6	2·15	18	6	2·19	20	6	2·22
6	7	2·14	8	7	2·39	10	7	2·56	12	7	2·68	14	7	2·78	16	7	2·86	18	7	2·92	20	7	2·97
6	8	2·47	8	8	2·60	10	8	3·05	12	8	3·23	14	8	3·37	16	8	3·46	18	8	3·65	20	8	3·66
6	9	2·75	8	9	3·17	10	9	3·48	12	9	3·73	14	9	3·91	16	9	4·06	18	9	4·18	20	9	4·29
6	10	2·98	8	10	3·48	10	10	3·86	12	10	4·15	14	10	4·39	16	10	4·58	18	10	4·74	20	10	4.87
6	11	3·17	8	11	3·75	10	11	4·19	12	11	4·54	14	11	4·82	16	11	5·05	18	11	5·25	20	11	5·42
6	12	3·34	8	12	3·98	10	12	4·48	12	12	4·92	14	12	5·22	16	12	5·48	18	12	5·72	20	12	5·91
6	13	3·48	8	13	4·19	10	13	4·75	12	13	5·20	14	13	5·57	16	13	5·89	18	13	6·16	20	13	6·38
6	14	3·53	8	14	4·37	10	14	4·99	12	14	5·49	14	14	5·91	16	14	6·26	18	14	6·56	20	14	6·82
6	15	3·72	8	15	4·54	10	15	5·20	12	15	5·75	14	15	6·21	16	15	6·60	18	15	6·95	20	15	7·23
6	16	3·82	8	16	4·69	10	16	5·39	12	16	5·99	14	16	6·50	16	16	6·91	18	16	7·29	20	16	7·62
6	17	3·91	8	17	4·83	10	17	5·57	12	17	6·24	14	17	6·75	16	17	7·21	18	17	7·62	20	17	7·98
6	18	3·99	8	18	4·94	10	18	5·74	12	18	6·43	14	18	6·99	16	18	7·50	18	18	7·93	20	18	8·32
6	19	4·06	8	19	5·05	10	19	5·89	12	19	6·60	14	19	7·22	16	19	7·75	18	19	8·22	20	19	8·63
6	20	4·12	8	20	5·16	10	20	6·03	12	20	6·77	14	20	7·42	16	20	7·99	18	20	8·49	20	20	8·94

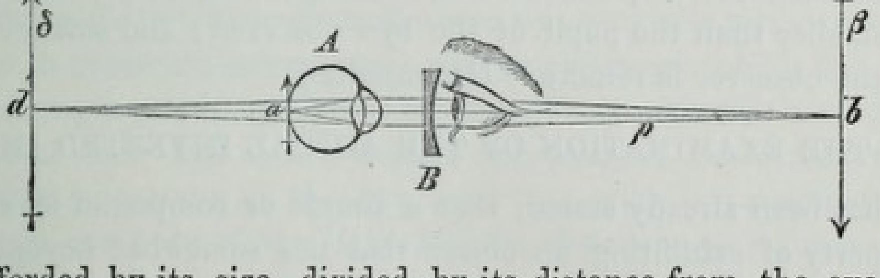
must be stronger when the examining eye is the most short-sighted, and weaker when it is the most far-sighted of the two. If, for example, the observing eye, *A*, has clear vision at 20″, and the observed eye, *B*, clear vision at 6″, and the lens *p* be distant $\frac{1}{2}$″ from *A*, and $3\frac{1}{2}$″ from *B*, then, according to the Table, the focal length of the lens $p = 2''{\cdot}21$; but, if the lens be placed at a distance of $\frac{1}{2}$″ from *B*, and $3\frac{1}{2}$″ from *A*, then its focal length must be $= 4''{\cdot}125$. Upon this principle, the observer may use his own visual power as the measure of the far or near-sightedness of any eye that he examines.

In cases where the observer has determined the concave lens necessary for his own inspection of an eye, and desires, as in clinical instruction, that the same eye should be examined by others, Ryba gives the following rule—

When the first observer has accurately determined the focal length of the lens necessary for himself, let him multiply this length by his visual distance, and divide the product of the two amounts by their difference; then let each subsequent observer multiply the quotient thus obtained by his own visual distance, and divide the product of these two quantities by their sum. The result will give the focal length of the necessary lens.

With regard to the enlargement afforded by the direct method, let *b*, Fig. 64, represent a luminous object, the image of which will be formed upon the observed eye at *a*. The returning rays form an image of the retinal image, congruent with the object itself at *b*. If we take β as the size of the luminous object, and of its image at *b*, and δ of that seen by the observer at *d*, then: $\frac{\beta}{\delta}=\frac{\alpha}{\gamma}$, in which α indicates the distance *B b*, and γ the distance *d B*. A measure for the apparent size of the image

Fig. 64.



seen is afforded by its size, divided by its distance from the eye of the observer. If this latter were placed close behind the concave glass, the apparent size of the image would be $\frac{\delta}{\gamma}=\frac{\beta}{\alpha}$. If we take *q* as the distance *A B*, then the apparent size of the object *b*, for the eye *A*, will be $\frac{\beta}{\alpha+q}$ and therefore somewhat less than that of the image δ for the observer.

If the visual distance of the eye A be very much greater than q, we may neglect q in comparison with a, and may find for the observed eye the apparent size of the luminous object to be equal to $\frac{\beta}{a}$. Under this arrangement, therefore, the retinal images of the observed eye appear to the observer under an equal or somewhat greater visual angle than that which the corresponding objects present to the observed eye itself: hence it is easy to compute the enlargement of the retinal elements of the latter. If X be the size of the image of β, formed at a, and y the distance of the retina from the posterior nodal-point of the eye, it follows that $\frac{X}{\beta} = \frac{y}{a+q}$ and $\frac{\beta}{\delta} = \frac{a}{\gamma}$. Both, multiplied, give $\frac{X}{\delta} = \frac{y \cdot a}{\gamma(a+q)}$. In Listing's ideal eye, y is equal to 15·0072 millimetres, and γ, the visual distance, to 8″. This would make the enlargement $\frac{\delta}{X} = 14{\cdot}34\ \frac{a+q}{a}$. and, since q is commonly very small in comparison with a, we may assume the (linear) enlargement to be $14\frac{1}{3}$ times the size of the objects.

The field of vision, obtained in the direct method, is not limited by the dimly-seen pupillary margin. In order to determine its proper boundary, we may imagine lines drawn from the pupillary margins of the eye observed, to the observer, and having their crossing-point in the centre of the observer's pupil. If these lines be considered as rays of light, emanating from this centre, we find that the observer's field of vision, upon the retina of the observed eye, corresponds to a dispersion circle, in which the central point of the pupil of the observer presents itself. If this central point, or rather its image, seen through a concave lens, be situated in the first focal point of the eye, the dispersion circle will then be equal in size to the pupil of the eye observed. Usually, however, the eyes of the observer and observed are not near enough to each other for this; and then the dispersion circle, corresponding to the field of vision, will be smaller than the pupil of the eye observed; and smaller still, the farther the observer is remote. (Helmholtz.)

II. THE EXAMINATION OF THE ACTUAL INVERTED IMAGE.

It has been already stated, that a simple or compound lens possesses the property of exhibiting an object that lies somewhat beyond its focal point, in a magnified and inverted image; and that this image is visible, when intercepted at the point of union of all the pencils entering into its formation. This property of lenses may be brought into application in examining the retina through its own refracting system; for, if the retina be at a sufficient distance behind the focus, or if we diminish the focal length by optical means, we obtain an inverted image of the retina at a short distance in front of the eye, and we may see this image clearly, by withdrawing from it so far as our own visual power may require. Luminous objects are visible to our eyes from different distances, accordingly as we may be able to accommodate. If proper accommodation be made, there will be formed, by focal union of the rays of light upon the retina, a clear inverted image. When, therefore, we perceive the inverted retina of the examined eye as an illuminated membrane, we know that the rays of light proceeding from it are united to form an image, for which our own eye is accommodated.

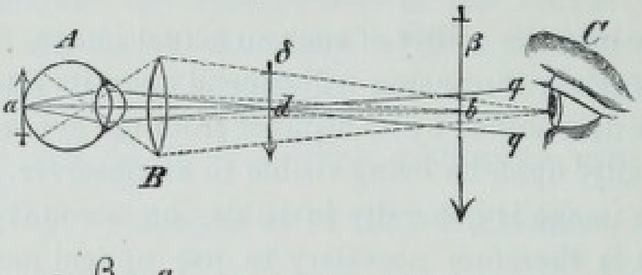
If we inquire into the utility of such an actual image, for the examination of the fundus oculi, the answer will depend upon its size and brightness (both of which are determined by its distance from the eye represented); and also, more especially, upon its being visible to an observer. To the unaided eye, however, the image is generally invisible, on account of its smallness and dimness. It is therefore necessary to use optical means, in order to bring it into view. If we consider the retina to be illuminated by a flame or mirror, situated in the far point for which the eye is accommodated, so that an inverted image of the flame is formed exactly upon the retina, then the rays leaving the eye will return by the same course that they pursued in entering; and, coming under slight divergence, they therefore return convergent. If now a convex lens of short focal length be placed a few inches in front of the observed eye, the rays passing through the lens to enter the eye will be strongly refracted, and will be united in front of the retina in the vitreous body, so that they will proceed, overcrossed, to form a dispersion circle on the retina. The rays reflected from the fundus of the eye will also be united, after they have again passed through the lens, in its focus, where they will form an inverted image of the circular illuminated portion of the retina; and this image, if regarded from a proper visual distance, will be clearly visible to an observer. It is necessary that the observer should look at the focal point of the convex lens, in which point the aerial inverted image will be seen. Since the obscurity of the image increases with its size, and with its distance from the eye, it is generally advantageous to be content with moderate enlargement, and to use glasses of $2''$, $2\frac{1}{2}''$, $3''$, $3\frac{1}{2}''$, or $4''$ focal length; although lenses of such strong refraction have the disadvantage that their foci are very small and narrow, and therefore are lost by the least movement of the eye; and that, with increasing strength of the lens, the intensity of the light for the observed eye is increased. In the description of the several ophthalmoscopes, it has been already stated what numbers of convex glasses should be used with each.

In this method of examination, the short-sighted observer can approach nearer than the far-sighted, and it will be advantageous for the latter to approximate his eye to the image, by the use of a weak convex ocular glass. If the examined eye be blind, it can only be determinedexperimentally whether any or what lenses will be required.

With regard to the enlargement afforded by the inverted method, the references to Fig. 65 are the same as for Fig. 64.

Let X be the magnitude of a portion of the retina at the point a, β the magnitude of its image at b, δ that of its final image at d, y the distance of the retina from the posterior nodal-point, and q the distance of the first principal point of the lens B from the anterior nodal-point of the eye A.

Fig. 65.



Then, $\frac{X}{\beta}=\frac{y}{a+q}$ and $\frac{\beta}{\delta}=\frac{a}{\gamma}$; these, by multiplication, give

$\frac{X}{\delta}=\frac{y \cdot a}{\gamma\,(a+q)}=\frac{y \cdot (a+p)}{p \cdot (a+q)}$, in which p indicates the positive focal distance of the lens B, a the distance $B\,b$, and γ the distance of $B\,d$. As a rule, the lens should be so placed as to bring the pupil of A into its principal focus, in which case p will be nearly equal to q, and the enlargement $\frac{\delta}{X}=\frac{p}{y}$. If we take the value of y from Listing's ideal eye, it follows that the image δ is

Twice magnified when $p = 30$ mm. (13·4‴),
Three times „ $p = 45$ mm. (20·1‴),
Four times „ $p = 60$ mm. (26·8‴).

Such is, at least, the actual enlargement of the objective image. The (linear) enlargement for the observer, if the distance $C\,d$ be supposed equal to c, is $\frac{p}{y\,c}+8''$. The field of vision of the observer is, in this method, limited by the pupil of the observed eye, as long as the lens is held close to it. The farther away the lens is removed, the larger the pupil will appear, until, in the neighbourhood of the focus of the lens, the pupillary margin disappears altogether from the field of vision, and the extension of the latter is only limited by the aperture of the lens itself. (Helmholtz.)

The inverted image may be magnified by a second convex lens. The rays from the inverted image reach the observer slightly divergent; but by a second lens they may be rendered less divergent, and will appear as if they came from the direction of a continuation of this less divergent course, and from a point, nearer to the eye of the patient, determined by the intersection of the peripheral rays.

The arrangement of the combination of two lenses necessary to obtain a highly-magnified image, may be, according to Stellwag:

By a combination of two convex lenses behind the opening of the mirror, so that the anterior will bring the inverted diminished image within the focal distance of the second. The enlargement will be very considerable, and the object will be seen inverted, as its inversion by the first lens will be left unaltered by the second.

Or, by placing before the observed eye a convex lens of shorter focal length than its distance from the hinder surface of the mirror, and looking at the inverted image thus produced through another convex lens placed behind the mirror, and of a focal length greater than its distance from the image formed by the first lens. The enlargement will be more considerable, the greater is the focal length of the first lens (so long as this is less than the distance between the two), and the greater the magnifying power of the second.

Or, by placing before the observed eye a convex lens, and intercepting the convergent rays returning from it by a concave lens behind the mirror. In this case the convex lens must have a focal distance greater than the sum of the distance between the lenses, added to the focal distance of the concave.

In order to obtain considerable enlargement of the inverted image of a myopic eye, Liebreich proceeds as follows:—He holds a convex lens, of greater focal length than the distance for which the examined eye is adjusted, at a somewhat greater distance in front of it than the focal length of the lens. The refracting media of the eye then form an image in the plane of the distance for which the eye is accommodated; and this already strongly-magnified image is seen through a glass, the power of which is, indeed, very limited, since the object is too far within its focus, but which can at once remove the image of the iris, and enlarge the field of vision.

Let it be supposed that the examined eye has a myopia $= \frac{1}{3}$, so that its far point is at a distance of only 3″; and that a lens of about 4″ focus is held about $4\frac{1}{2}$″ or 5″ in front of it. There will then be a highly-magnified inverted image of the fundus, distant 3″ from the eye itself, and $1\frac{1}{2}$″ or 2″ from the lens. By the latter, on the one hand, the image is enlarged; and, on the other, the inverted image of the iris is projected in a larger size and at a greater distance, so that it does not confine the field of ophthalmoscopic vision. The distance at which the observer must place himself will depend partly upon his own accommodation, and partly upon the strength and position of the lens and the position of the image—matters that can be easily determined by trial. It will be found, without reference to exact accommodation for the image, that the observer cannot depart much from a certain definite distance without diminution of the field of vision.

The precise manner in which the ophthalmoscopic image is inverted, has often been a stumbling-block to learners; and, although all the facts may be gathered from the foregoing, it is perhaps worth while to recapitulate them in few words.

Everything situate at, or within, the principal focus of the eye examined, may be seen erect with the mirror alone. Thus the retina of an emmetropic or hypermetropic eye, a detached retina, and an intraocular morbid growth or foreign substance, may be seen in their natural positions without an object lens.

Everything situated beyond the principal focus of the eye, such as the retina of a myopic eye, or the bottom of a deeply-excavated nerve disk, may be seen inverted with the mirror alone. Everything situated at, or not much within, the focus, may be seen inverted by the interposition of a convex lens.

The inverted image appears to move in a direction contrary to that of the movement of the head of the patient or of the observer, and in the same direction as the movement of the convex lens. The erect image appears to move with the head of the patient or the observer. By this difference the two can be distinguished apart at a glance.

In order to understand clearly the effect of the inversion, it is well to take a piece of thin writing-paper, and to draw upon it a circle to represent the fundus of the left eye of a person placed opposite to the spectator. The circle may be

Su

surrounded by the letters Na Te so arranged as to indicate the superior, inferior,

In

temporal, and nasal boundaries of the figure. To the nasal side of the centre a small circle may be drawn for the optic disk, with lines radiating chiefly towards the temporal side, to represent the blood-vessels. The sketch, as it stands, will give an idea of the erect image; with its temporal side to the right of the spectator, and the vessels passing to the right.

If the piece of paper be turned bottom upwards, with the written side still towards the spectator, the ordinary conditions of the inverted image will be fulfilled, and the inversion of all parts will be complete.

If the paper, still upside down, be now turned with the written side away from the spectator, and held towards the light, the effect will be like the inversion produced by the first form of Laurence's reflecting ophthalmoscope, or by the aut-ophthalmoscopes of Heymann and Giraud-Teulon. The figure is still inverted; but the spectator is placed behind it, and the position of his right hand is changed with regard to it: hence the vessels pass from his left to his right, as in the erect image; while the upper parts are seen below, and *vice-versâ*. The simple experiment described will make this clear in a moment.

The comparative uses of the two methods of examination may be stated in the following manner:—

So long as the observer is occupied with the relative positions of the larger parts of the fundus oculi, rather than with a close scrutiny of fine objects, the inverted image should be preferred; and, especially, when it is desirable to diminish illumination on account of disease. Notwithstanding the absence of high magnifying power, the examination of the inverted image, on account of the larger visual field and more comprehensive view that it affords, is sufficient to guard against any grave errors in practice. The examination of the erect image, indispensable for many purposes, such as the observation of changes in the optic nerve, pulsation of its vessels, and so forth, is chiefly needed for the investigation of the fine details of changes, the seat of which has already been made known by the indirect method. The same rules apply to these as to all diagnostic means; and for the right estimation of morbid changes, it is before all things essential to compare the diseased parts with the healthy tissues around them, as well as to compare different portions of diseased structure with one another. The relations between the two methods are, for the fundus of the eye, much like the relations between unaided examination, and examination through a lens, of the more external parts of the organ. For the inspection of a small corneal opacity, or of a pigment-spot on the anterior capsule, the magnifying glass renders us important service; but still we should diagnose the affections of the cornea and of the pupil badly, if we regarded the magnifier in any other light than as an occasional auxiliary. (v. Graefe.)

Since, in examination of the inverted image, we obtain a general view of the retina, while the examination of the erect image gives the clearest and most magnified view of details, it follows that in exact inquiries the two methods should be combined. Neither the one nor the other, however, should be continued too long, or repeated too frequently, as a diseased eye may be seriously injured by prolonged or unduly repeated examination.

The foregoing section still leaves room for a few observations, that may be useful to beginners, with regard to the best method of conducting an ophthalmoscopic examination.

It is an important element of success that the patient should be comfortably and easily seated, well back in the chair, and with the head erect. Mr. Streatfield has invented a special chair for the purpose, with a high straight back, that may be occasionally useful. It is described and figured in the third volume of the "Ophthalmic Hospital Reports."

The observer should be seated with his eyes not perfectly on a level with, but a very little higher than, those of the patient. The two faces should be precisely opposite to one another, feature for feature; and the surgeon should use his right eye for the inspection of the left, and *vice-versâ*. The patient should be cautioned not to turn his head, when told to alter the direction of his gaze. Before commencing, it is well to observe what amount of control he possesses over the movements of his eyes, and how far he is able to look upwards and downwards, to the right hand or the left.

It is well known that ocular movements are best guided by reference to some object of vision. Mr. Hulke has made the useful and practical suggestion to place a large screen, divided into numbered compartments, at some distance behind the surgeon, who, knowing the position of the figures, would tell the patient to look at 7 or at 9. This is an excellent contrivance; but still it may sometimes be replaced by objects that are always in readiness: namely, the fingers of the hand that holds the mirror. For this purpose I depart from the common practice, and, for the inverted image, place the handle of the mirror horizontally across my face, applying it to the right eye, with the left hand, for examination of the left eye; and to the left eye, with the right hand, for examination of the right. I take the handle between my forefinger and thumb only, turn the palm towards the patient, elevate the remaining fingers, and tell the patient to look at them steadily, and to follow their movements. If the sight be tolerably good, the observer will thus obtain complete command of the position of the globe, and may guide it in any direction. If the optic-disk be nearly out of sight, a slight change in the place of the fingers will bring it into, and keep it in, the centre of the field. If the sight be defective, it is easy to keep the fingers in to-and-fro movement, by which means they are seen more readily than any stationary object.

If the sight be good, and the pupil not under the influence of atropine, the fingers will be too near the patient to serve as suitable objects of vision. In accommodating the eye for them, the contraction of the pupil that is usually associated with the action of the ciliary muscle, would interfere with the admission of light. This difficulty is easily obviated, by directing the patient to look past the fingers, at an object on the other side of the room.

The horizontal position of the mirror handle has the additional advantage of placing the object lens in the hand that corresponds to the temporal side of the eye examined. If it be held in the other hand, the nose of the patient is in the way; and he breathes over the hand, and up the sleeve of the surgeon.

I am accustomed to take the object lens between the thumb and index finger, and to rest the ulnar side of the tip of the third finger against the upper margin of the orbit, a little external to the vertical meridian of the eye. If there be any tendency to closure of the lids, it is easy in this position to take up a fold of skin with the finger, and to control the upper lid without in the least alarming or hurting the patient; and it is also easy to exert any degree of pressure upon the globe.

To use the ophthalmoscope of Coccius in the manner described, it is necessary to remove the handle from its usual position, and to fix it opposite to the horizontal axis of the collecting lens.

The ophthalmoscopes of Coccius and Zehender, on account of their collecting lenses, require slightly different management from the simple concave mirror. The beginner will find it best to place either of them nearly in the position it will require to occupy, and to arrange the position of the collecting lens, so as to throw a brilliant inverted image of the flame upon the cheek of the patient, as a preliminary to looking through the perforation and guiding the light into the aperture of the pupil.

In the examination of the erect image, the eye of the observer is brought close to that of the patient; so much so, as to interfere with any object of vision. The movements of the globe can therefore only be guided by verbal directions, or by slightly moving the head of the patient with the hand; and the observer will find it useful to vary his own point of sight, and to look into the eye from every possible direction.

The binocular ophthalmoscopes require the same general management as the monocular, and may be fitted with mirrors of any surface, and with or without a collecting lens. As usually made, they are only adapted for vertical illumination; but I find that they will work equally well with lateral. It is evident, however, that binocular vision is of less importance for the direct image; and I hardly think that Zehender's instrument is likely to be superseded.

The lenses commonly sold with ophthalmoscopes are altogether insufficient for the demands of practice. I have had the small clips removed from my instruments, and replaced by others, large enough to carry the lenses of the spectacle-box. By this plan a great variety is at command, and will be found highly useful. For the erect image, the weaker concaves are often advantageous; and, for the inverted, the common 12″ ocular may be replaced by much higher powers. I frequently use a 5″ ocular, in combination with a 4″ object lens. It must be remembered that the distance between the lenses must be equal to the sum of their focal lengths; and that hence every increase in the power of the ocular must bring the mirror nearer to the patient.

III. THE EXAMINATION BY INCIDENT AND TRANSMITTED LIGHT.

The preceding methods of examination are only applicable to the interior of the eye in a restricted sense, that is, to the retina and choroid;

while, for examination of parts anterior to these, the iris, and refracting media, it is necessary to adopt another kind of procedure, by means of incident or transmitted light.

In strict language, the expression transmitted light cannot be applied to rays received upon the fundus oculi; but two different sorts of illumination are commonly expressed by it:—in one of which the image of the flame would fall exactly upon the retina, while in the other it would be formed before or behind it, and therefore produces upon it a dispersion circle of greater or less magnitude. In the first case, only a small portion, corresponding to the inverted image of the flame, will appear brightly illuminated; in the second, there will be an equal illumination of the whole fundus. The latter is therefore especially adapted to afford a general view, the former to allow an exact examination of particular details.

The greatest advantage has attended the use of this double method of illumination in the examination of the vitreous body; opacities in which are liable to be erroneously estimated when only one of the two methods is pursued. Such opacities, if solid, appear entirely black by transmitted light; while by incident light they exhibit their proper colours, and enable the observer to estimate the inequalities and other peculiarities of their surfaces.

By the examination with incident light, the image of the flame being thrown upon the object inspected, changes in the cornea, iris, and lens can be detected more easily, and their structure more clearly seen, than with a magnifying-glass by daylight. An especial method of employing incident light is by—

THE EXAMINATION OF THE EYE BY LATERAL ILLUMINATION.

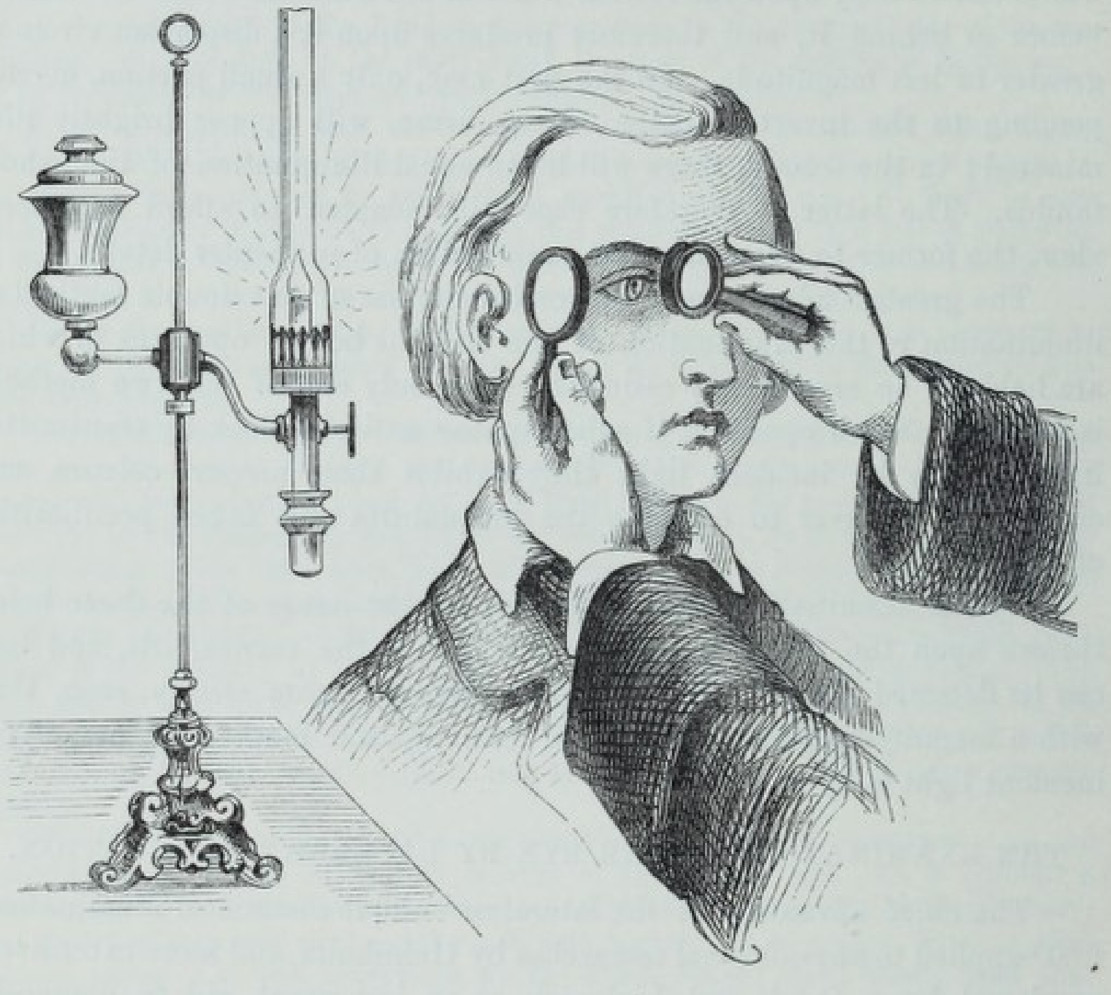
The chief advantage of the lateral or oblique method of illumination, first* applied to physiological researches by Helmholtz, and more extensively employed by v. Gräfe and Liebreich as an important aid to diagnosis,

* The first who applied this kind of illumination to the examination of the eye was Himly, who says, in his instructions for symptomatic investigation ("Krankheiten und Missbildungen des menschlichen Auges," Bd. 1, S. 17), "In those cases in which stronger illumination is required, for example, in order to see clearly into the depths of the eye, or to observe the texture of the iris, the increase of blood-vessels, and the like, the object may be attained by the reflection from a mirror, or by the concentration of light by means of a not very weak convex lens, held at a suitable distance before the eye. If the glass be too convex it must be held so close that it will interfere with the observation. It must also be rightly directed, or it will only show its own disk-like reflection from the cornea. Such a glass may be set as a spectacle-lens upon the patient's nose; but it always requires caution, as to whether the eye can bear its light. The reflection of the mirror can be employed only in rare cases, and in blind eyes, as in the totally amaurotic, or in those suffering from cerebriform fungus. The focus of a strong convex glass is not equally dazzling, and therefore not so dangerous. This, however, ought not to be allowed to fall directly upon the retina. Moreover, the observer must not be deceived by the circumstance that the interior of the eye loses its blackness in strong illumination, and appears greyish, smoky, or greenish."

consists in this, that by its means the front portions of the refracting media can at once be brilliantly illuminated, and considerably magnified.

A brightly-burning lamp, covered only by a chimney-glass, is placed at the side (and a little in front) of the patient, in a dark room, the flame being on a level with his head. The observer sits in front of the

Fig. 66.



patient; and, either with a concave mirror of short focal length, or a biconvex lens of $1\frac{1}{2}''$ or $2''$, directs a cone of light into the eye, and then examines it through a magnifier. The concave mirror must not be held so that the observer looks through its central opening, but laterally, and quite out of his line of sight, and the lenses are held as shown in Fig. 66.

Liebreich gives the following, as considerations that determine the position of the lamp and lens in this method of examination :—" The more illumination is required, the nearer to the patient the lamp must be placed, and the stronger must be the lens. When we wish to examine any extent of surface, this surface must cut the cone of incident light obliquely, before it has been united in a focus. On the other hand, if attention be directed to a single point, the cone may be brought to a focus on this point. The angle that the axis of the cone of rays forms with the visual axis of the eye observed must be larger, as we approach the equatorial portion of the lens, smaller as we approach the pole. It must naturally be very small, when we inspect the vitreous,—opacities in which, illuminated in this way, exhibit their actual colours much more clearly, and allow their positions to be determined more easily and completely, than in the common method of examination."

Focal illumination is especially valuable for minute scrutiny of the iris and pupillary margin; for inspection of the ciliary processes, which may be singly followed to their origin; but, above all, for the examination of wounds and exudations of the capsule, and for determining the consistence of the cortex, or the size, colour, and position of the nucleus of the lens. In examining for cataract, and parts behind the iris, the pupil must be completely dilated by atropine.

Simple and easy as this method of inspection may appear, it still requires a certain dexterity, especially of the hand that carries the lens—a dexterity that cannot easily be described, and that can only be attained by practice.

I am informed by Dr. Liebreich that, although others had previously illuminated the eye by the convergent pencil afforded by a convex lens, he was the first to combine with this illumination the systematic use of a second lens, or a combination of lenses, to magnify the parts inspected. For this purpose he contrived his ophthalmo-microscope; which, as well as those of Coccius and Wecker, would have been more suitably described in this place than among the ophthalmoscopes. (See pp. 32 & 40.)

Dr. Heddaeus has recently advocated the use of daylight for lateral illumination, as well as for microscopic inspection of the eye. For these purposes, he uses a pencil of rays admitted through a central perforation, from one to two lines in diameter, in a screen sufficiently large to shield the head of the patient from diffused light. The pencil is concentrated by a lens in the usual way; and Dr. Heddaeus claims for it many advantages over the usual lamp flame. He thinks it exhibits objects in more natural colour; that it is more easy of application, and more comfortable both to patient and observer. He does not use the direct rays of the sun; but finds the diffused light even of a cloudy day amply sufficient for all purposes.

SECTION THE THIRD.

THE OPHTHALMOSCOPIC APPEARANCES OF HEALTHY EYES.—(Liebreich's Atlas, Plates I. & II.)

Structure of the Choroid.

THE aspect of the fundus oculi, both in its healthy and diseased conditions, is so much governed by the state of the choroid, and is so much more easily interpreted by the aid of continual reference to that complex membrane, that I have thought it desirable to introduce, in this place, a brief outline of its structure. The following account is condensed from the *Etudes Ophthalmologiques* of Professor Wecker, to whom the original was furnished by Professor Manz, of Fribourg:—

"The incomplete vascular membrane which forms the second coat of the eye is at once distinguishable into two parts; of which the posterior, applied to the sclerotic, is called the choroid; and the anterior, free from the external covering, the iris. The anatomical elements of the two portions are so similar, that, even apart from the history of their embryogenic development, they can only be regarded as constituting a single structure. The stroma of the choroid consists of a tissue intermediate between the elastic and the cellular; and presents, in different parts, a predominance sometimes of one and sometimes of the other character.

"The tissue is composed of cells provided with numerous prolongations, that unite to form a slender and elegant network, as in the cellular tissue of other parts. The cells of the choroid are, however, distinguished from all others by containing, besides their nuclei, a variable quantity of brown or black granules of pigment. Some of them are almost filled, while others contain only a few particles. The latter kind must be regarded as intermediate between the former, and other cells destitute of pigment, that occur in the same stroma under two forms. The first resemble the pigment cells in outline, and are very like those of ordinary cellular tissue. The second, much more rare, are nearly round, without nuclei or prolongations, and contain fine granules. The last-mentioned cells, of which the histological character is still unknown, and which were formerly regarded as morbid formations, are constant, but have no visible relation to the other elements. The mean measurement of the pigment cells is from 0·018$^{mm.}$ to 0·045$^{mm.}$ in their largest diameter; and the largest cells are found adjacent to the sclerotic.

"The cells of the choroidal stroma are divided into definite strata by the presence of an intercellular substance, arranged in delicate homogeneous lamellæ, which increase in thickness towards the internal layers, and there assume distinctly the characters and the chemical properties of elastic membrane; whilst the cellular elements, especially the reticulated pigment cells, diminish in number and size, and are replaced by small cells with nuclei and very short prolongations. Even these last soon disappear, and the internal face of the membrane presents only a homogeneous structure, with nuclei here and there, and grooved by blood-vessels.

"According to the latest researches of H. Müller, the choroid contains typical cellular (connecting) tissue. This is found under its habitual form of interlaced fibres, and presents the characteristic reactions. It is most abundant on the external face of the membrane, which has received the name of *lamina fusca*. Histology teaches, however, that this is in no way distinct from the subjacent portions, although in some cases it much resembles a separate membrane. It forms, so to speak, a bed for the vessels and nerves that proceed to the iris; and terminates, anteriorly, in the ciliary muscle, posteriorly by being lost around the insertion of the optic nerve.

"In the tissue already described as being predominant in the choroid, there are found other elements,—vessels, nerves, and muscles. The first are so numerous, and so singularly distributed, that they have received the name of the vascular membrane (*tunica vasculosa*). According to the division and arrangement of these vessels, they are considered as forming two, three, or more layers; of which I recognize three. The arteries arise from the posterior short ciliary branches; that, to the number of twenty or more, are given off by the ophthalmic. These surround the optic nerve; and, at a greater or less distance from their entrance into the globe, they perforate the internal surface of the sclerotic and subdivide dichotomously. Their first division is in the choroid; and their branches are distributed in different methods. A small portion, after many subdivisions, become transformed directly into veinlets; but the greater number form by their ramifications a layer that will presently be described, and that gives origin to the capillaries. These again form the third vascular stratum, known as the *chorio-capillaris*, or *membrana Ruyschiana*.

"It has been already mentioned that the most internal layer of the choroidal stroma has lost nearly all the distinctive characters of that tissue. It consists of a homogeneous membrane of considerable rigidity, which the capillaries traverse as if they were channelled in its substance. The number of the capillaries is such that the space they cover exceeds the interstices between them. Their diameter is generally $0{\cdot}009^{mm.}$ and upwards; and that of their interspaces varies from $0{\cdot}006^{mm.}$ to $0{\cdot}001^{mm.}$ The chorio-capillaris, therefore, when injected and examined with a low power, presents an appearance of uniform redness; but, under a higher power, the interstices left by the capillaries become visible as little islets.

"The so-called tunica vasculosa consists of innumerable interlacing and anastomosing vessels, and of veins that form the remarkable star-shaped figures known as the *venæ vorticosæ*. These are indebted for their peculiar aspect to the convergence, from all directions, of many veinlets, to unite in a single trunk that perforates the sclerotic. Of such vortices there are usually four, or six, or more; and blood is also carried away from the globe by the short posterior ciliary veins that emerge from the sclerotic around the optic nerve.

"A third and inconsiderable portion of the branches of the short ciliary arteries, after many subdivisions, assume a rectilinear direction, and pass forward to assist in the nutrition of the iris. These are the choroidal vessels, of moderate size, that may be seen with the ophthalmoscope in most eyes, near the ora serrata.

"Besides the vessels, the stroma of the choroid contains also striped muscular fibres, and nerve-fibres with ganglionic cells. The uses of these elements of its structure are not yet clearly understood.

"While the external layer of the choroid—the lamina fusca of old writers—unites, although not closely, the choroid to the sclerotic, the internal surface is perfectly separated from the retina by the lamina elastica. This structure belongs to the vitreous membranes, is more or less easily separable from the chorio-capillaris, with which it is in contact, and is provided with epithelium on its internal surface. In appearance it is identical with the membrane of Descemet (lining membrane of the cornea); but is far more delicate, possessing a thickness of only $0{\cdot}0012^{mm.}$

"The epithelial layer of the choroid, which has been badly called the *tapetum*, is composed simply of a stratum of flattened cells, regularly hexagonal, containing each a round transparent nucleus, and a considerable number of brown pigment-granules. These granules vary in colour and in abundance according to the general tint of the hair and of the irides. The hexagonal cells themselves possess a diameter of from $0{\cdot}01^{mm.}$ to $0{\cdot}015^{mm.}$; and a thickness of $0{\cdot}008^{mm.}$

"In the neighbourhood of the optic nerve, the sclerotic and choroid are more closely united; and, according to H. Müller, the nerve, a little before its expansion, is surrounded by a fine and tight ring, formed essentially from the elastic lamina and the chorio-capillaris. Seen from before, this ring presents irregularly concentric striations. Its sharp internal edge gives off fine fibrillæ, which enter between the fasciculi of the nerve, and form the anterior surface of the lamina cribrosa. The latter is a membrane of small thickness, presenting a slight anterior concavity."

I have not thought it needful to follow Professor Manz in his description of the parts of the choroid that are situated anteriorly to the field of ophthalmoscopic vision. The foregoing includes all that is of any practical value with regard to our present subject; although it perhaps gives hardly sufficient prominence to the pigment-cells of the stroma, which, in all but light eyes, are present in great abundance, filling up the meshes of the tunica vasculosa, and usually surrounding, and in great measure concealing, the vessels by which that structure is characterized.

I. THE PAPILLA NERVI OPTICI, OR OPTIC DISK.

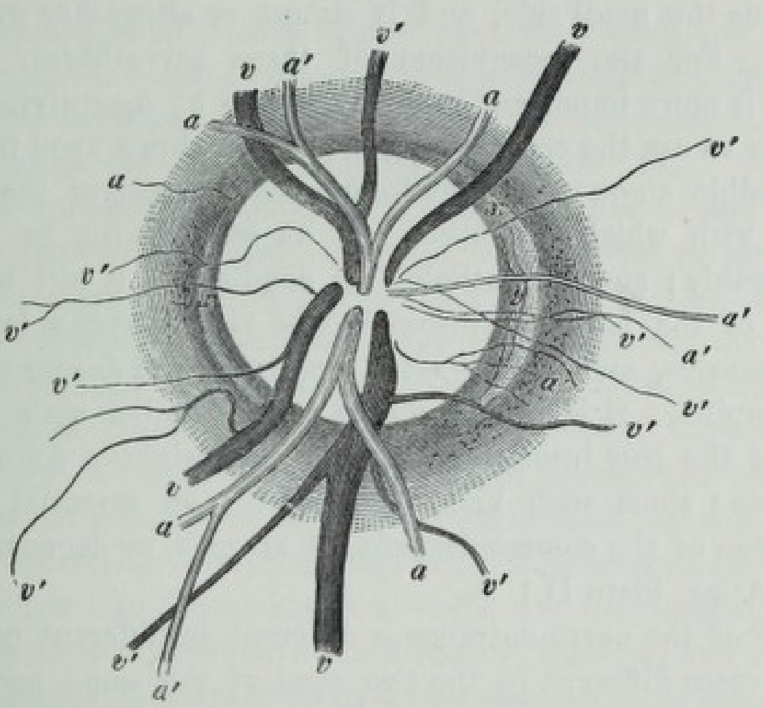
It is necessary to remember that the optic nerve, if prolonged in the direction of its entrance into the globe, would strike the outer third of the cornea; and that it is therefore seen most easily when the eye under examination is directed inwards, and somewhat upwards. If the papilla be not immediately visible, but if vessels are perceived passing over a red ground, any one of these vessels, traced backwards in the direction of its increasing thickness, will be found to terminate in the nerve.

The entrance of the optic nerve presents, within normal limits, considerable diversities of shape and colour. With regard to shape, it is in most cases round, but seldom perfectly circular, often oval,—with the long diameter perpendicular,—angular in almost all cases of convergent squint, never oval with the long diameter horizontal. In many cases, the ophthalmoscope exhibits round the entrance a dark ring or crescent, which depends upon a collection of pigment in the choroid, in the immediate neighbourhood of the nerve, and has no pathological signification. At the point where the lamina cribrosa ceases, the nerve is contracted, and the opening in the choroid is narrow, and in a certain measure compresses the trunk. For this reason, a sort of double border, *x*, is often seen around the nerve-entrance, and between the limits of this border it is still surrounded by the choroid, in which, at this part, Donders has sometimes seen a choroidal vessel (*y*), Fig. 67.

With regard to the limits of the nerve, the following description is quoted from Liebreich:—" Under the choroidal margin is the line, more or less dark, that indicates the border of the opening in the choroid; under the sclerotic margin is a bright crescent or circle, formed by the curving round of the sclerotic fibres, and appearing between the choroidal margin and the fine greyish line that indicates the narrowest part of the nerve itself, and is therefore called the proper nerve-boundary."

The colour is either white, yellowish, reddish, or bluish, with grey or greenish admixture. The glistening whiteness described by some observers (tendinous glistening of Coccius) is not found in healthy eyes; but is present, as we shall see hereafter, in many conditions of disease. Among the causes of variation of colour, within normal limits, may be mentioned the age of the individual, the manner of distribution of the vessels upon the optic disk, the illumination, and the colour of the surrounding field. In eyes rich in pigment, the illuminated disk is compared by Desmarres to the moon in a fine summer night, and contrasts strongly

Fig. 67.



Vessels of the Papilla Nervi Optici and its neighbourhood, as seen with the Ophthalmoscope in the Left Eye, after Donders.
a Arteries, *v* Veins, *x* double Boundary of the Papilla, *y* Choroidal Vessels.

with the neighbouring parts. It is sometimes surrounded by a margin of pigment granules, often perceptible as a dark ring. In eyes with less pigment, the disk cannot be so conspicuously illuminated or so sharply defined, and presents usually a more reddish tint.

In the bright disk of the papilla there may often be observed an admixture of a delicate greyish or bluish stippling, in elongated dots, lines, or clouds, by which the intensity of the light is so increased, sometimes at the periphery, more frequently in the centre, and especially between the vessels, that the parts displaying it appear to shine. Of this appearance, Jaeger gives the following explanation:—"The great diaphaneity of the nerve-tubes of the n. opticus, when deprived of their investments of connecting tissue, allows the vision of the observer to penetrate their structure as far as to the plane of the inner surface of the sclerotic, and even farther. The stippled appearance of the optic disk is due to the circumstance that the interstitial neurilemma, terminating at the plane of the inner sclerotic surface as a sieve-like or perforated membrane (lamina cribrosa), reflects the light and appears whitish and shining; while the tubules in its interstices allow a deeper penetration of the rays. The observer, looking at these tubules in the direction of their axes, sees them in section as roundish grey or bluish spots; and, by looking at them obliquely to their course, the spots appear somewhat elongated. The stippling corresponds to the position of the nerve-tubules, and is commonly clearest and best defined in the centre of the disk, and in a direction towards the macula lutea; but becomes uncertain and confused from the centre towards the nasal side, and is almost or altogether wanting at the periphery." For the recognition of these nerve-fibres, the kind of illumination is more important than the degree of magnifying power, and it is necessary to use the erect image, in order to throw upon the papilla the greatest possible amount of light from a small image of the flame. The distinctness with which the fibres will be seen varies, in normal eyes, very considerably; and in pathological conditions, it will be found that the network of the lamina cribrosa will be visible over a larger surface; the more extensive, and with greater clearness, the deeper is the excavation of the papilla. It is of importance to be familiar with the size and abundance of the grey interstices, and of the brighter connecting tissue between them; since such knowledge affords an essential standard by which to judge of the commencement of atrophy or degeneration. (*See* Liebreich's Atlas, Plate II.)

The size of the nerve-entrance is different in different persons, but is only in rare cases different in the two eyes of the same person. In the dead subject it has an actual diameter of about one line; but in the examination with the ophthalmoscope it is magnified by the refracting media, in a degree governed by the vision of the person examined. The disk of a normal-sighted (emmetropic) eye, examined in the inverted image with a convex lens of 2″ focal length, appears about 3‴ in diameter. The disk of a short-sighted eye, seen in the inverted image without a convex lens, and without artificial mydriasis, will appear so large as to occupy the whole pupillary opening; and the same disk, by the application of a convex lens, will appear smaller than in any other case. In presbyopia, an opposite result is obtained, and the apparent size of the disk is increased by the interposition of the lens. It follows, as a rule, that the more short-sighted the eye examined, the weaker should be the convex lens, and the more presbyopic the eye, the stronger the convex lens, for the production of the inverted image.

The magnitude of the nerve-disk bears little relation to the general dimensions of the eye. Jaeger found the largest in a normal eye of medium size. Of eyes taken from the dead subject, and measured by the same observer, the largest, with an axis of 12 Vienna decimal lines, a horizontal diameter of 11·6, and a vertical of 12 decimal lines, had a nerve-surface that measured 0·75 d. l. in the horizontal direction, and 0·7 in the vertical. The smallest eye (of an adult) had an axis of 8·2 d. l., a horizontal diameter of 8 d. l., and a vertical diameter of 7·9 d. l. The horizontal diameter of its nerve-disk was 0·55, and the vertical 0·49 d. l.

Since the apparent form and dimensions of the optic disk are modified by different lenses, and even by different positions of the same lens, Desmarres advises that, in order to exclude, as much as possible, errors from this source, and in order to compare the sizes of the disk in different persons, the same power of lens should be always used, and that, as soon as the fundus and the nerve-entrance have been examined, the lens should be moved in all directions, in order to study the influence of its different positions upon the size and shape of the parts inspected.

Contrary to the anatomical fact, the optic disk of the normal eye appears somewhat convex, and this wholly independent of its shape, from a certain combination of light and shade. Upon the nerve-surface, furthermore, the image of the flame appears not to be sharply defined; an appearance attributed by Helmholtz to the translucency of the nerve-substance, and by Coccius partly also to irregularity of the surface.

Upon the white surface of the nerve-disk emerge the vessels (arteria et vena centralis retinæ), in most cases peripheral, usually towards the inner side, very seldom towards the outer, and sometimes central, and spread themselves like the spokes of a wheel over the fundus. The larger branches present many diversities in direction, number, and size; but the normal arrangement appears to be an artery and two veins passing upwards, and the same downwards. Sometimes the arteries and veins pierce the nerve at the same, and sometimes at different openings; sometimes each vessel at its own. The artery is very often external to the vein, and sometimes crosses it, sometimes is crossed by it, in their respective courses. With regard to size, it may be said, as a general rule, that an optic disk of small diameter presents small vessels.

The arteries are smaller and of a brighter red than the veins, and pursue a straighter course from their entrance to the periphery of the optic disk. Their diameter varies from about 0·05‴ to 0·025‴. The veins are larger, darker-coloured, and more winding. In their course over the optic disk both arteries and veins are without branches, or may rarely give or receive a few; but beyond the periphery of the disk they subdivide dichotomously (in the first divisions an artery and vein usually accompanying each other, and, in their frequent over-crossings, the artery being mostly superficial) and ramify over the concavity of the fundus, sharply defined against the choroid. They do not, however, approach close to the macula lutea, upon which, in the normal condition, no large vessel is visible. The retinal vessels, the walls of which are transparent, and in intimate union with the retina and hyaloid membrane, appear more distinct, the more light returns (through them) from the deeper membranes; so that they are best seen in fair persons and by transmitted light.

The appearance of a double outline to the arteries, described by Helmholtz, depends, as van Trigt has shown, upon an increased reflection from their walls. Jaeger observes: "The lighter and brighter central line of both arteries and veins, in their whole length, presenting an appearance as if they were transparent, and seen by transmitted light, so that their sides showed a somewhat darker tint, depends entirely upon the greater reflection from the surfaces of the vessels. The rays that are received upon the highest part of the vessel (relatively to the axis of vision) are mostly returned in the direction of their incidence upon the eye, but the rays that fall upon the lateral declivities are in great measure reflected in a lateral direction. The vessels in their actual breadth are completely uniform in colour, and are opaque; as may be shown, not only by their considerable diameter, by the bright central line and dark margins of the larger trunks, the difference being less pronounced in smaller; but also by the fact that they exhibit the bright centre where they are perpendicular to the axis of vision of the observer, and lose it when they become placed obliquely with regard to him; that the lighter arteries, in passing over the darker-coloured veins, present the same appearance, the same colour and bright centre, at the crossing-place, as upon the general surface of the fundus; and, lastly, that the central reflection is easily displaced laterally by slight movements of the mirror, and is made to disappear entirely by changing the mode of illumination, and by using a mirror of very short focal length." Furthermore, in young fair persons, Liebreich has observed fine bright streaks on the retinal vessels that penetrate to the choroid; streaks that pass from one side of the vessel to the other by slight movements of the mirror, and that are only visible in places that receive the brightest and most direct light.

The pulsation of the central vessels, first seen by Coccius, noticed by van Trigt, and accurately studied by Ed. Jaeger, von Graefe, and Donders, is visible as a venous and as an arterial pulse.

The venous pulse is discoverable under normal conditions in all eyes, but in different degree and extent, and is strongest in the most flattened and apparently pointed veins. Moreover, it is easily produced by pressure with the fingers upon the outer side of the globe. By rhythmical intermittent compression the veins may be seen to contract and dilate as the pressure is applied and withdrawn; in gentle continuous pressure the pulsation is clearly apparent; and in steadily increasing pressure the veins continuously diminish, until at length the movement of the blood ceases. When a gentle pressure has been applied for a long time, its sudden removal is attended by a sudden venous dilatation, which again gradually disappears, and, after the lapse of a minute, ceases to be visible. Dilatation of the veins may also be observed in forced expiration, while in forced inspiration they become emptied.

The venous pulse is characterized by a very quick contraction, from the centre to the periphery, of the part of the vein lying on the plane of the optic disk, synchronous with the systole of the heart; and by a dilatation proceeding in the opposite direction, synchronous with the diastole of the heart.

The contraction of the vein, to the extent of one-fourth or one-third of its transverse measurement, occurs rapidly, the dilatation slowly; and the period of rest coincides with the time of greatest dilatation. The pulsation is not regular, but will often go on continuously for from three to five minutes, and then for fifteen minutes may wholly disappear.

It is observed by Jaeger that the appearance of the venous pulse is essentially altered, according as the plane of movement of the pulsating portion of the vessel may be parallel, or perpendicular, to the surface of the optic disk. In the first case the curvature of the whole vein remains undisturbed; and its outer side approaches to, and recedes from, the other. The moving portion does not approach the other, during the systole, simultaneously in its whole extent, but in a direction from the centre of the nerve towards the periphery, the vein then, for a moment, appearing uniformly narrowed. In the diastole the pulsating side of the vessel recedes from the other in a direction from the periphery towards the centre, and the vein for a short time appears uniformly broad. The pulsating portion is of the same or a somewhat darker colour than the rest of the vein, and shows no change of tint during the impulses. In the second form of venous pulse there is no change in the breadth of the pulsating portion; but the anterior wall approaches and recedes from the posterior in a manner chiefly to be recognized by change of colour. The vein, during the diastole, assumes an uniform dark aspect in its whole extent, and this changes, in the pulsating part, during the systole, to a lighter red; as if, during the narrowing of the vessel, the lighter colour passed quickly from the point of emergence towards the branches, and during the dilatation, back again from the latter to the former.

Among the appearances presented by the veins, Jaeger makes mention of a blood stasis. This is only seen immediately within the angular curvature of a vein at its point of entrance at the centre of the optic nerve; and appears as an oscillating cone of blood, by which the vessel inclosing it is considerably dilated, and rendered dark-coloured, as also happens in common venous pulsation. The movement inwards is synchronous with the diastole, the movement outwards with the systole of the arteries.

The arterial pulse, in healthy eyes, can only be produced artificially, by compression; and, indeed, by steadily increasing compression. In very strong pressure it appears as a jerking movement, which extends to all the chief branches of the arteries, and sometimes over the boundary of the papilla. In the strongest pressure it wholly disappears.

The arterial pulse is characterized by an uniform pulsatile dilatation of the parts of the arteries lying on the plane of the nerve-surface, synchronous with the systole of the heart.

There is in the arterial pulse no visible curvature of the vessels, but a simultaneous sudden dilatation of all the pulsating portions, to the extent of about one-third their transverse measurements. The dilatation happens quickly, the contraction slowly, and the period of rest occurs at the time of greatest dilatation. At the same time the veins, so far as they lie upon the nerve, are either wholly compressed, or else they exhibit at its margin an effort at venous pulse, in which, naturally, the distention of the artery coincides with the collapse of the vein.

The nerve-entrance and its vessels in the lower animals have been examined by van Trigt, and show many peculiarities; so that it is often possible, by a glance at the vascular distribution upon the optic disk, to determine the species to which the beast belongs. According to van Trigt, the tapetum appears as a greenish metallic glistening surface, marked with blue and gold-coloured spots and clouds, passing over, through different tints of blue and purple, to the dark pigment of the choroid, which is, during life, of a brownish red.

"At the lower edge of this strongly reflecting surface the entrance of the optic nerve appears as a peculiarly luminous disk, of a clear yellow colour, and surrounded by a purple pigment margin. In dogs and cats it presents also a dimple, which again in cats is surrounded by other smaller ones. From the optic nerve emerge the twigs of the arteria centralis, and in cats these emerge at the periphery and curve round the outer margin of the nerve, so as to surround it with a corona.

"In dogs, a large number of small arteries come into view at the periphery of the nerve; and some larger veins, that are sometimes united into a complete ring by anastomosis, and that penetrate into the depth of the nerve towards the centre. The dark red vessels are very beautifully and clearly seen upon the golden-green ground, so that the smallest of them, and under favourable circumstances even the capillary vessels, are visible. In dogs and cats the vessels of the choroid, in the depth of that membrane, may be seen in those parts not covered by tapetum.

"In common rabbits, which have no tapetum, and eyes rich in pigment, the field of vision is much less strongly illuminated. In them the entrance of the nerve appears white, and as though phosphorescent, and from it proceed, to the right and left, bundles of white strongly reflecting fibres, that at first lie closely together, but presently diverge, and become very conspicuous upon the subjacent dark brown pigment. The central arteries, which are visible to some depth in the nerve, divide also into two bundles, which accompany the above-mentioned fibres, and lie, sometimes much interlaced, upon their surface.

"The entrance of the optic nerve is commonly found a little within or in front of the vertical meridian of the fundus, and at the upper boundary of the field of ophthalmoscopic vision. It exhibits at its centre a funnel-shaped or navel-like depression; and, from its circular white disk, fibres of a satin-like lustre radiate in all directions, but chiefly in two lateral bundles. The parts to which these bundles proceed are of most striking aspect; since the radiation in other directions resembles only a small shining circlet, that surrounds the optic disk, and is soon lost in the red colour of the background.

"In white rabbits, in which abundant light is reflected from the choroidal vessels and the sclerotic, and much light also penetrates the sclerotic from without, the choroidal vessels are very clearly apparent. In looking directly backwards, they appear as closely packed, parallel, light red, scarcely branching lines, that traverse the dead white sclerotic from the periphery to the centre. By looking into the eye from one side, these lines, radiating from a point, may be recognized as venæ vorticosæ. Here and there will be visible between them a dull grey mark (according to Liebreich, the point at which a choroidal vessel penetrates the sclerotic).

"In an owl, after the instillation of atropine, the whole fundus appeared pale green, moderately reflecting, with fine, closely-packed yellowish-red vessels, ramifying irregularly over it. But most conspicuous was the *pecten,* peculiar to the eyes of birds, and appearing as a movable, wave-shaped prominence. This organ, whose nature and purpose is little understood, is studded with dark pigment, and may be seen to extend forwards from the deeper parts of the eye towards the lens; and, in good illumination, to possess fine transparent blood-vessels. Of the optic disk there was only visible a small, dead white, sharply-defined portion, behind the margin of the *pecten;* and the vessels of the disk were not visible." (*See* van Trigt's Dissertation, translated into German by Schauenburg, pp. 40—42.)

In the eye of a dog, van Trigt observed a venous pulse of this kind; that all the anastomosing vessels, already described as uniting into a ring, more or less perfect, from time to time became suddenly pale and wholly invisible, without the phenomenon being associated with any movement of the globe, or any perceptible effort whatever.

In the eyes of oxen, H. Müller found a whitish peg-like projection, coming into the vitreous body from the entrance of the nerve, and sending forwards a thread-shaped prolongation towards the lens. This, according to Müller, is a vestige of the artery of the capsule, that once passed through the hyaloid canal. In ophthalmoscopic examination, this structure appears as a more or less white streak; and it may also be easily perceived by making a section of the eye.

II. THE RETINA AND MACULA LUTEA.

That the retina exercises an influence upon the colour of the fundus oculi has been generally acknowledged, since the admirable researches of Professor Coccius. These researches proved the retina not to be transparent, but only in a high degree translucent, and taught also the different conditions under which it may become visible. The pigmentation of the choroid is what chiefly determines the visibility of the retina; and the less is its degree, so much the more red will be the fundus, and so much the less will the retina be apparent. It certainly will somewhat damp the subjacent colour; but, when itself bright and clear, this effect will be but trifling. But the richer the choroid is in pigment, so much the more plainly the retina will appear as a light grey membrane. It is seen most clearly in persons with dark pigment, as a bluish film over a dark reddish-brown ground. To illustrate this by an example, Coccius says,—" If moistened tissue-paper be placed upon a red, and also upon a brown ground, side by side, and compared, the incomplete transparency of the covering will be more apparent upon the latter than upon the former." The transparency of the retina is also modified by differences in its structure dependent upon age and constitution, and Coccius has found that in delicate or young persons, it is more transparent than in robust and old ones, with irides of the same colour. Moreover, in judging of the state of the retina, optical differences must be taken into account. The more brilliant the illumination, the more visible will be the proper colour and incomplete transparency of the retina, especially in eyes rich in pigment; but even in eyes that are less rich there may be seen (in the inverted image) fine bright fibres that radiate from the nerve-entrance to the periphery, and there disappear; being especially visible where they cross the retinal vessels, and have them for a background. Lastly, it may be observed that the retina is more transparent at its periphery than in the neighbourhood of the nerve-entrance, where its fibrous texture is most dense.

The vessels of the retina are but the continuation of those that issue from the optic papilla. Towards the periphery they diminish regularly in size, and form an extremely characteristic ramification, that affords, especially by its contrast to the peculiar vascular system of the choroid, where this is visible, a definite standard by which to estimate the seat and extent of material changes in the fundus of the eye. The branches of the retinal vessels can be followed to an extreme fineness, and especially those of the darker coloured veins; but the small twigs ultimately disappear against the yellowish-red background. They become clearly visible, however, if there be a deficiency of choroidal pigment, or in the presence of light-coloured sub-retinal exudation; and they might then easily lead to the idea of an anomalous vascular development. The proper capillaries of the retinal vessels form a moderately wide network, and cannot, of course, be seen in the healthy eye with any degree of magnifying power that is attainable with the ophthalmoscope. In abnormal vascular development, it is possible that they may be perceived in the aggregate, by increased redness of the fundus.

Of the layers of the retina there is only one, the layer of nerve-fibres of Liebreich, that can be separately recognized. It appears to produce, almost alone, the small share of the retina in the image of the background of the eye; namely, the already-mentioned greyish film that, especially in dark eyes, appears to rest upon the surface, and that, in young persons, possesses a somewhat fatty lustre. From the peculiar relation of this film to the retinal vessels, and from its total absence in the neighbourhood of the macula lutea, Liebreich traces its source to the nerve-fibres, in their gradual distribution over the periphery. In the erect image, no sufficient general view of the film can be obtained; but the single bundles of fibres are discernible as fine interwoven lines, having generally a radiating arrangement.

Senile Changes.—"These affect chiefly the interfibrillar connecting tissue. The radiating fibres become turbid from molecular detritus, and give to the retina, when viewed from before, a marbled appearance, that is especially visible in the dead subject. Moreover it is usual to find, in the greyheaded, scattered, strongly-refracting, globular glass-like particles, which are sometimes present in such abundance that the retina appears spotted over with white. The membrana limitans retinæ is also, as a rule, rendered turbid by the deposit of organic molecular masses, often collected into figures of various outline. Atheroma of the vessels is occasionally discovered."—Stellwag. (See also von Wedl, "Atlas der path. Histologie," &c.)

THE MACULA LUTEA.

In order to see this clearly, it is necessary to use a plane mirror, with a concave lens behind it (Helmholtz's, Coccius's, or the instrument of Epkens & Donders). As an object of vision, the flame itself may be used, or the micrometer of Donders's ophthalmoscope. The observed eye sees the selected object reflected in the mirror, and the patient is directed to accommodate for this mirror image, and to fix his gaze steadily upon some particular portion of it. The observer will then see a perfect inverted image of the object upon the retina of the eye examined, and the part of the object that is specially looked at by the patient will have its image upon the fovea centralis. Should this at first be too faint for observation, the patient must be directed to move his gaze sometimes to this and sometimes to that part of the object, so that the corresponding small reflection of the retinal image may also change its position. For the easier discovery of the fovea, Coccius recommends the use, as a guide, of the small image of the flame, reflected from the corneal surface of the eye examined. From this image the fovea will appear but little distant, either inwards or outwards.

The macula lutea lies to the outer side of the nerve, at about two diameters of its disk distant from it, and somewhat lower in horizontal position. It usually differs in no respect from the surrounding retina. As already observed, there are in its neighbourhood no large retinal vessels; from which cause, as well as from a denser pigment-layer in the stroma and epithelium of the choroid, it often happens that in feeble illumination the vicinity of the macula appears somewhat dark, as if the fovea were surrounded by a dim circular halo.

The fovea, described by Donders as the point of clearest vision, appears, according to Helmholtz, as a small bright speck of transversely oval form, according to Coccius mostly as a half-moon, or crescent, sometimes as a small star, rarely as a small snout-shaped prominence; according to Liebreich as a small bright point, or as a circle, or as a little hook changing its place in the circumference of a circle, in a single case as a luminous tuft, that assumed different degrees of glistening by the use of different reflectors.

According to Liebreich, however, "it is possible to recognize with the ophthalmoscope, and to define sharply, not only the fovea centralis, but also the yellow-tinted portion of retina in its neighbourhood, and the part that is histologically distinguished from the rest by the absence of a continuous stratum of nerve-fibres. By examining in the inverted image the darkly pigmented eyes of young people, and by making slight movements of the mirror, the film due to the presence of the nerve-fibres may be seen to surround a circular, or oval, or somewhat angular spot, against which it abruptly terminates. This spot, the horizontal diameter of which is somewhat larger than that of the papilla, is lustreless, and the choroid behind it contains somewhat more pigment than at other parts. In its centre, when the magnifying power is sufficient, may be seen a small bright point,—the fovea centralis, surrounded by a rust-coloured halo, that rapidly diminishes in distinctness towards the periphery.

"When the ocular fundus is of brighter colour, the layer of nerve-fibres is less distinctly marked, and in older persons it possesses less lustre. The clearness with which it defines the dull spot is naturally considerably diminished, but is never altogether lost. The yellow tint of the retina produces, against a dark brownish-red background, a more rust-brown halo around the foramen centrale; while the latter, in a bright-red ground, appears so red itself as to resemble the result of an extravasation. The diameter of the halo varies much; from being scarcely visible, it may cover a third of the whole macula lutea; and the yellow colour cannot be traced so far with the ophthalmoscope as in anatomical examination of a recently extirpated eye; or, therefore, over the whole extent to which it exists in the living subject.

"It is evident, from the foregoing, that the observer who wishes to see this structure, which is not very readily discernible, must, in the first instance, be careful to select suitable cases; and, having succeeded with them, he will be prepared to succeed under less favourable conditions. It is necessary to use the inverted image, and the highest magnifying power that is attainable."

III. THE CHOROID.

In examining the fundus oculi with the ophthalmoscope, the red colour is the first and most remarkable appearance. This must be ascribed to the reflection of red light from the vascular system of the retina and choroid; and especially from the numerous capillaries on the inner side of the latter.

The red colour of the fundus is not always the same, but presents in outline, tint, and brightness, the greatest variations; caused by the manner of illumination, the age of the person examined, the transparency of the retina, and, above all, by the pigmentation of the eye. With regard to the influence of illumination, it is sufficient to observe that, in a strong light, it being supposed that the pigment-layer is not present in its highest degree of development, there will be no discoverable difference in the brightness of different parts of the fundus; while, in a weaker light, this brightness will diminish from the entrance of the nerve to the margin of the retina. The influence of age is seen so far as this, that the red colour is generally brighter in young and delicate persons than in the older and more robust. The influence of the retina has been already described, and there remains to consider only the most important element, the pigmentation of the eye.

The most common condition is for the pigment-layer not to form so close a covering of brown as would suffice wholly to conceal the vasa vorticosa, and, with them, the small quantities of light reflected from the deeper parts of the structure, but only to mingle with the red of the subjacent vessels a tint ranging from greyish-yellow to coffee-brown; and to give, in combination with the fine capillary web, that peculiar granular appearance that is especially manifest in the erect image when much magnified.

The fundus appears of a more or less bright red when the pigment lies more between the vessels than upon them. When, moreover, it is only present in small quantity, red rays are reflected from the capillary net.

The red is, however, most brilliant when, as is the case in blonde persons, the pigment-layer is very trifling. We may then see "the fine ciliary arteries enter in the neighbourhood of the macula lutea, ramify in a very winding course, and partly pass on into the more direct vasa vorticosa. These latter can be easily followed, uniting into continually larger branches, until they vanish, as if cut off, in a dark trunk in the equatorial plane of the globe. To the same spot converge also from the front the anterior, usually finer veins, belonging to the same vortex." In rare cases and with greater difficulty it is sometimes possible to trace the anterior twigs of the ciliary arteries in their course in front of the veins.

In contrast to this brilliant red we find a prevailing brown colour of the fundus, through which no trace of the choroidal veins can be discerned, in cases of especially dark pigment-layer, such as sometimes present themselves in persons with deep black hair. The vasa vorticosa may be seen clearly, but the meshes of the venous network will be speckled with more or less dark, or grey, or sometimes lustrous violet patches,—almost constantly in brunettes with blue, very often in brunettes with brown irides.

Cases moreover occur, in which the choroid is so loaded with dark brown or nearly black pigment, that the pupil scarcely becomes luminous under the ophthalmoscope, or at least is not red, but of a dull greyish lustre. The fundus will then appear not red or reddish-brown, but almost black, with a superimposed bluish film, that is occasioned by the retina. Liebreich has seen this very strikingly, once in a case of cyanosis bulbi, and once in a negro.

In Liebreich's Atlas, Plate XII. Fig. 3, there is a drawing of one of these cases of excessive pigmentation, to which the following description is appended:—

"Herr S., aged 21 years, had bright chestnut-coloured curly hair, with light eyebrows and eyelashes, alike on both sides. The iris of his left eye was a bright brown, that of the right a very dark brown, so nearly black that it could not be distinguished from the pupil without close examination. Around the cornea, at some distance from its margin, the sclerotic was studded by groups of dark grey spots, passing into violet.

"On ophthalmoscopic examination the pupil shone but faintly, and presented a dark red tint. On looking straight into the eye, the reflection disappeared almost entirely; and, on looking inwards towards the nerve, it became faintly whitish. On examination of the inverted image, the general surface appeared of a dark reddish-brown; and, with sufficient magnifying power, the fine granulation of the choroidal epithelium was seen as a greyish-brown stippling upon a dark red surface. In a few isolated spots choroidal vessels were faintly visible; but in one of the other cases (out of a total of three mentioned by the author), in which the pigmentation was still deeper, no trace of them could be perceived.

"Upon this dark background, the retinal vessels themselves appeared much darker than usual, and reflected little light from their surfaces. The presence of the retina, however, was marked by a bluish-grey film, and a peculiar lustre, that, in slight movements of the mirror, played over the surface around the macula lutea. The macula itself appeared almost black, and was surrounded by a very dark reddish-brown halo, due to the yellow tint of the retina itself, which, even on a brighter ground, increases the depth of colour at this point. The papilla generally was reddish, its external margin sharply defined, the vessels emerging nearly from the centre, and surrounded, at their point of exit, by bundles of close black lines, that covered the central third of the disk, and caused that portion to appear black, which in a normal eye is the most luminous. At the periphery also, just within the border on the outer side, there was a little pigment, which appeared to be seated deeply upon the lamina cribrosa, while the central pigment-bundles were distinctly upon the surface of the papilla, and extending on to the nerve-fibres.

"I will also mention that the eye, although myopic, possessed good vision; and, the other being amblyopic, the first only was used."

Isolated black spots, formed by a group of perfectly black epithelial cells, may be found in normal eyes, and have no pathological signification. Liebreich describes a spot of this kind, in the vicinity of the macula lutea of a perfectly healthy eye. It was about the size of the nerve-entrance, somewhat angular, perfectly black, and rendered its retinal covering apparent as a bluish film. In the neighbourhood of the optic disk, Liebreich has also found, instead of the common crescentic line, or small points, that have their seat in the stroma of the choroid, a perfectly black circlet, or a crescent, of the breadth of the nerve itself, that could be positively referred to the epithelial layer. Sometimes, too, there may be seen, at the extreme periphery of the ophthalmoscopic image, parallel to the ora serrata, and bounded on either side by indented lines, a delicate zone of pigment, situated in the epithelium, and causing an otherwise bright fundus to appear at that part dark, or even black.

The cells forming the epithelial layer of the choroid may, according to Liebreich, be recognized after some practice. When not visible over the whole fundus, they will almost always be found over the greater portion, and especially near the region of the equator. To obtain the necessary magnifying power, the observer must use the inverted image, with a weak objective, and comparatively strong ocular lenses. Very dark eyes are unsuited for this examination; since in them not only the state of the cells themselves, but the inferior illumination of the ground, and the comparative conspicuousness of the retina, exert a disturbing influence. Liebreich wisely counsels, however, that an inspection of the pigment-cells, when possible, should never be neglected; since a knowledge of them is of high importance in the differential diagnosis of various morbid changes, as well as in determining the precise position of pathological formations in the retina and choroid. The pigment-layer, while by its colour, position, and relation to neighbouring parts, it forms a chief object of ophthalmoscopic investigation, and allows this investigation to be conducted with great accuracy, is yet an impediment in many respects, and especially so to observation of the membrana chorio-capillaris.

In incompleteness or absence of the inner pigment-layer, the larger choroidal vessels, chiefly seated in the external vascular stratum, are rendered visible. They are usually separated by interspaces containing a greater or less quantity of pigment-granules; and, if this pigment be wanting, the sclerotic itself will be seen. Of these vessels Jaeger gives the following description :—"The choroidal vessels, thus rendered visible, clearly and sharply defined, present an orange-yellow colour, which, however, according to the tint and influence of the stroma pigment lying between and around them, may pass into a yellowish-red or cinnabar; or, by contrasting with or being covered by translucent exudations, may assume a bright-yellow appearance. These vessels are characterized by their position behind those of the retina, their direction towards the periphery, their peculiar winding course, their frequent divisions and anastomoses, their numerous intertwinings and consequent disappearances, their breadth, exceeding that of the retinal vessels, and by the absence of a central bright line with dark margins; so that they present the appearance of ribbon-like bands. The absence of a stronger reflection from their middle portions is due to the great dispersing power of the membrana chorio-capillaris, as well as of the choroidal stroma, in which they are imbedded. The vessels constituting the external layer of the choroid, and passing into the short ciliary arteries and veins, can be followed in their whole course, and sometimes to their origin. The arteries take the shortest path from the trunks that pierce the sclerotic, are seen in section as roundish central points, and give out transverse or obliquely-inclined branches. Towards the neighbourhood of the equator, the veins may be seen passing more or less directly towards the venæ vorticosæ, in which the union of many single radiating trunks gives rise to the formation of the well-known venous star or vortex."

With regard to the perception of the membrana chorio-capillaris (*membrana Ruyschiana*) in the living subject,—this structure, according to Liebreich, exercises only the smallest possible influence upon the colour of the fundus, mixing a pale orange with the intense red of the parts lying behind it. Even under a high magnifying power, and with the fullest ophthalmoscopic illumination, the details of a vascular net so faintly coloured can only be seen easily when it rests upon a pure white ground; with difficulty when the ground is a dull yellowish-red, or brownish-red, as in the intervascular spaces of brighter or darker pigment; with still more difficulty upon the shining red of the larger choroidal vessels; and cannot be seen at all when between it and the observer is interposed a layer, however thin, of pigment; such, for example, as the inner pigment-layer of the choroid.

In white rabbits, after long and laborious examination, Liebreich was able to follow the capillaries of the choroid to their finest ramifications. Complete immobility, intense illumination, high magnifying power, and entire absence of pigment, were united to facilitate the ophthalmoscopic examination. The small trunks of the capillary layer appeared, as they rested upon the larger vessels, as extremely fine, small, red points, from which radiated scarcely-coloured prolongations, to form a network, that could be traced over the large vessels and the white intervascular spaces. In these extremely difficult examinations, Liebreich was also able to watch the circulation in the choroidal veins. "In a vessel that had been for some time in perfect view, there would be seen a sudden increase of action, the blood commencing to pour through it with great rapidity. A short twig, serving to unite two contiguous veins, would become pale, and would exhibit only a fine red line as an indication of the channel through which red corpuscles had passed; and, at the same time, a cone of blood would be urged, by rythmical pulsations, to enter it at the other end, and would eventually succeed; so that blood would stream forcibly through the short branch in a direction opposed to that of its former current; until, after some time, the original conditions would be restored. This sudden emptying appears in many parts of the choroid, especially at the spherical or pointed origins of the veins; which, from this cause, may appear shortened, as I had often observed, even before I saw the circulation. The difficulty of this investigation, which, however frequently it may be overcome, recurs in every new experiment, depends, I believe, chiefly upon two conditions:—First, upon the necessary intensity of the illumination, which causes the reflection, from the retina and the walls of the vessels, of an amount of light that impedes observation (and that should be diminished by such an arrangement of the instrument as may rather exhibit the vessels by transmitted light); and, secondly, that, in consequence of the clearness with which the vessels are seen in merely approximative accommodation, the observer has no guide to that accurate adjustment of his eye that is necessary in order to observe the circulation."

Senile Changes.—"These, like similar changes in other parts of the body, are developed earlier or later in different persons; and, at the same period of life, may have attained a higher or lower degree of development. The pigment suffers most remarkably. At various parts of the parenchyma, but chiefly upon the surface, it becomes collected together, and forms larger or smaller irregular brown or black spots with granular margins, which stand in relief upon the background. In most cases, these spots are scattered without order, but sometimes they form arborescent figures, which accompany the vessels lengthways. The chief part of the pigment disappears, and the remainder changes its colour to a light brown, tan, rusty yellow, or smutty brownish yellow. It is first lost in the immediate neighbourhood of the vessels forming the vortices, and remains longer in the intervals between them. When the involution is not very far advanced, we see the whole thickness of the choroid occupied by arborescent, ramifying, frequently anastomosing, bright, pigmentless streaks, that unite into star-like figures, and precisely correspond to the vasa vorticosa. In the meshes of this coarse network, the choroid still remains somewhat better provided with pigment; and the surface therefore appears covered with spots, which perfectly coincide in shape with the intervascular spaces, and which vary in tint, through all shades of brown, to smutty yellowish grey. In more advanced stages, the pigment disappears from the intervals almost entirely; and the choroid, over larger or smaller spaces, is seen of a dirty greyish white, and so transparent as to display the subjacent sclerotic.

"The elastic lamina appears thickened, either in places, or over the whole surface of the choroid, in such a manner that it is perceptible to the naked eye as a distinct pellicle, and can easily be torn away in large shreds. It is usually somewhat turbid, and always dry, hard, and brittle, so as readily to split in radii. It frequently displays a cloudy opacity beneath and between the masses of altered pigment, and sometimes fine granulations, that are intimately united with its structure. The conjoined chorio-capillaris and tunica vasculosa become also drier, harder, and more brittle; and the whole membrane tears easily. In far advanced involution, the capillary network partially disappears; and even the trunks of the tunica vasculosa become partly wasted. More often, however, they are still pervious, but atheromatous and much enlarged.

"The ophthalmoscopic image of the fundus oculi, under such conditions, becomes essentially modified. It is self-evident that a preponderating influence must be exerted by the changes in the pigment, which becomes more conspicuous against neighbouring parts, and displays its own colours more strongly. In those places, therefore, where the pigment molecules are altered in their arrangement within the cells, or where their relative quantity is much increased, the above described dark spots will be conspicuously visible.

"The whole fundus will also appear traversed by a network of ramifying and apparently interlacing bright streaks, which accurately correspond with the arrangement of the vessels of the t. vasculosa. Within the streaks, the vessels themselves are sometimes visible. They exactly traverse the axis of a streak, and appear bordered on both sides by a bright fringe. The spaces between the streaks are occupied by sharply-defined blackish brown or dirty brownish yellow spots, upon which the superimposed retina may be seen, especially by oblique illumination, as a cloudy film;—mixing more or less greyish white with the spots, and somewhat altering their tint. At times, the streaks and dark interspaces disappear almost entirely, and are replaced by irregular and badly-defined patches of white or dirty yellow, giving the impression that the sclerotic itself is exposed to view. In isolated cases it is possible to observe, under the elastic lamina, spherical vacant spaces left by the removal of pigment, and producing, in extreme development of the condition, the appearance of a fine network with roundish interstices." (Stellwag.)

IV. THE SCLEROTIC.

Only under the most favourable circumstances, as in white rabbits, but seldom even in perfectly albinotic men, is it possible to see through the substance of the sclerotic to its posterior surface. As already observed, the greyish spots seen in the fundus oculi of a white rabbit, indicate the points at which the short ciliary vessels perforate the sclerotic. The long ciliary vessels penetrate this tunic very obliquely, and occasion, therefore, a marked streak or line in its substance, before they emerge upon its ocular or internal surface. They appear as long brownish red stripes, passing from behind forwards on both sides of the globe, and continuous with the clearly-seen trunk of the emerging vessel.

V. THE REFRACTING MEDIA.

The examination of the refracting media is best conducted by throwing light into the eye with a plane mirror only. For minute investigations, a convex lens may be placed close behind the mirror as a magnifier.

In general, in normal conditions, the result of the examination is simply negative; but it must be remarked that, sometimes, small particles, more or less translucent, are perceived on the surface of the cornea. These are small scattered particles of mucus, or sometimes slowly-ascending air bubbles. In order to remove them, the patient is directed to close and reopen the eyelids, or the upper lid is moved over the corneal surface; and in either case, the specks, if not produced by disease of the substance of the cornea, will be removed, and disappear. Moreover, prior to ophthalmoscopic examination, the polish of the cornea should be carefully tested by incident light, in order that inequalities of surface may not be mistaken for wave-lines in the lens.

A perfectly clear crystalline lens will seldom be found in persons somewhat advanced in life; but it appears that only linear opacities indicate the commencement of cataract. For exact examination of the lens, the use of lateral illumination must never be omitted.

The vitreous body, like the lens, can only be the object of ophthalmoscopic examination in its diseased conditions, in which, however, the examination is of great importance. Formerly, all the various particles floating in the field of vision were classed together under the general name of muscæ volitantes, and were attributed to the presence of microscopic corpuscles. It has now become necessary, however, accurately to distinguish muscæ, properly so called, from floating opacities in the vitreous body. The former are due to the essential microscopic elements of the structure, and are found in the healthy condition; the latter are purely pathological formations, and these only possess a sufficient magnitude to be seen by means of the ophthalmoscope.

In Dr. Heymann's description of his aut-ophthalmoscope, he enters into a minute account of the appearances visible in his own eyes. I do not discover that he has made out any point of structure not previously described, except that the vessels of the retina terminate in a distinct circle of loops around the yellow spot. With the recently acquired facilities for viewing the yellow spot, this fact, if confirmed by more extended observation, may perhaps be made to serve as an ophthalmoscopic test of the existence of retinitis, in which an increased vascular development would be very likely to occur. Dr. Heymann also calls attention to the greater transparency of the retina in the same region, shown by the increased visibility of the finely-granular appearance due to the epithelial cells of the subjacent choroid. He mentions the effect of changes in the quantity of light upon the apparent tint of the fundus, and points out that this tint naturally varies, in accordance with the decreasing thickness of the retina towards its periphery, and becomes somewhat brighter from the optic disk to the margin of the field. To this, the colouration of the yellow spot is, of course, an exception.

Dr. Heymann has succeeded in establishing some interesting facts bearing upon the physiology of the eye; although, with great modesty, he professes to have done but little, in comparison with the field that still remains unexplored. He has commenced investigating the movements of the eyeball, and the functions of the retina.

When the image of the fundus is fairly and steadily in view, it will be seen to undergo slight tremulous movements, of which the observer has no consciousness from any other sense. In Dr. Heymann's own eye the movements are horizontal, and are about as extensive as the diameter of the nerve disk, which, twelve times magnified, measures about 1 centimetre. The regularity of the movements is still a matter of uncertainty; but some experiments made to test it, in inclined positions of the head and instrument, afforded incidental proof (of what is now otherwise well established) that the meridians of the eye follow the movements of the head, and do not, as was formerly supposed, remain stationary.

Another visible ocular movement is that of accommodation. Dr. Heymann was led to observe it by seeing that the apparent size of the vessels of his optic disk and retina frequently changed during an examination. At the beginning, they were usually larger than they appeared after a time. It has still to be determined whether the alteration was due to a change in the observed or the observing eye; or, what is very possible, to a change in both. Dr. Heymann inclines to attribute it to a change in the refraction of the eye observed.

Movements affecting only a part of the image were limited to the vessels, and were occasioned by the movements of the blood in them. The known phenomena of the venous pulse, and of the arterial pulse, produced by pressure, can be observed by the aut-ophthalmoscope, with some care about the displacement of the globe, and consequent loss of the image, that pressure tends to produce.

The retinal function has been tested both quantitatively and qualitatively. The first observations had reference to the extent of the sensitive surface; the second, to the different sensitiveness of different spots.

The quantitative testing is only practicable with the instrument of Coccius, and shows how far the sensitive portion of the retina encroaches upon the optic disk. When the papilla alone is illuminated, the image of the flame is not visible; but it comes into view as soon as it falls upon a sensitive portion of the surface. Hence, by bringing into view the margin of the disk, the image of the flame will appear interrupted at the point where the retinal function ceases.

The qualitative testing has been attempted by casting the image of a small object upon different parts of the retina, but there are many difficulties to be overcome before the results obtained can be considered trustworthy. I learn from Dr. Heymann that he is pursuing his inquiries, and that he is also seeking to find the smallest point of perception on the retina, the varieties of illumination in artificial astigmatism, and other matters. He informs me, further, that Professors von Gräfe, Donders, Coccius, Knapp, Rothmund, and others, are using his instrument to carry out similar observations.

It is evident, I think, that the possessor of an aut-ophthalmoscope will be much tempted to subject his own eyes to prolonged examinations, such as no patient would undergo at the hands of a surgeon. On this account the apparatus is probably a dangerous one. Dr. Heymann speaks of secondary images, colour phantoms on the dazzled portions of his retina, which I should myself prefer not to experience; and I hear from Dr. Giraud-Teulon that he has found it necessary to lay aside his instrument. The fundus of one's own eye is, beyond all doubt, a highly interesting object; but the evidence now in existence tends to show that natural curiosity concerning it may be gratified at too high a cost.

It would be of great value to determine, if possible, the degree in which the intra-ocular circulation is liable to be affected by various conditions of the system; by differences in the quantity and quality of the blood, and by differences in its distribution as governed by the nervous system. It is unquestionable that the fundus oculi shares in the general pallor produced by anæmia, although it is probable that the impaired vision of the anæmic is chiefly due to feeble and uncertain action of the ciliary muscle. Dr. Hughlings Jackson has used the ophthalmoscope in brain disease; not only in cases attended by actual amaurosis, but in cases of trifling defects of sight; as, for instance, after a paroxysm of epilepsy; and once during a paroxysm. He has recorded one case in which changes in the optic disk (absolute anæmia) were well marked during a fit of epileptiform convulsions, induced by placing the patient erect; he has also examined the retina in a case of paralysis of the cervical sympathetic, but did not discover any changes in the circulation.

Dr. Hughlings Jackson has examined the retina during sleep (atropine being used), and has found that, in this condition, the arteries are slightly smaller, and the veins a little larger, than at other times. He has also examined the retina in tubercular meningitis in children, and in acute cerebral disease in adults, and thinks that the ophthalmoscope will afford considerable information as to the state of the cerebral vessels in brain disease; and, indeed, that we may, by its help, study generally the condition of nerve and blood-vessel in many constitutional diseases. For instance, when "head symptoms" come on in fever, we may speak more precisely as to their cause if we look at the retinal arteries and veins. We ought, he conceives, besides paying the utmost attention to the defects of the organ, to take the opportunity of studying tissues, as the choroid (the pia mater of the eye), the retina (a nerve termination), and an artery and a vein, so strangely brought from their long concealment by the ophthalmoscope.

Dr. Hughlings Jackson has looked at the retina immediately after slow death, and found the disks quite white, both arteries and veins being empty. The same condition was found in the retinæ of a kitten killed by a wound of the heart. He has likewise suggested that the action of poisons on blood-vessels may be studied by observing their effect on the arteries of the retinæ; and that in the same way we may form some idea as to the effect, on the cerebral circulation, of strangulation, bleeding, and ligature of the vessels of the neck.

Dr. Hughlings Jackson has described a form of temporary failure of sight, an epileptiform amaurosis. It sometimes occurs alone, sometimes with slight giddiness, and sometimes precedes a more or less complete epileptic paroxysm. In none of these cases has he been able to make an ophthalmoscopic examination. He imagines that when a fit of epilepsy begins by this temporary amaurosis and giddiness, that the cause of the symptoms may be defective circulation (temporary) in the parts supplied by the internal carotids only—that is, the anterior parts of the brain.

Temporary defects of sight, he says, are frequent in cases of epileptiform convulsions affecting one side of the body, but are due to very different causes. Dr. Hughlings Jackson has recorded cases of temporary coloured vision preceding epilepsy. These various conditions, and the possibilities of extended utility for the ophthalmoscope that they suggest, are certainly worthy of the attention of medical practitioners.

SECTION THE FOURTH.

THE OPHTHALMOSCOPIC APPEARANCES OF DISEASED EYES.

I. THE OPTIC NERVE AND ITS VESSELS.

I. THE OPTIC NERVE.

ON account of the intimate connection between the optic nerve and the retina, it is not surprising that a great part of the affections of the former should extend also to the latter. There are, however, a number of changes peculiar to the nerve itself; and their early recognition is important, since they are all dangerous to vision. Such early recognition, in the living eye, has now been rendered possible by the ophthalmoscope; and the intra-ocular extremity of the nerve may be regarded in some degree as a second pupil, brought within reach of observation; possessing, like the opening in the iris, its own proper semiotics, and therefore requiring essentially local study.

Leaving out of consideration the occurrence of small pigment spots, small punctiform hæmorrhages, and the exceptional presence, here and there, of crystals of cholesterine upon the papilla, there remain for present consideration chiefly changes of level of the nerve entrance, opacity of the nerve fibres, and atrophy of the nerve; while, in the subsequent description of other diseased conditions, the nerve-changes associated with them will be noticed in their proper places.

1. INFLAMMATION OF THE OPTIC NERVE.

(*Liebreich's Atlas, Pl.* xi., *Figs.* 6—9.)

Optic neuritis, according to Stellwag, occurs chiefly by the extension of the inflammatory process from neighbouring parts; and also, in many cases, primarily, in consequence of some traumatic or functional source of irritation, either general, such as pyæmia or tuberculosis, or affecting the circulation in the ophthalmic artery or vein. It is characterized by change of colour, opacity, indistinct limitation, great hyperæmia and ecchymosis of the optic disk, dilatations of the veins, and mistiness, with contraction or interruption of the field of vision. "The direct symptoms, however, are sometimes entirely wanting, since the neuritis may either be limited for a time to the posterior parts of the nerve, or since, when the anterior portion is affected, the sympathy of the internal structures of the globe, and the consequent turbidity of the dioptric media, may render ophthalmoscopic examination impossible. Even when the necessary conditions for such an examination are present, the direct symptoms are not always sufficiently clear to afford grounds for a conclusive diagnosis. In the less severe inflammatory processes, with serous infiltration, and scanty development of nuclei and cells, the appearance of the nerve surface presents little change that can be appreciated by the low magnifying power afforded by the ophthalmoscope. It will often only appear discoloured by dirty greyish brown or greyish yellow tints, its choroidal margin somewhat indistinct, and the central vessels more or less obscured. These alterations may be seen, not unfrequently, in eyes of normal function; and it is therefore only in combination with subjective signs that they can aid in the diagnosis of the disease.

"The ophthalmoscope affords greater certainty of the existence of optic neuritis, when the appearances indicated above are associated with very decided hyperæmia of the papilla, when this appears dotted or streaked with blood over its whole extent, the chief nerve fibrils dilated, covered with a network of small injected vessels, or surrounded by extravasated blood. In occasional cases the inflammation displays itself by a swelling of the whole papilla, or by the increased prominence of portions of it, so that they appear like hillocks upon the general surface.

"When neuritis of greater intensity, and occasioning an abundant formation of cells and nuclei on the surface of the disk, coincides with transparency of the media, its recognition, apart from the elevation of the disk, is scarcely more possible. The inflammatory product imparts its own peculiar colour and opacity to the nerve surface, the choroidal boundary is almost completely concealed, and the central vessels, in places, at least, are rendered invisible." In such cases, the retina will also suffer; as will be more fully considered under the head of Retinitis.

2. EXCAVATION OF THE PAPILLA.

(*Liebreich's Atlas, Pl.* xi., *Figs.* 1—5 *and* 10 & 11.)

One of the great difficulties of ophthalmoscopy consists in the right estimation of elevations and depressions; and the errors formerly made with regard to them, even by distinguished ophthalmoscopists, are very easily intelligible. The chief basis of our judgments about small bodies, the convergence of the two eyes, is lost in ophthalmoscopic examination; and the guidance afforded by one eye only is, in direct vision, very deceptive.

The conditions in which illusions about this matter originate, and the way in which they may be avoided, have been fully explained by A. Weber. Independently of the ophthalmoscope, circumstances peculiar to an inverted image are sources of error; and Weber found experimentally that an impressed seal, or an engraved signet, was deceptive in its appearance, in consequence of inversion of its shadows, and of the inexact accommodation of one eye.

The means by which these illusions can be avoided in ophthalmoscopy, and by which a correct estimate of the object can be gained, are, for the inverted image, the following:—*a*. By the movements in opposite directions of two points situated in different planes, when the eye either of the observer or the observed changes its position. If the convex lens be slightly moved in a direction perpendicular to its axis, the parts lying nearest to the observer will appear to move with the lens, and the parts more remote from him in the opposite direction. For example, if the object were an optic nerve, concave on its entire surface, the observer would see the yellow ring presently to be described, with the hook-like bending of the vessels at its margin, moving apparently to and fro in front of the central disk forming the background. *b*. By the use of prisms, which, according to their strength, produce the effect of a degree of ocular movement scarcely to be obtained in ophthalmoscopy. *c*. By causing the patient during the examination to accommodate for different distances, or by using convex lenses of different powers. The strongest lenses, which form near and small images, afford the most correct idea of the conditions. *d*. By moving the convex lens to and fro, and thus changing the position of the inverted image; so as to determine, by the earlier or later indistinctness or disappearance of its several parts, what is their relatively elevated or depressed position.

Although, by the above methods, the inverted image will in most cases afford perfectly certain conclusions, the question may yet be left doubtful, if the differences of position be very small. It is then necessary to have recourse to the erect image. The movements described in the last paragraph under *a*, which, in the inverted image, are somewhat complicated by the complete inversion of the field, may be distinguished in the erect image with far more exactness, both from its simplicity and from its greater enlargement. The erect image affords, moreover, two other very trustworthy guides for the estimation of elevations and depressions. The first is by the use of concave glasses of different powers. If a prominence be so great, that its summit stands in front of the plane of the posterior focus of the eye, then, according to the accommodation of the eye examined, and the refraction of the observer, either a very weak concave, or even none at all, will be required for the most elevated portion. On the contrary, if a depression be present, the strength of the concave lens must be increased in proportion to the depth of the cavity; and it will be easily perceived that this increase, even for the smallest changes, will not be inconsiderable, on account of the short focal distance of the human eye. The second guide is the direction of the shadows, which often affords the most certain information about the relative position of parts.

Lastly, according to Förster, a third guide is afforded in the examination of the erect image, under the widest possible dilatation of the pupil, by the *small* vessels that pass from above, from beneath, and from the outer side, over the margin of the papilla. "On account of their fineness, they must lie close to the surface of the nerve disk, as they would otherwise be concealed, or at least partly obscured; and it may therefore be presumed that their curvatures and changes of position follow those of the nerve surface itself. In excavation, these vessels almost always make a bend or curve in their passage over the margin of the disk; or they appear, in this situation, to be wholly cut off. If they are observed from the side opposite to that on which they cross the nerve margin (as, for example, if a vessel crossing the lower margin be looked down upon as much as possible from above), the union of the two portions may sometimes be observed. This would only be possible when they made a curve backwards at the point where their continuity seemed interrupted, or when they passed over a concave surface. If they ascended a ridge, such a method of examination would only conceal the lost portion more completely. Moreover, in one fortunately occurring case, in which a vessel passed in a horizontal direction over the inner margin of the disk, this vessel seemed to lie near the upper margin, when looked down upon as much as possible from above; and near the inferior margin, when looked up to as much as possible from below. If the optic disk were prominent, as from the effect of shadow it often seems to be, the reverse of all this would be the case. Further, it may be observed that the vessels terminate abruptly on the margin of the disk with a slightly convex contour, so that their terminations are of a darker red, and have sometimes a short lateral beak-shaped point. The convex contour corresponds to the prominence of the wall of the vessel, produced by the strong backward curvature. This curvature also produces the darker colour of the part; just as, normally, the central termination of a vein appears dark; and as, in retinitis, many of such dark points may sometimes be seen in one vein. The lateral beak-shaped or hook-like point of the apparent termination of the vein is chiefly seen in vessels that pass over the margin of the disk, not as radii, but in a somewhat oblique direction."

The signs characteristic of this kind of disease of the nerve are:—

a. The colour and shape of the optic disk.—The depression, extending often over the whole surface of the disk, yet spreads from the centre, and shows itself there by a brighter and more glistening colour against the less bright and less glistening periphery. The disease extends on all sides, but most rapidly towards the outer; and the inner, or nasal side, often appears for a long time normal. The choroidal margin, that is commonly only covered by a thin and irregular pigment layer, terminates undefinedly towards the scleral margin, and this, two or three times magnified, instead of a fine bright line, appears a broad, often yellowish-coloured ring, surrounding the whole disk. The proper nerve margin shows itself far more clearly than common; the nerve itself appears perfectly circular, and its colour, different in different cases, often presents a slight admixture of greenish-blue, or blue, with the ordinary tint. Towards the periphery this assumes a greyer tone, and at the extreme limit appears suddenly darkened. This shading, the sharp margin, and perfectly circular form, allow the disk to be recognized as cup-shaped at a single glance.

b. The appearance of the vessels.—When these are followed from the periphery towards the centre, they are seen to disappear suddenly at the edge of the depression as if cut off, while their apparent terminations make a short hook-shaped bend towards the excavation. If their continuations be sought, they may be found; but the part of the vessel traversing the disk will not be visibly united to the part traversing the retina.

Partial depressions, holes, are not unfrequently found in the disk, and they occupy the whole outer quadrant, or a smaller sector of this portion, more frequently than the middle of the papilla. The upper and under margins of such defects are rectilinear, and meet in an angle at the centre of the nerve disk. The colour of the hollow is always brighter than that of the remaining parts of the nerve; the margins, as a rule, are sharp. The retinal vessels terminate at the upper and under margins, from which they turn away either straight and abruptly, or, as is more common, in an oblique direction. The signification of these partial depressions is not yet ascertained; probably they have no pathological value; possibly they may be congenital.

Pathological Anatomy.—Excavation of the optic nerve forms by far the most important of the changes of the surface of the disk—changes which have been especially studied by H. Müller and von Ammon.

The alterations in the surface of the optic nerves may consist either of greater projection (prominence), or in levelling and depression (excavation). Increased projection of the disk may depend upon wasting of the external layers of the retina, with integrity of the nerve fibres forming the papilla, or upon increase in the bulk of the papilla by thickening of these fibres, or by infiltration with blood, exudations, cretaceous deposits (v. Gräfe and v. Ammon), or morbid growths.

Of the morbid depressions of the nerve, H. Müller believes it necessary to distinguish two varieties: levelling and depression from atrophy, and depression produced by pressure together with atrophy. Von Ammon limits the term excavation to the concavity of the degenerated lamina cribrosa, and distinguishes excavation of the body of the nerve as central wasting.

As distinguishing signs between the two forms that he describes, Müller mentions a considerable difference in the depressions. In pure atrophy, the depth of the floor of the excavation does not sink below the level of the choroid; but in the other form there appears a steep pit, of much greater depth, in which the lamina cribrosa, that in pure atrophy maintains its position, is pushed back more or less considerably, to the extent of 0·5 millimetre or more, and sometimes appears thickened anteriorly. In the second form, atrophy of the nerve is equally present, but the pit will be already deep when the degree of atrophy is small; and the latter is apparently only a secondary result of different affections of the choroid and retina, that assume the form of glaucoma more plainly, the more the results of pressure predominate.

As the principal cause of excavation of the nerve, Müller assigns increased pressure by the vitreous body, without denying that the same condition may be occasioned by traction from without, shrinking of exudations, and the like. To the latter would belong v. Gräfe's "amaurosis with excavation of the optic nerve," which he regards as a cerebral amaurosis, produced, in contrast to pressure, by traction upon the nerve trunk from without. With regard to this explanation, von Ammon thought it important to note that he always found the vessels of the trunk obliterated, by which cause alone a depression of the nerve surface, and a concavity of the lamina cribrosa, must be mechanically produced.

A short notice is required of the condition of the vessels upon the excavated papilla, and especially of the fact that the arteries often remain normal, when the veins exhibit the appearances already described. Förster gives an explanation of this circumstance, based upon anatomical differences, and says that the trunk of the arteria centralis retinæ first divides into its chief branches at the level of the retina. These branches remain there, even in retraction of the tissue on which they rest, and appear as if strained over the sclerotic opening. The veins, on the contrary, that first unite into one trunk deeper in the nerve, and that usually lie behind the arteries, bend back more readily, curve suddenly round the sharp ring, and appear, therefore, S-shaped, or even for a short time pass wholly out of sight. They first return to view deeper in the nerve, where they approach its axis, since they are then covered by transparent substance. If, in a sound eye, the veins had an arrangement resembling that of the arteries,—that is, if they united into one trunk upon the level of the retina,—they would, if the eye became diseased, still remain visible, even if somewhat obscured, in their passage to the centre. But when, in the sound eye, many venous branches emerge from the periphery of the papilla, and first unite into one trunk deeper in the nerve, we see, in the case of excavation, as many interrupted veins as there are branches passing over the periphery. The arteries also would show similar modifications, according to the manner of their distribution; and all the different appearances of the vessels about an excavated papilla may in this way be explained.

In eyes thus diseased, the point of exit of the vessels is commonly more internal, nearer the centre of the body, than is normally the case. Sometimes this point is removed almost to the inner margin of the papilla, and is therefore dislocated in the direction of the axis of the optic nerve. The reflection of light from a concavity is always on the side which the rays strike in a perpendicular direction; and hence the point of exit of the vessels is in such cases always the brightest, as well as the deepest, portion of the pit.

Very complete observations upon this subject have been made by Ed. Jaeger,—whose results, differing in some respects from those of others, are here subjoined.

At this point Dr. Zander quotes from Professor E. Jaeger nearly sixty paragraphs of extraordinary prolixity and tediousness. It would be easy, by the mere omission of repetitions and superfluous words, to condense them to half their bulk in translation, but even then they would be intolerable. I have determined, therefore, to substitute a brief summary of their contents :—

Professor E. Jaeger recognizes two chief forms of excavation of the optic nerve: the congenital, and the acquired. The former may be real, or apparent, or both combined; and the latter may depend upon atrophy without intra-ocular pressure, or upon intra-ocular pressure, with or without atrophy. The last-mentioned variety he designates "glaucomatous."

"1. Congenital excavations, which, in the eyes of new-born infants, are as clearly marked, and proportionately as extensive, as in adults, exhibit very considerable differences of general appearance, as well as of depth and superficies. Some of them are so slight as to be difficult of detection; and, if these be minutely searched for, there are but few eyes in which they may not be found. In other cases, the depression is more considerable, but its gradual formation has allowed the vessels to accommodate themselves to it in gentle uniform curves, so that they exhibit no sudden bending by which the margin may be defined. Such depressions are only to be recognized by the greater brightness of their surface, which increases towards the centre, by the wide separation of the curvatures of the vessels, and by the greater depth of their union in the nerve.

"Very frequently, however, from the abrupt sinking of their walls, congenital excavations exhibit well-defined margins, and appear as glistening spots upon the nerve disk. Such spots occur chiefly near the centre, and extend usually in a direction outwards, towards the macula lutea, either horizontally or obliquely. They display, however, great irregularities, not only of form and size, but also of depth; sometimes only reaching the level of the deeper retinal layers, sometimes extending far into the sclerotic canal. Their depth may be ascertained, in examining the direct image, by finding what change of accommodation, or of correcting lens, is needed for the floor and the aperture respectively; and also by looking into them as obliquely as possible, first from one side and then from the other, and observing the apparent overhanging of the margin, the changes in the aspect of the vessels, and so forth. The aperture is usually small, often not exceeding the diameter of one of the vessels on the disk. More often it covers a fourth, or a third, or even half, of the nerve surface; and, in very rare cases, it covers nearly the whole. When this occurs, the diagnosis from glaucomatous excavation is rendered very difficult.

"In all depressions of any extent, whether congenital or acquired, the vessels of the fundus oculi exhibit certain common characteristics, which vary with the depth of the cavity and the inclination of its walls, and which present very numerous gradations between cases of extreme depression and the normal state.

"Let it be supposed that the vessels, traversing the plane of the retina, arrive suddenly at the sharp margin of a pit. In bending over it, they will form curves nearly rectangular, and the convexities of these curves will project beyond the margin. The circulation will be interrupted, the vessels rendered more full, and therefore larger and more dark-coloured, than in their normal state; and, if their continuations beyond the margin proceed directly backwards from the observer, the vessels will appear absolutely to terminate, where they bend, in rounded, slightly-projecting extremities. If their continuations have a slight obliquity, and come partly into view, they will seem like little beaks or hooklets caught round the edge of the cavity.

"When the vessels have completed their course down the sides of the pit, and traverse its floor to reach their point of exit from the globe, they will have resumed their original direction, but in a posterior plane. It is manifest, that, unless the intermediate portions recede in lines exactly perpendicular, the continuity of the vessels will appear more or less interrupted, and the parts on the nerve disk more or less displaced from those on the retina. The displacement may be even less than half the width of each vessel, or it may be so great as to destroy the possibility of determining the retinal branches to which the deeper ones belong. These changes may be present in any degree of development, from the slightest possible S-shaped bend at the margin of the cavity.

"The examination being by the erect image, and the accommodation of the observer for the plane of the retina, parts posterior to this plane will be obscure. The vessels on the floor of a deep cavity will be wholly invisible. Those of a shallow cavity will appear of paler colour and less distinct outline than their retinal portions, and will cease to return any bright reflection from their centres. By accommodating for a greater distance, or by using a concave lens of sufficient power, the posterior parts of the vessels will become clearly visible, and will present a normal aspect. If the cavity be abrupt, with perpendicular walls, a concave lens may be found that will at once bring its entire floor into view. If it be funnel-shaped, it may be necessary to use a stronger lens for its deepest than for its intermediate parts; and in such cavities the vessels appear to fade away gradually, instead of passing suddenly out of view. Whether the arteries or veins shall first become invisible will depend partly on their position and their place of division, partly on their colour. If the chief vein trunks divide considerably deeper, and if their branches are deeper and more lateral than those of the arteries, then the veins withdraw themselves first from sight. If, however, there be no considerable difference in their position, then the lighter coloured arteries are the first to become indistinct, in consequence of the recession of, and other changes in, the nerve-substance covering them; and the darker veins often remain visible as faint, reddish, delicate, obscurely-defined bands.

"It is, therefore, generally difficult, in such cases, to determine which vessels are arteries and which veins; and, since the veins often display a marked pulsation, the observer is not only hence more easily deceived, but is also led to an erroneous belief that he sees an arterial pulse.

"In congenital excavations, the edge of the cavity is usually decidedly within the circumference of the nerve itself, and is therefore surrounded by a circle of nerve tissue that retains its proper level. The cavity itself is usually brighter, more diaphanous, than normal nerve tissue, and is mostly of a whitish colour, tempered towards its margins by a slight admixture of grey or greyish blue. The surrounding ring of nerve is usually darker than natural, somewhat reddish, and often, here and there, as deeply coloured as the surrounding fundus; so that the brightness of the excavation is enhanced by contrast. The darkest colouring is usually next the cavity, and the tint decreases from this to the periphery of the nerve. By accommodating for the floor of the cavity, this, from the visibility of the lamina cribrosa, and of the terminations of the central nerve tubules, will appear more or less regularly spotted with grey or greyish blue.

"The periphery of the nerve, besides displaying a gradual decrease of tint from the edge of the cavity, is defined from the surrounding fundus, at least in parts, by a more or less clear, bright, whitish ring of connecting tissue. The appearance of this ring, in the majority of cases of congenital excavation, is an important guide to their diagnosis.

"The apparent congenital excavations are due to increased transparency of the central portion of the nerve disk, or to prolongation of the sheaths of the nerve tubules through the lamina cribrosa, or to other causes that may produce an increased reflection from some part of the surface. The effect of an actual cavity is often enhanced by conditions of this kind.

"2. Acquired excavations occur usually with and in consequence of atrophy, or with secondary atrophy, of the optic nerve at its place of entrance. The ophthalmoscopic aspects of atrophy of the nerve are extremely different, according as the disease is seated in the retina or in the nerve alone, and is accompanied or not by atrophy of the central vessels, according as it is simple or degenerative, with or without inflammatory phenomena, with or without considerable diminution of the circumference of the nerve, with or without curvature of the outline of its section, with or without bulging of the lamina cribrosa, and so forth.

"Of these varieties, we may still follow H. Müller, in saying, that two are chiefly to be distinguished:—*a*, excavations produced by diminution of the substance of the nerve; *b*, excavations produced by bulging of the lamina cribrosa.

"*a*. In the first variety, the excavation is mostly characterized by a shallow, gradual, bowl-shaped, sinking of the disk in its whole extent; and hence the vessels passing from the retina to the optic nerve show no interruption or considerable bending in their course. Especially when atrophied themselves, they sink gradually into the deeper parts, and show from their origin an increasing change in their colour and their clearness of contour. Only by very exact observation is it possible in individual vessels, or rarely in the vessels collectively, to see at the circumference of the nerve a slight, gradually occurring displacement of a short portion of the vessel, as a gentle double bending.

"The external contour of the nerve disk remains more or less intact, and first becomes obscured at later periods, or by extension of the disease to neighbouring tissue. But above all, especially in central amaurosis, the ring of connecting tissue around the nerves is rendered sharper and more distinct, especially at its inner contour, by the colour-changes in the nervous substance; and usually remains clearly visible, at least in parts, up to the latest period of the disease, if not concealed by changes consequent upon inflammation or degeneracy.

"The excavation does not present the whitish-yellow brightly-glistening colour, and the sharp edges seen in congenital excavations. According to its depth, there appears towards the centre of the disk a dull, veiled, greyish-white opacity. Frequently the nerve texture is darker, and of a bluish-grey tint, which colour is clearest at the periphery, especially to the outer side, and diminishes towards the centre.

"*b*. The second form of acquired excavation (glaucomatous excavation), that occurs with or without the cöetaneous or consecutive occurrence of atrophy, is chiefly characterized by stretching and bending back of the lamina cribrosa, and has a like value with ectasiæ of other parts of the ocular coats. It is, essentially, an ectasia of the lamina cribrosa.

"Its symptoms are very characteristic, and differ from those of the other forms. The depth of the excavation is usually considerable, and often extends far into the sclerotic canal. The surface is usually equal to that of the whole disk. The chief mass of the optic nerve recedes, and leaves its canal more or less free, even to a thin layer clothing the sides. The lateral walls of the excavation sink suddenly from the plane of the retina towards the axis. Hence the excavation usually presents sharp edges, and allows the characteristic effects to be very strikingly perceptible.

"It has been already stated, that, in the congenital excavations, the margins are usually within the nerve disk, and that the bending of the vessels takes place on the nerve. In glaucomatous cases, on the contrary, the aperture of the cavity coincides with the circumference of the disk, and the bending takes place at its margin. This appears to be the most trustworthy diagnostic sign between the two.

"The colour of the glaucomatous disk is weakest at the centre, and increases quickly in intensity towards the periphery. It reaches to the circumference of the nerve, and there ceases with a sharp dark border, or partially with a nearly black line. The colour slightly varies with slight movements of the mirror, and changes in its intensity, especially towards the periphery. Since, moreover, in accommodation of the eye of the observer for the plane of the retinal vessels, the optic nerve appears in its whole entrance in a high degree diaphanous; in its middle parts more, and in its periphery less luminous, so the entrance obtains a very peculiar, characteristic, and in extreme cases deceptively vesicular appearance."

It is hardly necessary to observe, in conclusion, that the use of a binocular ophthalmoscope removes nearly all the difficulties that attend the diagnosis of excavations with monocular instruments. In using the latter, the observer must bear in mind the foregoing observations; but in using the former, he will at once see a cavity, if a cavity be present.

3. OPACITY OF THE NERVE FIBRES.

(Of Liebreich; Hypertrophy of the Nerve Fibres of Müller; Nerve Extension of Jaeger.)—Liebreich's Atlas, Pl. xii., *Figs.* 1 & 2.

The parts forming the boundaries of the optic nerve (the choroid and sclerotic), and the opaque part of the nerve itself, are not in immediate contact with the vitreous body, but are separated from it by a transparent layer of nerve tissue, upon the clearness of which depends the possibility of seeing the parts lying behind it, and of following the vessels that pass through it in a short portion of their course. In examination of the erect image, there may be perceived in this tissue a fine, irregular, radiating fibrillation, and here and there a single fibril reflecting more strongly and almost isolated.

In pathological opacity of these fibres, according to Liebreich:—

1. The nerve-entrance appears as a round, uniformly dull disk, with its contour softened down and ill defined against the surrounding ground. The papilla loses its lustre, its definition, and its shading, the scleral margin disappears, the choroidal foramen is less sharp of contour, and apparently increased in diameter. This apparent increase depends upon the visibility of the boundary of the nerve at the plane of the retina, which in normal eyes is scarcely perceptible. The nerve fibrils, immediately after passing through the narrow openings in the sclerotic and choroid, bend round towards the periphery of the fundus; and hence the nerve, in the plane of the retina, has already attained a marked increase of diameter, and its boundary will be a much larger circle than that of the choroidal opening.

2. The retinal vessels appear essentially changed. The dark red colour of the fuller and more winding veins, at their entrance into the

dull disk of the nerve, is obscured by a light greyish cloud that increases in density towards the centre; and that, in the passage of the vessels to a greater depth, becomes so considerable, that parts of them are wholly concealed by the thickening and opacity of the nerve fibres. Before they reach the disk, the vessels sink somewhat in the thickness of the retina, and rise again in stronger curvatures than usual. As a cause of this condition, Liebreich found a remarkable prominence of the whole entrance of the nerve.

Liebreich has also studied another anomaly, to which Virchow first directed attention. In this the whole transparent portion is not rendered opaque, but only a portion of it; and the nerve fibres forming this portion do not assume their dull contour in the neighbourhood of the lamina cribrosa, but after leaving it, and after they have already traversed a small portion of the retina. The ophthalmoscope exhibits the individual bundles as white, glistening, perfectly opaque streaks, that reflect the light exactly in the same way as the bright streaks that radiate normally from the papilla of a rabbit. The result is a very peculiar figure, that either abuts immediately upon the optic nerve, or is a little distance removed from it, and that terminates towards the periphery in one or more sharp, flame-shaped points. When this figure trespasses upon the margin of the papilla, the latter is at that point completely concealed, and the otherwise normal vessels are rendered invisible.

Pathological Anatomy.—According to von Ammon, simple hypertrophy of the optic nerves consists of an uniform increase of the parenchyma of the collective neurilemma of the individual fibrils, by which they become thickened, the neck of the nerve shortened in the neighbourhood of the cauda equina, and the lamina cribrosa rendered nodulated. The vessels disappear, the trunk of the nerve increases laterally in volume, but without displacing its extremity; the sclerotic increases in thickness in the neighbourhood of its foramen, and in section appears unusually hard and very white, as if its individual fibres were thickened. True hypertrophy of the optic nerve is attended by no change in its shape.

In Virchow's case, and also in one subsequently examined by Beckmann, the microscope showed, as the cause of the opacity, that the nerve fibrils, usually in this situation uncovered and translucent, were darkly margined, broad, and furnished with a sheath. A longitudinal section of the ocular extremity of the nerve showed it to be in both eyes contracted, as usual, at its entrance into the sclerotic canal, but less on the right side than on the left. Virchow, however, was able to show that the sheathed fibres became pale during their passage through the lamina cribrosa, that they regained their sheaths in the retina, and that they again ultimately became pale. In the retina, the passage of the dark into the pale fibres could be very accurately traced. It happened very gradually, the sheath becoming paler and paler, and being lost to sight so gradually that it was impossible to define with certainty the point at which it ceased. The very clear axial cylinder was continued in the same way in the pale as in the sheathed portion of the fibre; except that in the former no division into sheath and axis was discernible. The transformation of the dark fibres into light ones occurred at very different distances. Becker, who more recently has had opportunities of examining a similar case ophthalmoscopically, believes that this condition, which, after Jaeger, he designates extension of the optic nerve, can with the greatest probability be regarded as a malformation, and that it is neither dependent, therefore, upon any particular construction of the eye, nor possesses any influence upon vision. The case described and figured by Desmarres (III. p. 465) as plastic retinal exudation, I conceive to have been one of this kind.

4. ATROPHY OF THE OPTIC NERVE.

(*Liebreich's Atlas, Plate* xi., *Figs.* 8, 9, 10.)

Atrophy of the optic nerve, by which it is gradually changed into a cord of cellular tissue (ligamentous degeneration), is apparently a common cause of extreme amblyopia or complete amaurosis. It appears either as an independent disease (progressive atrophy) or more often as the last phase of many morbid changes, of very various seat and character, affecting the globe, the orbit, the meninges, the cerebrum, the cerebellum, the spinal cord, and so forth.

The characteristic ophthalmoscopic appearances are:—

1. THE PAPILLA.—This, at the commencement of the disease, is bright and sharply defined, the scleral margin somewhat broader and clearer than in the normal state, the proper nerve boundary distinct. The form differs in different cases; and is sometimes prominent from exudation deposits, rarely only flattened, frequently excavated. In later stages it appears irregular, indented, elliptical, or diminished in diameter. The ordinary admixture of reddish grey is superseded by a white, sometimes bluish colour; the network of the lamina cribrosa appears thickened; the darker and wrinkled interspaces of its meshes gradually disappear; and the whole surface assumes an uniform tendinous lustre, sometimes exhibiting a play of greenish or bluish tints, more often resembling silver or mother of pearl.

With regard to the diminution of the diameter of the papilla, it has been very pertinently remarked by Liebreich that different observers have chronicled its diminution or its increase, without there being, at present, any definite standard for the exact determination of either. Generally, he observes, we include under the term papilla the whole bright disk, to its extreme limits upon the fundus (the choroidal margin); and if it be considered how significant would be the slightest diminution or increase of the nerve substance itself, and how many accidental or unimportant neighbouring conditions may produce an apparent diminution or increase of the diameter of the whole disk, it must be conceded that our judgment of the proportionate magnitude of the papilla must be based upon other grounds than these. In two perfectly normal eyes, in one of which the nerve passed through a very narrow choroidal opening, while in the other the choroidal opening was wider than that of the sclerotic, in the first the bright line of the scleral foramen would be scarcely visible, while in the second it would have such breadth as to increase considerably the diameter of the whole disk. The actual diameter of the nerve might be exactly the same in both, and the difference of the ophthalmoscopic image would depend wholly upon the choroid. It will, therefore, be prudent to follow the counsel of Liebreich, and to estimate the relative size of the nerve entirely by the part of the disk that is included within the proper nerve boundary.

2. The Vessels.—With the progress of the disease the small arterial trunks vanish completely; and the larger become smaller and paler, and in old cases are converted into fine white lines, without wholly disappearing. The veins undergo the same changes as the arteries, but later in point of time; and, even in advanced cases, are still visible, although somewhat less clear and less winding than usual.

The pathologico-anatomical conditions have been described by von Ammon.

Atrophy of the optic nerves depends frequently upon fatty degeneration of the fibrillæ and of their neurilemma, or upon defective nutrition caused by compression of the capillaries by exudations within the sheath, or by their impermeability from other pathological conditions. In all stages of development of the disease, all exudations are formed within the sheath, separating its inner surface from the trunk of the nerve. It is remarkable how much the sheath may be dilated by such effusions; and how great may be the disproportion between the actual nerve and its distended covering. The latter no longer closely envelopes the former, but is widely distant from it, and the ample space between them is filled up by effused fluid. The nerve itself dwindles more and more, and undergoes a great variety of modifications.

Sections of the atrophied nerves, which have always lost their roundness and become flattened, present many and various changes. The external neurilemma is either dilated or wanting, and there is also deficiency of the stroma of the interior neurilemma surrounding the individual fibrillæ. This may have disappeared either partially or almost entirely; so that scarcely a trace can be observed between the closely-packed fibrillæ, which are commonly themselves thickened. With the disappearance of the internal neurilemma disappear also nearly all the vessels of the nerve, both central and peripheral; and only occasionally can one be found that still remains permeable. Of such an one, the calibre is commonly very small and obstructed, and mostly flattened.

The occurrence of atrophy of the optic nerves has lately attracted considerable attention, and has been attributed, in cases not otherwise accounted for, to the excessive use of tobacco. Many years ago, by Mackenzie and other writers, a so-called "tobacco amaurosis" was described; and, quite recently, Mr. Wordsworth in this country, and M. Sichel in France, have revived a belief that had, for a time, passed out of view and been lost, so to speak, under the great accumulation of more exact pathology, for which we are indebted to the ophthalmoscope.

It is obvious that the question, whether atrophy of the optic nerves can be numbered among the injurious effects of tobacco, is, on the one hand, of the highest possible importance to society, and, on the other, is beset on every side with difficulties and sources of error. The use of tobacco is so widely spread, or almost universal, and its consumption by the young so plainly upon the increase, that a perfect knowledge of its effects, both noxious and salutary, is necessary to the comprehension of many of the sanitary problems of the day; while the same facts, that render the knowledge desirable, oppose the most formidable obstacles in the way of its attainment. The certainty that tobacco, if a chief cause, is yet not the only cause, of optic-nerve atrophy; the certainty that thousands of those who smoke to excess do not suffer from the disease, or from any symptom premonitory of it; and the liability, at every stage of the inquiry, to mistake coincidence for causation, all these are considerations that should lead to the careful avoidance of any hasty or presumptuous judgment upon a problem so profoundly difficult.

Mr. Wordsworth states it to be his experience that patients suffering from optic-nerve atrophy are frequently great smokers; and Mr. Critchett confirms this statement. So far, then, we have the positive testimony of two most trustworthy witnesses; and we must consider that their evidence proves the fact to which they speak—proves it beyond the possibility of dispute or cavil. These gentlemen are surgeons to an eye hospital that receives about 14,000 patients yearly; and it follows that their experience is sufficient to establish the general truth of their statement, and to eliminate sources of error that might arise from the narrowness of the ordinary field of personal observation. I dwell upon this part of the question because other writers have disputed the statement for no other reason than because their own opportunities have not allowed them to confirm it. They put themselves in the position of the culprit who, being in danger of conviction from the positive evidence of two witnesses of his crime, sought an acquittal from the negative evidence of those who had not witnessed it. Their testimony is simply irrelevant. If they say that they have seen optic-nerve atrophy in non-smokers, no one will be disposed to doubt their accuracy. But they still leave the indisputable fact, that, in the majority of cases, the patients smoke largely.

Mr. Wordsworth and Mr. Critchett go farther; and express their belief that, in such instances, the much smoking is the ordinary cause of the atrophy. Here, then, they step out of the domain of observed facts, and enter upon the debateable ground of opinion.

Before attempting to follow them, it will be worth while to glance at the various causes from which optic-nerve atrophy may arise; and to see what classes of cases must be put on one side in order to leave those in which the influence of tobacco may possibly be predominant. The known causes may be arranged, I think, under the following heads:—

1. Functional disuse, from disorganization of the retina or parts anterior to it.
2. Optic neuritis.
3. Blows and injuries on the head.
4. Acute intra-cranial disease, not destructive to life, and usually occurring as a complication of typhoid fever, or of some one of the more severe exanthemata.
5. Chronic intra-cranial disease, affecting the nervous centres; and often, but not necessarily, associated with paralysis or epilepsy.
6. Chronic sources of pressure, either cranial, orbital, or intra-ocular, benign or malignant; and extremely various in point of nature, locality, tendency, and termination.

Besides the above, there remain, I think, cases which cannot be referred to any of them. Patients present themselves, with complaints of failing vision, in whom the disease has commenced so insidiously that they are unable to specify the time of its origin; and who hardly realize their condition, or seek medical assistance, until it has made considerable progress. The earliest stage that I have myself seen was in a young man of twenty-four, who had not applied previously to any other practitioner, and who was able, at the time of his first visit to me, to read No. 12 of Jaeger's test types. He complained simply of increasing dimness, like that of the approach of dusk, and of want of power to define the margins of small objects. He was apparently in robust health, and was occupied in riding and driving about as traveller for a large flour-mill, but he was in the habit of drinking spirits largely. His eyes were perfectly free from pain or irritation, were of normal contour, tension, and refraction, and he stated that his sight had been very good. His pupils were a little larger than the medium size, and acted sluggishly to light. A weak solution of atropine scarcely influenced them; but a solution of four grains to the ounce produced tardy and imperfect dilatation. The media were perfectly transparent; and the general aspect of the retina and choroid was normal. The optic disks were each invaded by a white patch, covering a segment of about one-eighth of the circle, and extending from the centre to the periphery in a direction downwards and inwards. The remaining seven-eights of the circle appeared to me decidedly hyperæmic; and, in the inverted image, looked as if uniformly coloured by a pink wash, which was resolved, by higher magnifying powers, into a fine stippling. The patient remained under my observation for five or six months, during which time the white patches spread over nearly half of each nerve disk; and the vision faded so much that he could with difficulty decipher No. 19 of Jaeger. At the time of seeing him, I was not sufficiently familiar with the erect image of the several boundaries of the disk to express any positive opinion about their state; but the distinctness of the general outline was not impaired. The patient was a moderate smoker, taking his two or three pipes in the evening, and an occasional cigar upon his journeys.

Now this case, which precisely corresponds with others that I have first seen at a more advanced stage, is a fair type of what Mr. Wordsworth describes as tobacco amaurosis. Mr. Wordsworth recently declared, at the Hunterian Society, that he believed he could, with the ophthalmoscope, pick out smokers from non-smokers in cases of optic-nerve atrophy. In reply to my inquiry as to the general characteristics on which he would rest his diagnosis, Mr. Wordsworth favoured me with a letter, in which, after setting forth the difficulty of describing slight differences of colour and appearance, he proceeds to say, "I believe that the earliest changes, observed in tobacco cases, are those of increased vascularity of part or the whole optic disk. After an uncertain period, the nerve is very unequally coloured, part being over vascular and part anæmic. In several cases that I have seen, this has been very palpable, about one-half of each nerve being so changed. In more advanced stages, the outlines of the disk have been observed to be undefined, the choroidal margin being blurred, and the area of a bluish-grey colour. Lastly, the conditions of white atrophy are approached. I say approached, for I have never seen this appearance so distinctly marked from tobacco as from cerebral disease. Nor have I met with any case that has ended in *total* loss of sight * * *. In many smokers that I have examined, I have almost invariably found the optic disk hyperæmic, even when this physiological condition has not prejudiced vision. I am now seeing from time to time cases of defective sight that I can find no other cause than tobacco smoking to account for; and I begin to think it much more frequently the source of disease than I had expected."

In considering whether the conditions last indicated may be safely attributed to tobacco, it is evident that the first thing necessary is to exclude the six classes of causes already enumerated. To do this completely, especially with reference to classes 5 and 6, would require the highest degree of diagnostic caution, tact, and skill, exercised about symptoms with which the most accomplished ophthalmologist is not necessarily familiar. I am bound to remark that the weak point of Mr. Wordsworth's published cases is, as it appears to me, the absence of any evidence of the degree of caution proper to be observed in this particular. The absence of past or present cerebral mischief in the patients seems, judging from the report, rather to have been assumed from the absence of prominent symptoms, than established by minute and careful scrutiny. I mention this, because, in the out-patient room of the hospital for the paralysed and epileptic, it would at any time be easy to find cases of partial or complete cerebral amaurosis in which the cerebral symptoms do not by any means force themselves upon the observer. It may be urged, of course, that tobacco may produce cerebral disease, and secondary atrophy, and I do not dispute that such a thing is possible. But that is not the present question. As I understand Mr. Wordsworth, and those who think with him, they believe in the direct influence of tobacco upon the optic nerves.

Having excluded the more evident causes of atrophy, the next question has reference to the actual pathology of the doubtful cases. What is the "atrophy"? or, in other words, what is the condition that tobacco is supposed to produce? This can only be decided by the most careful ophthalmoscopic examination, elucidated by equally careful dissections.

In the cases that I have seen, the original slight hyperæmia of the disk, the pallor of a continually increasing portion, the dwindling of the arteries, and the slight dilatation of the veins, have seemed to point to a state analogous to cirrhosis. I have suspected sub-acute inflammation, and secondary contraction, of the inter-fibrillar connecting tissue of the nerves. Against this view I may adduce that I have never seen sub-retinal serous effusion; and also the opinion of Mr. Critchett, to the effect that, in many cases, although all medical treatment will be unavailing, yet *the abandonment of tobacco will arrest the further progress of the disease*. I do not think that the abandonment of tobacco could by any possibility arrest post-inflammatory contraction, even if it had, in some way not understood, been the original cause of the inflammatory mischief.

I have adverted at some length to this highly interesting subject, because the disease is prominent among the causes that produce blindness in adults, and because it is, in the present state of knowledge, wholly incurable. It is most desirable, therefore, that the tobacco hypothesis should be either established or overthrown. If established, it will not only assist in the prevention of a most distressing calamity, but will probably aid in the elucidation of the general effects of the drug upon the system. If found erroneous, its overthrow will clear the path for inquiries resting upon other grounds. In the meanwhile, the materials for judgment can be collected by the general practitioner rather than by the specialist, who, as a rule, only sees pronounced cases, and only keeps them in view until their ultimate issue is no longer doubtful. The early ophthalmoscopic examination of smoking boys, and the post-mortem preservation of eyes rendered useless by nerve atrophy, are desiderata that will be attainable, generally speaking, only by family medical attendants.

It is very remarkable that a condition not very rare in this country should be left unnoticed by Dr. Liebreich. There is no figure in his Atlas that at all represents either the earlier or the final appearances in this disease. Fig. 8, plate xi., which represents the invasion of atrophy in neuritis optici, is the nearest approach to a delineation of the supposed "tobacco amaurosis."

5. ABNORMAL INSERTION OF THE OPTIC NERVE.

The optic nerve has been observed by Desmarres, and in a single instance by von Gräfe, to enter the eye more or less distant from its natural position. This, in a completely normal condition of the other eye, should produce amblyopia and strabismus, to be removed by the use of convex glasses for the one affected.

II. THE VESSELS.

In the diseases of the vessels, either of the trunk of the optic nerve, or of its intra-ocular extremity, the lamina cribrosa, the connecting tissue, and the membrana limitans suffer from infiltration or exudations. Among morbid changes, thus affecting all the elements of a limited space, it is often impossible, in the living eye, to distinguish with the ophthalmoscope the exact pathological conditions of the several parts; but a certain series of remarkable changes has been observed, among which the following are the most important :—

1. DILATATION OF THE VESSELS

is described by Liebreich under the following forms :—

a. Turgescence of the Arteries and Veins.—Considerable expansion of the arteries is, in general, easy to recognize; but it is of very rare occurrence. Liebreich found it chiefly in artizans working among fires. The veins sometimes show strong pulsation, and this, unlike what is seen in the normal eye, passes beyond the limits of the nerve disk. In one case, Liebreich observed a rythmical movement of the parts of the retina lying near the vessels. Much more frequently occurs :—

b. Turgescence of the Veins with a Normal Condition of the Arteries. —The veins appear darker, and of an increased diameter; they often emerge as thick cords from the centre of the optic nerve, and lose nothing of their thickness until they deviate, more or less suddenly, from a vertical to a horizontal direction. It is also characteristic that they follow a more winding course, and seem, "in different parts, to lie in different planes, so that in following the course of a vein it may appear, for a short time, under the same accommodation, clearly and sharply visible, and uniformly coloured, but will soon assume a darker colour, showing that, by a characteristic curvature, it has passed into a deeper layer than the plane of its former course. It will thus be obscured both in its contour and its whole diameter, and, although it may be followed for a time by changed accommodation, it soon disappears from sight, more or less completely, either not to be seen again, or to become visible at a distance with the same dark colour and the same aspect as at the point of disappearance, and gradually to regain its original distinctness. In the farther course of the vessel the same changes may be twice or thrice repeated."—(Jaeger.) The arteries commonly appear smaller and paler than in health.

2. OBLITERATION AND WASTING OF THE VESSELS.

Obliteration of the vessels is commonly combined with atrophy of the optic nerve or of the retina, as a result of numerous diseases, especially apoplexy and fatty degeneration of the retina, and retino-choroiditis. According to Liebreich, both arteries and veins appear uniformly thinner and paler, so that they can scarcely be distinguished from each other by their colouring; and, especially on a bright red fundus, are less conspicuous than in the normal state. Their first divisions can therefore be followed only with difficulty; and their finer twigs wholly disappear. Under still greater impediments to the circulation, some vessels, most commonly arteries, remain entirely empty, and yet do not become invisible, but appear as white lines against the red ground, and may be clearly traced over the bright surface of the nerve. In the neighbourhood of the papilla, they often for a while continue red; and show on both sides a white streak, which, after the circulation has wholly ceased, passes into the broader white line. These changes may be either limited to certain vessels, or to one half of the retina, or may extend over the whole eye; in which case the vessels sometimes become no longer discoverable by the ophthalmoscope, and the papilla appears as an uniform dull white disk. To such a condition must be attributed, in all probability, the isolated cases in which a complete absence of retinal vessels has been observed.

3. EMBOLIA OF THE ARTERIA CENTRALIS RETINÆ.

(*Liebreich's Atlas, Plate* viii., *Figs.* 4 & 5.)

In the case of a man suffering from stenosis of the aortic valves, and who became suddenly blind of the right eye, von Gräfe found with the ophthalmoscope the media transparent, the papilla nervi optici perfectly pale, and the vessels traversing it reduced to a minimum. The principal arteries appeared, beyond the papilla, as very fine lines, and their branches, in like manner, became smaller and smaller; portions that in a normal state would be very apparent having completely disappeared. The veins exhibited a different condition, being at all parts thinner than usual; but their distension increasing towards the æquator bulbi. In the left eye the vessels were perfectly normal, both upon the papilla and upon the retina.

Two days later von Gräfe observed a peculiar kind of circulation in one vein (the largest visible, and having, in the inverted image, a course upwards and inwards). There appeared a great inequality in the distribution of its blood, of such a kind that comparatively full portions alternated with portions that were empty. The attention being steadily fixed upon one part of the vessel, an irregular movement of its contained blood became apparent; the column being sometimes impelled by starts towards the nerve, and then again becoming stationary. In the movements, it sometimes happened that the portions empty of blood remained as before between the full portions; and that only their respective positions on the retina were changed. As a rule, however, the blood was driven from the full portions into the empty interspaces, so that the difference between the two was diminished, and the interruption of the blood-column became less evident. Gradually, however, the blood again collected itself into determinate portions of the vessel, so that the former appearance was restored. The whole shape and course of the vein varied during this phenomenon. The appearance was most evident in a part situated about 3‴ from the boundary of the papilla, where there was often a very sudden propulsion of the blood towards the optic nerve, up to a certain limit, beyond which the vessel remained completely or nearly empty. The part of the vein lying on the papilla itself remained, as a rule, perfectly empty, unless when a strong impulse drove the blood through it completely to its point of exit. By very careful observation, the same circulation could be traced to the middle zone of the retina.

A week later the neighbourhood of the macula lutea was no longer normal. The central region of the retina had thrown out a turbid film over the subjacent choroid, which film increased more and more in thickness, and appeared at last as a completely opaque greyish-white infiltration. The immediate neighbourhood of the foramen centrale appeared, in the middle of the infiltration, as an intense cherry-red spot, of about one-fourth of the diameter of the papilla. The limit of the diseased and degenerated portion of the retina was not defined in all directions, but appeared to fade imperceptibly into the surrounding healthy parts. From the neighbourhood of the cherry-red spot that indicated the foramen, the infiltration increased in density on all sides, and attained its greatest intensity at the margin of an oval figure, the longer horizontal diameter of which somewhat overpast the papilla. From this margin the infiltration gradually diminished in a direction outwards. The neighbourhood of the nerve, on the outer side, was only in a slight degree diseased; and on the other side of the papilla, towards the nose, the retina was perfectly normal. In more exact examination the opaque portion appeared dotted over with numerous whitish points and granules, which were assumed, from analogy, to consist of aggregations of granular cells.

In another case, observed by Liebreich, of a woman who became suddenly blind, the ophthalmoscopic appearances were as follows:—Upon the papilla, that was partially covered by radiating, white, strongly reflecting fibres, the arteries appeared perfectly empty, and the veins nearly so. By following the veins to the periphery, they were observed to increase in thickness, and in their fine divisions to be even more full than in the normal state, especially in the neighbourhood of the macula lutea, where some venous twigs, ordinarily scarcely visible, appeared very thick and covered by small extravasations. This condition Liebreich had observed before; as if the macula lutea, under pathological conditions, did not remain free from vessels. Near the small extravasations, changes were visible in the retinal texture, in the form of small, roundish, milk-white spots in the vicinity of the macula lutea. The arteries were empty, not only on the papilla, but on the greater part of the surrounding fundus, so that it was extremely difficult to distinguish them from the red background. They were easily discernible only in isolated spots, where small portions were still filled by red plugs, that commonly extended a short distance into the next ramification.

In consideration of the rarity of such observations, and their value as contributions to general pathology, and pathological physiology, I subjoin an account of two other cases of impeded circulation; the first of which was seen by Liebreich, in a case of separation of the choroid and retina from the sclerotic, in two large vessels passing horizontally across the tumour. "Into these two straight and parallel vessels, the blood was seen to flow, sometimes quickly, sometimes slowly, and rarely by jerks. In the upper, a vein, the course was from the periphery towards the centre, and in the lower, an artery, from the centre towards the periphery. The movement was recognized by that of the small cylinders of blood into which the contents of the vessels were divided, and that were separated by interspaces, smaller in the vein, broader and brighter in the artery. The appearance could be followed over the whole of the smooth anterior surface of the tumour, and even farther, since the retina, forsaking this surface, and no longer smoothly stretched, became wrinkled, and separated from the choroid by opaque fluid. At this part the vessels appeared almost black upon the greenish ground, while the still visible circulation showed that they were not obliterated. The phenomena were for a long time visible, but changed from day to day, the artery becoming smaller and smaller, its separate blood-cylinders shorter, the interspaces larger, the impulses more slow, until at last it appeared completely empty; while in the vein, although the blood-movements were more tardy, and the cylinders smaller, the flow yet remained perceptible."

Ed. Jaeger, also, has observed obstructed circulation in the eye of a man 72 years old, the subject of hæmorrhoids; and has given the following description. "The ocular media were perfectly transparent, the retina appeared of a medium yellowish red, without visible morbid change. The optic nerve, slightly pigmented at the circumference and somewhat yellow-tinted, exhibited slight indications of bluish spots. The vascular system of the retina, generally of small development, exhibited, in the larger trunks more especially, a proportionately small diameter. The corresponding large arteries and veins were equal in diameter, and alike in their dark red colour. No double contour was apparent, so that arteries and veins could only be distinguished by their clearly visible respectively centripetal and centrifugal circulation. This had not the appearance of a pulsation, since the walls, especially of the larger vessels, remained undisturbed, but it was a movement, slower or quicker, uniform or interrupted, but not rythmical, of an unequally coloured stream of blood. In the larger vessels, the blood stream exhibited, at distances of from one-fourth to the whole diameter of the vessels, intervals of lighter and darker red colouring; which, however, in the movements of the column, were continually changing, the lighter spaces becoming smaller and wholly disappearing, to be formed anew elsewhere. The movement of the blood appeared in such places uniform, but extremely sluggish. In the vessels of medium size the movement was quicker, and often for a short time pulsatile; the light intervals were of a paler red, and, as well as the dark portions, of a greater comparative length, being from twice to four times the diameter of the containing vessel. In the finest twigs visible upon the optic nerve, the movement of the blood was most rapid, and, at the same time, most disturbed. The extremely delicate stream of blood would be suddenly interrupted, the dark red part of the blood would disappear, and the little vessel, scarcely discernible upon its bright background, would seem to have assumed the tint of the optic disk. Then, in interrupted course, a shorter or longer column of blood would pass through the vessel, followed at greater or less intervals by a larger or smaller mass of blood globules, so that the observer almost appeared to see single globules, and then suddenly the vessel would be filled in its whole course with dark red blood, the portions of which seemed rather to roll through than to flow quietly. This circulation, which in arteries and veins of like calibre was of equal rapidity, diminished by degrees, and remained here and there suspended for longer periods, until, at the end of twenty-four hours, it was wholly obstructed. The retina generally had then assumed a somewhat darker red; and the diameter of all the vessels was visibly increased. The smallest were distended with blood, unless when a lighter portion or an interruption of the dark red column was perceptible, and were proportionately the most enlarged. The vessels of medium size showed here and there a short break in their colouring, to the extent of from half to twice their diameter. The chief trunks were for a considerable extent uniformly filled by red blood. On the other hand, the more faintly-coloured portions of the vessels, of equal intensity of colour to that of the background, were from twice to four times their natural diameter. Their walls, which were clearly visible, exhibited no diminution of calibre. It appeared as if the blood globules had at parts crowded themselves more closely together (the blood dividing itself into a red and into a transparent part), and uniformly filled the vessels. In the medium sized and smallest vessels not the slightest movement was visible; but in the larger, by careful attention for one or two minutes, the lighter parts might be seen to diminish and disappear, at the same time reappearing in another place."

In the Arch. f. O. (B. 8. Abth. 1) two cases of embolia of the art. cent. retinæ are recorded, one by Dr. Blessig of St Petersburg, the other by Dr. Schneller. Both patients suffered from disease of the aortic valves. In Dr. Blessig's case, the appearance of empty intervals in the veins was observed; but no movements are recorded. In Dr. Schneller's case, the intervals are not mentioned; and the symptoms and appearances pointed to the conclusion that the obstruction was only partial. Perception of light was never wholly destroyed; and, after a time, a considerable amount of vision was recovered.

The pathological conditions actually found in the above described disorders of the circulation, afford a brilliant testimony to the accuracy of ophthalmoscopic diagnosis. Von Ammon has repeatedly found dilatation, both of veins and arteries, at the intra-ocular extremity of the optic nerve. Such dilatations were either present in distinct spots in the form of sacculi, or they extended along an entire branch,—the former chiefly in veins, the latter in arteries. In the former the substance of the vascular wall was very thin, but in the dilated arteries there was usually an uniform thickening of all the coats. Narrowing of the vessels, even to their entire disappearance, was rendered evident by sections. In a medium state of contraction, usually produced by compression, the calibre of the divided vessel appeared no longer round, but oblong; and in a more advanced stage as a small point, in which a strong magnifier would exhibit the compressed and wrinkled wall of the vessel, when no open channel was perceptible. Von Ammon also found vessels obstructed by coagula, that appeared under the microscope as amorphous granules, both at the lamina cribrosa and in the retinal branches, where their presence had been already recorded by Virchow.

Ischæmia Retinæ.—Under this name Dr. Alfred Gräfe has described the case of a little girl, 5½ years old, who was found to have become suddenly blind of both eyes on the morning of the 9th of December, 1860. She had gone to bed in health on the previous evening.

She was first seen by Dr. Gräfe on the 15th of December, six days after the commencement of blindness. She had the aspect of an amaurotic, and her skin and mucous membranes were very pale, but she presented no other symptoms of disease of any kind, excepting that her pulse was very small and rapid, averaging 160 beats per minute. The eyes showed no sign of inflammatory irritation; the conjuctivæ of the globes were of marble paleness, and the pupils were widely dilated, and immoveable under the influence of light. There was no increase of tension.

Ophthalmoscopic examination showed the ocular media to be perfectly clear. The trunk and branches of the arteria centralis were dwindled to the size of hairs.

The veins were unusually winding, and considerably, but not uniformly, distended. In all other respects the appearances were natural. Perception of light was totally destroyed, and the patient was unconscious of the sun's rays, concentrated upon the eye by a 2″ convex lens.

Dr. Gräfe attributed the rapidity of the pulse to the excitement of the child, as there was no other derangement of the heart's action. Digitalis was prescribed, but failed to influence the pulse, and was abandoned, on account of its producing sickness.

The methods of treatment usually pursued in obscure cases of sudden blindness —depletion from the temples, blistering of the neck, irritating foot-baths, large doses of calomel, and mercurial frictions—had been applied without the slightest benefit. Dr. Gräfe, however, convinced himself that an experimental application of Heurteloup's leech to both temples produced no effect, either on the ophthalmoscopic image, the general condition of the eye, or the functional disturbance.

By a process of exclusion that I need not follow in detail, every successive conjecture upon the cause of the disorder was set aside as untenable, until Dr. Gräfe felt unable to arrive at any other conclusion than that some unknown condition of intra-ocular dynamics prevented the admission of blood. The child had been for ten days without perception of light, and Dr. Gräfe determined to try the experiment of iridectomy.

On the 19th of December a broad piece of iris was removed from the upper part of the right eye, and paracentesis of the anterior chamber was performed upon the left. In twenty hours after the operation the pupils acted to light, the difference between light and darkness was perceptible, and the movement of a hand before the face was recognized. The vision was limited to the right eye, and the pupillary movements of the left were only sympathetic. On the next day the right eye saw a finger at two feet distance, and the left had still no perception of light. Iridectomy was then performed on the left eye also; and from that time the two improved day by day at an equal rate. Fifteen days after the second iridectomy the child could count, correctly and easily, with the left eye, small dots at a distance of one-half millimetre asunder. The ophthalmoscopic image had become completely normal. Three months later the child continued in possession of perfect vision.

Dr. Gräfe thinks the disorder must have been due to a diminution of the proper tension of the arterial walls, and to a failure of the circulation from consequent wasting of the *vis a tergo*.

II. THE RETINA.

I. HYPERÆMIA OF THE RETINA.

The characteristic indication of hyperæmia of the retina is :—

Increased vascular development and vascular redness in the district of the central vessels. This condition, at the beginning of the affection, is often very difficult to determine, the limits between physiological and pathological redness being undefined. For example, the degree of redness shown by the ophthalmoscope may be perfectly normal in one individual, while in another the same degree only exists in consequence of morbid processes. In all cases therefore it is desirable, when possible, to examine both eyes together; but even this precaution will not always be sufficient, and it may be only after the occurrence of farther changes, or even of hæmorrhages, that the existence of congestion is first recognized.

The redness, more or less deep, appears either in single places or over the whole field, as an effect of the development of numerous fine capillaries, winding one about another immediately upon the chief trunks, and appearing either as fine dots or stippling on the nerve disk (central hyperæmia), or spread over the whole fundus (peripheral hyperæmia). The latter appears finely granulated and uniformly red, also in consequence of the development of fine capillaries between the retinal vessels, capillaries that thickly cover the whole surface with a net or lattice work, and that are often accompanied by small ecchymoses or reddish patches.

The arterial or venous character of the disturbance of the circulation declares itself, according to Stellwag, with more or less of certainty. In hyperæmia of a sthenic character, such as readily follows any actual irritation, the congestion occurs chiefly in the arteries, and commonly extends to their finest branchlets. Patches, and even large tracts of the fundus, are rendered almost uniformly bright red by a fine and close vascular network, that gradually becomes less dense at their margins, and is resolved into trunks that are in evident union with the chief branches of the arteria centralis. By their bright redness, and by the gradual enlargement, at their margins, of the meshes of the vascular net, such hyperæmic spots are easily distinguished from patches of effused blood that are sometimes present, and that are darker and perfectly uniform in colour, with margins evidently obscured by reddish or yellowish tints. When, on the other hand, the hyperæmia has been caused by venous obstruction, the congestion is chiefly evident in the venous trunks, recognizable by their dark colour and large calibre. The injected patches already described will be wanting, and the vascular network will remain of its usual coarseness. Moreover, in such cases, the congestion is commonly spread uniformly over the whole retina, and extravasations of blood are also widely scattered, but maintain each a narrow boundary, so that the retina appears tiger striped. Lastly, pulsation of the vessels is often visible.

I introduce here the description of certain morbid appearances in the fundus oculi, that, under the name of mechanical hyperæmia, have a wide pathological signification. They owe their origin to extra-ocular influences, and appear to be usually the result of intra-cranial processes. Coccius was the first to describe disease of the retina consequent upon morbid growths (tumours) at the base of the skull. He was followed by Sichel, and especially by von Gräfe and Schneller, who gave the following account of the ophthalmoscopic appearances in extra-ocular amblyopia and amaurosis. The first stage visible in diseases of the orbital textures or of the brain is that above described (p. 134), as turgescence of the veins with a normal condition of the arteries. The retinal vessels are thicker than is natural, diminish less quickly towards the periphery, and become winding. The sectional surface of their curves is usually perpendicular to the surface of the retina, seldom oblique, and still more rarely parallel. Each primary curvature requires a compensating second curvature; but the first, upon the nerve disk, is by far the strongest. The venous pulse is absent; the arteries are normal; and the choroidal vessels are somewhat enlarged, winding, and more clearly visible than usual.

The second stage is characterised by large retinal veins, curving in prominent bends, and by normally situated retinal arteries; the vessels appearing dimmed or obscured, like dark threads seen through tissue paper. In the deeper parts of the curves the obscurity is greater; but neither in the deepest layers of the retina, nor upon the nerve disk, does it ever totally conceal the vessels. The thickening and turbidity are chiefly present in the vicinity of the disk, and diminish circumferentially, but extend chiefly in the course of the larger vessels. The neighbourhood of the macula lutea appears scarcely turbid; and at a distance from the nerve disk of two and a half times its diameter the cloud markedly diminishes. It has a bright greyish colour, and is never so pronounced as in Bright's disease affecting the retina, or in retinitis. The second stage is further characterised by retinal hæmorrhages, both superficial and deepseated, and proceeding from larger and smaller veins and capillaries; by loss of choroidal pigment and by tumefaction of the membrane, with thickening and tortuosity of its vessels; by loss of sight that bears no proportion to the retinal changes; by contraction of the field of vision; and by symptoms of brain disease manifested through other organs. In the third stage the vessels and the turbidity of the retina remain unaltered, except that the arteries appear somewhat smaller; if the pupil had contracted under light hitherto, that action ceases; the blood effused in the second stage is often absorbed, or more frequently becomes a centre of fatty degeneration, a manifest step towards farther atrophy of the tissues, that declares itself by small, dull-white, sparsely-scattered patches, that Schneller, after von Gräfe, considers to be portions of modified retina.

In a fourth stage the atrophy proceeds farther, and involves both the retina and the choroid. The curves of the retinal veins diminish in length and in height, the veins themselves become thinner, and are more difficult to follow into the deeper layers than in the earlier stages. The arteries are less conspicuous than normally, the retina more opaque, especially near the nerve, but less thick than before, and marked by scattered small brown spots, the remains of hæmorrhages, as well as occasionally, near the larger veins, by yellow patches of fat, ranging from the size of a lentil to that of a pea, and also by the white flecks already described. The boundaries of the nerve disk are more distinct than at an earlier period, but are not perfectly clear. There is seldom any excavation, since the atrophy of the choroid depresses the textures surrounding the nerve almost to the level of the lamina cribrosa.

Von Gräfe, who agrees generally with the foregoing description, found, in the cases that he examined, the papilla very considerably although irregularly tumefied. It was abruptly elevated on one side, and on the other sloped down gradually to the level of the neighbouring parts. Its naturally transparent substance exhibited a grey turbidity, with a strong admixture of red, like that of the surrounding retina, so that the choroidal margin of the nerve was completely obliterated. The turbidity was generally diffuse, and in the erect image had usually a striated appearance, following the distribution of the fibrillæ.

While von Gräfe, from these appearances, was led to diagnose the existence of inflammation of the optic nerve and the surrounding parts of the retina, occasioning hypertrophy of the interstitial connecting tissue, and degeneration and destruction of the nervous element, he agreed with Schneller in the opinion that the cause of the phenomena was a mechanical hyperæmia, produced by pressure upon the cavernous sinus, and by the consequent obstruction to the circulation in the common outlets of the blood. These outlets are the veins of the orbit and of the floor of the skull. The central veins of the retina, and the choroidal veins, discharge their blood chiefly by the ophthalmic vein, through the superior orbital fissure, into the cavernous sinus, which, after union with the sinus of the opposite side, rests upon the body of the sphenoid bone, and terminates in the internal jugular vein. A small outlet for the internal ocular veins is afforded by the v. ophthalmica facialis, which, however, is not sufficient for all the blood from the choroid. Obstruction of the veins at the back of the orbit, or of the cavernous sinus, or even of the internal jugular, produces, therefore, necessarily, a stagnation of blood in the veins of the retina and the choroid. The veins of the orbit proceeding from the retina and the choroid may most easily be compressed, either close behind the eye, or at their passage through the superior orbital fissure, or in their course from thence over the base of the skull. Tumours, or inflammatory processes with induration, may at these places very well compress all the veins, and may also disable the optic nerve in its course close to them. Obstruction of the more remote veins, as of the sinus cavernosus, may be produced by coagula, meningeal inflammation and its consequences, indurations, and so forth; or by tumours of the base of the skull near the superior orbital fissure, at the side of the body of the sphenoid bone, or near the upper lateral parts of the clivus, as well as by all processes that augment the total bulk of the brain. General hyperæmia, effusions, and so forth, may both compress at once the cavernous sinus and its outlets, and may also influence the optic nerve lying in the immediate vicinity. It is, therefore, intelligible that they should produce the hyperæmia of the retina and choroid described as occurring in the second stage, and also the turbidity and tumefaction of the retina and optic nerve from serous infiltration, an œdema, the result of simple mechanical congestion. Post-mortem examination has shown the correctness of the inference, since in von Gräfe's cases there were tumours in the right cerebral hemisphere; while the same or similar phenomena occurring in connection with other causes of pressure about the base of the brain, have shown that the combination of retinal with cerebral symptoms possesses a not unimportant significance in the study of nervous diseases.

II. INFLAMMATION OF THE RETINA.

Every inflammation of the retina, whether primary, or secondary to inflammation of contiguous parts, must necessarily disturb the nutrition of the membrane, and produce changes in the transparency, thickness, and density of its texture, by which an ophthalmoscopic diagnosis is rendered possible. It may readily be inferred, and is confirmed by experience, that the chronic forms of retinitis and their results are, almost alone, the objects of such diagnosis. In the rarely occurring acute inflammation the ophthalmoscope either affords no information; or, since in the early stages the effused product will consist of a transparent serosity that scarcely disperses light, the image of the fundus will be the same as in simple hyperæmia.

Since, therefore, the inflammations to be described are chiefly chronic, it is not a matter of surprise that the neighbouring membranes should more or less participate in the disease; or that their participation, and the exudations they afford, should modify the ophthalmoscopic image.

It is therefore necessary, before entering upon a description of retinal inflammation, to refer to certain general considerations with regard—1st, to the different exudations in the retina, their diagnosis, peculiarities, and results; and, 2nd, to the influence of the choroid upon the image of the retina in diseases.

Serous Exudation (*Œdema of the Retina of Desmarres*).—The presence of serous effusion in the retina and optic nerve has not only been suspected on theoretical grounds, but has lately been proved by anatomical investigations. Its existence can, however, only be shown by the ophthalmoscope, when the serum is present in sufficient quantity to produce separation of the retina. Desmarres, who considers retinal œdema a very common disease, easily diagnosed with the ophthalmoscope, and produced by disturbances in the retinal circulation, as chemosis is by disturbances in the conjunctival, gives as its symptoms a certain pallor of the fundus, together with a bright yellow (according to Schneller, pale green) reflection in the neighbourhood of the papilla. If these appearances coincide with extreme amblyopia, for which no other peripheral cause is discernible, the presence of serous effusion may be suspected.

About three years ago, by the kindness of my then colleague, Mr. Stephenson, my attention was called to a young woman under his care, in whom the existence of retinal serous effusion was unquestionable, although it had not absolutely detached any portion of the membrane. *Mutatis mutandis*, the appearance was like that of slight chemosis in an anæmic subject. The patient, a domestic servant, found herself nearly blind on awaking in the morning, and I saw her a few hours afterwards. The treatment, based on the ophthalmoscopic diagnosis, was followed by speedy and complete recovery.

Extravasations of Blood.—These are chiefly found in the inner layers of the retina, the elements of which they separate, but seldom destroy. In many cases, they penetrate the loose texture of the membrane, as far as the granular or even the bacillary layer, or pass between this and the choroid. Schweigger has convinced himself that retinal hæmorrhages have more tendency to penetrate outwards, towards the choroid, than inwards, to the vitreous body; and he believes this tendency to rest on the anatomical ground, that the arrangement of the basic connecting tissue of the retina favours cleavage in a perpendicular direction. Extensive separations of the retina are not produced by hæmorrhage, apparently because bleeding from the fine vessels is not attended by sufficient pressure to produce absorption of the vitreous body. Perforation towards within is less common than towards without, on account of the stronger formation of the inner layers, and the greater resistance of the membrana limitans; but such cases do occur, and one published by Esmarch was apparently of this kind. Von Gräfe limits the occurrence of retinal perforation from choroidal hæmorrhage to the anterior portions of the membrane, near to the ora serrata.

According to Schneller, four kinds of blood-spots may be distinguished. First, punctiform spots, round, ranging from the size of a pin's point to that of a pin's head, scattered over the retina, chiefly in a zone surrounding the optic disk and about twice its diameter, and so superficial that they appear to be situated almost in front of the retina. The second kind are very narrow, slit-shaped, in the erect image about $1-1\frac{1}{2}'''$ long and $\frac{1}{10}'''$ broad. The third kind are larger, about $\frac{1}{2}'''$ long, and equally broad, or broader; and irregularly elliptical or semi-elliptical in outline. The last kind are large irregular patches, from the size of a split pea nearly to that of a silver threepence. They are usually found beside a vein, with the greater part of the spot on one side of it, and a very small part on the other.

A zone of the retina, defined by the second and third divisions of the veins, appears to be the most frequent seat of hæmorrhages. All four kinds are sometimes found together in the same eye, and sometimes only two of them. The punctiform hæmorrhage is the most rare, the second and fourth kinds are the most frequent.

On account of their more or less superficial position in the usually turbid membrane, blood-spots sometimes appear to possess some elevation. They are known as belonging to the retina by their position near its vessels, and they are distinguished from dark-brown pigment spots by their brighter or darker tint of red.

As to their results, they sometimes disappear almost entirely. They first appear fringed or indented at their margins, and gradually break up into assemblages of scattered points, that continually assume a darker colour. Finally, they pass through the appearance of a fine shade, as of charcoal dust upon paper, into the normal aspect of the retina. The small spots disappear in the same way as the large, and the time required for their absorption is very variable—perhaps about four weeks or more—while sometimes new effusions are seen near those that are passing away. Sometimes the blood-spots undergo changes of colour. These changes mostly commence in the middle of the spot, which becomes of a bright yellow. In time, this yellow overspreads, and even exceeds, the original territory of the extravasation; and it indicates that the spots consist chiefly of fat. In other cases, the hæmorrhagic patches become the seat of dark spots, in the form of larger or smaller islets, that appear to be formed from the remains of incompletely absorbed blood-corpuscles, changed into a kind of black pigment. Lastly, may be observed sometimes the small, dull, white, scattered patches already mentioned, and described by von Gräfe and Schneller as portions of indurated retina.

In pathologico-anatomical observations Virchow found these spots precisely analogous to the hæmorrhagic points seen in the substance of the brain, and consisting in the centre entirely of a cohering assemblage of free blood-corpuscles. "The corpuscles within the mass may be either completely unchanged, or partly studded with fine granules. In the interior of these red masses, as well as at their circumference, may be seen fat corpuscles and conglomerate granules, that are either collected into firmly-cohering masses, or sometimes appear united into a network. The retinal elements themselves, in this condition, appeared either wholly unchanged, or the granular layer and the ganglion cells somewhat opaque—the latter, although not enlarged, presenting a more granular and yellowish aspect than natural; over which the bacillary layer was not easily discernible. Also, the capillaries of the retinal vessels, which often form an interwoven net, showed changes both in their walls and in their channels; the former, in retained permeability of the vessels, being sometimes thickly set with fat granules, the latter occluded by capillary obstructions (embolia)."

Plastic Exudations.—The plastic exudations in the retina are characterized ophthalmoscopically by the presence of a turbid film, more or less uniform according to the amount of effusion, presenting a whitish-grey, greyish-red, or dirty greyish-yellow colour, and chiefly occurring in the neighbourhood of the papilla and of the macula lutea. In parts they may appear as granules, greyish-white, whitish-yellow, or reddish-grey, ranging from extreme minuteness to the size of a millet-seed or more, sometimes scattered, sometimes collected together in groups that coalesce to form larger patches. In other parts they are seen as white or whitish-yellow, or dirty greyish-yellow flecks, sometimes glistening with fat, and having very irregular, indistinct, punctated, or indented margins.

The following indications serve to distinguish between retinal and choroidal effusions:—

For effusions beneath the retina, between it and the choroid, the erect image affords, in normal and far-sighted eyes, the best method of examination. The choroidal effusions are usually circumscribed, and rarely form a continuously extended layer. The uninterrupted continuity of the retinal capillaries, which, against the white background, are more clearly seen than in the normal eye, is sufficient to show that such effusions are sub-retinal, even when they are of considerable extent. The diagnosis is frequently confirmed by the presence of pigment spots in the retina, which lie in the same plane with its vessels, and therefore in front of the effusion.

The capillaries are also available for the determination of the precise position of effusions in the retina itself; since the vessels are either concealed by such effusions, or remain visible in front of them. The capillaries require attention in the diagnosis of pigmented effusions and simple pigmentation beneath the retina; since pigment is sometimes present in the turbid membrane itself. If the masses, in the latter case, appear somewhat obscured, it may yet be determined, by observation of the vessels which pass beneath or through them, that they are actually situated in the retina.

The diagnosis of thin, slightly turbid retinal effusions is often difficult, since they are gradually lost in the healthy portions around. The observer must be chiefly guided by the effect of the effusion in damping the red of the subjacent choroid. It is easy, however, to mistake the deeper red of the parts free from effusion for rust-coloured retinal turbidity; as the retina, in bright illumination, exhibits its own aspect more clearly than is usual, and the reddish transpicuity of the choroid is, in many eyes, very like the appearance that bright rust-colouration of the retina will produce. It is possible, therefore, to err by inverting the conditions actually present, and to mistake the turbid spots for intensely illuminated portions of healthy retina, and the transparent parts for patches of rusty opacity. The opposite error may also be committed: rusty patches being mistaken for healthy retina, and the healthy retina adjacent to them for the seat of interstitial turbidity. (Coccius.)

Another error, against which it is necessary to guard, may arise in cases in which considerable retinal infiltration surrounds a portion, commonly the neighbourhood of the macula lutea, that retains its normal aspect, and that may, by the comparative intensity of its red, be mistaken for a hæmorrhagic spot. This appearance, as Liebreich has shown, is entirely an effect of contrast. The limited infiltrated region conceals the choroidal colour, which, in the part free from infiltration, remains clearly apparent. The latter also appears absolutely more vivid, since the pigment near the macula lutea is physiologically more abundant than elsewhere, and its tint against the turbid white retina is extremely conspicuous.

In anatomical examinations have been found chiefly granular cells of roundish or irregular outline, sometimes with a cell wall and one or two nuclei rendered turbid by fat, and mostly situated in the granular layer. They have been present in great numbers, partly scattered, partly aggregated in voluminous clusters, and are resistent, strongly opalescent bodies, very insensitive to re-agents, and in appearance sometimes irregular, sometimes resembling ganglion cells, possessing a similar contour, with processes, and containing in the centre a dark opalescent body like a nucleus. There has also been hypertrophy of the basic connecting tissue, with molecular turbidity and fatty degeneration, such as always attend saturation of the tissue and separation of its elements by a coagulable homogeneous fluid. The nerve elements are often unchanged, often thickened, fatty, and turbid.

Purulent Exudations.—If ophthalmoscopic examination be possible, the retina and papilla in their greatest, or even their entire extent, will at the commencement appear in a very striking manner discoloured, yellowish-white, turbid, and somewhat hyperæmic. Afterwards, they become wholly opaque, of a pus-yellow, dotted by effused blood, swollen, and considerably increased in thickness, friable, and partly converted into a purulent mass. The vessels are almost entirely covered by the products of inflammation, by which many arteries appear to be filled and even distended. In most cases, however, these appearances are not visible; since it is most usual for the ocular media to participate in the disease, and for their turbidity to conceal the retina.

The difference between the aspects of the retinal exudations is heightened by the influence of the choroid, and by the degree of its visibility between the vessels and the effusions. This influence is naturally increased, when the choroid itself becomes involved, sooner or later, in the morbid processes. If the retina be rendered turbid by commencing effusion, the whole fundus will appear as if covered by a slight cloud; and, in this condition, the choroid exerts very little influence upon the general picture, and only shimmers in uncertain colours and outlines through the mist. If, in the progress of the disease, or in consequence of fatty degeneration, the retina entirely loses its transparency, then the influence of the choroid upon the ophthalmoscopic image ceases. In course of time, and by diminution of the effused matters through absorption, some of the affected parts become less dense, are distinguishable from the rest of the fundus by cloudy margins, and allow the structures behind them to become by degrees more and more apparent. Under such conditions the choroid may again be seen, and will modify the aspect of the fundus materially, being usually itself far advanced in atrophy. Its patches of pigmentary débris are distinguished from spots of colouring matter on the retina by their more considerable size, the irregularity of their aspect, and especially by the fact that they are often impressed by the outlines of the arborescent ramifications of the choroidal vessels. Such patches present a bluish-grey colour when the débris of pigment are dark brown or black; and a dirty greyish-yellow or greyish-brown when the choroid is covered by a more scanty pigmentation. Where the choroidal pigment has entirely disappeared, the sclerotic will be seen in its white or whitish-yellow colour, and may be confounded with yellow or white effusions; but the patches being bounded by scattered punctiform brown or black figures, indicative of atrophied choroid, would allow their true character to be determined; especially when they are partly covered by the portions of retina that are still opaque. Moreover, in the thin crape-like portions of retina, clouded or indented patches are still covered by filamentous exudations. These strongly reflect white light, and present a very remarkable tendinous lustre, so as to afford a striking contrast to those parts of the fundus in which fatty infiltration of the retina is present, or in which the atrophied choroid is seen through the gauzy retina; or, lastly, where the choroid is almost devoid of pigment, and where the sclerotic is almost universally visible. The sclerotic, in such cases, reflects much white light, and presents irregularly-bounded white or whitish-grey flecks; but it has not the tendinous lustre of retinal effusions, in consequence of being covered by turbid membranes. It is always dull and opaque; and plainly displays its deeper position behind the remains of the light-reflecting portions of the retina and choroid. (Stellwag.)

1. RETINITIS SIMPLEX.

The symptoms rendered visible by the ophthalmoscope are chiefly—

a. Turbidity of the Retina.—In trifling effusions, the appearance of turbidity is often only as if the fundus returned less light than usual, or as if it were feebly illuminated by the mirror. The colour is duller, fawn-tinted yellowish-brown, the choroidal margin of the papilla indistinct, the papilla itself turbid. The proof of this condition is sometimes very difficult, and only possible in a certain direction of the incident light, and by exact estimation of the functional disturbance. In higher degrees of effusion the retina appears as a more or less uniformly clouded, whitish, whitish-yellow, or whitish-grey layer, covering the choroid like a veil, and finally becoming wholly opaque, and uniformly yellowish-grey or dirty greyish-white. If the effusion be irregular, the aspect of the retina will be diversified by spots of different forms, sizes, and colours. In many cases there are only a few larger and smaller spots of translucent grey, or opaque dirty greyish-yellow, scattered over the retina; and in other cases they especially surround the papilla, that appears itself as a spot whiter and more opaque than the rest.

b. Aspect of the Nerve Disk.—This is characterized partly by the colouring produced by the already described pathological injection and effusion within its boundary, and partly by alterations of its margin. With regard to colour, the papilla, especially towards its periphery, assumes a light reddish-yellow; while in the middle its white tint is longer preserved. In consequence of a numerous development of capillaries, the disk often presents a finely stippled or striped redness that gradually acquires a dirty tint. The obscuration of the margin is equally important, and occurs partly through the dense capillary injection that almost always covers some portion, and partly from simple or pigmented opacity of the immediate vicinity, from which causes the shape of the disk may appear transversely oval, or even wholly irregular.

c. Aspect of the Central Vessels.—These assume in a most striking manner the appearance already described as turgescence of the veins with a normal condition of the arteries.

In many cases the ophthalmoscope will also show associated phenomena; such as extravasations of blood, either clearly visible around the veins, or deeper and seemingly covered by turbidity; pulsation of the central vein; hyperæmia or inflammation of the choroid with its consequences, increased redness, variously coloured spots, destruction of pigment, pigment masses, sub-retinal ecchymosis, and opacities of the vitreous body.

If the disease undergo resolution, the vessels first return to a more normal aspect, the effusions diminish, the texture of the retina brightens, its redness and the reflection of its turbidity disappear, the margin of the papilla becomes clear, and the visual power is gradually restored.

2. RETINITIS APOPLECTICA.

(*Liebreich's Atlas, Plate* viii.)

As characteristics of this disorder, it is necessary to observe:—

a. The Entrance of the Optic Nerve.—This loses its defined margin and normal outline, and appears as a reddish disk, which often differs so little from the surrounding fundus, that it can only be recognized as the point of union and origin of the central vessels. The fundus appears dark red, reflecting little light, and showing a delicate spoke-like radiation of streaks from the centre towards the periphery. The optic nerve loses its transparency, and therefore the vessels cannot be followed into its deeper parts, but disappear as soon as they reach the papilla.

b. The Aspect of the Central Vessels.—The vessels themselves undergo peculiar changes, the veins show the turgescence already described, are irregularly dilated, have sharp spiral curvatures, that lie alternately deeper and more superficial; while the parts most enlarged, and nearest the surface, show their dark red colour very clearly, and the intermediate parts are concealed. The arteries, on the contrary, deviate in no respect from their natural courses, but appear very thin and pale, so that often it is difficult to recognize them on the nerve disk. The chief cause of this appearance is—

c. The Colour of the Retinal Substance; since this is the only condition in which the retina itself becomes actually reddened, on account of the effused blood, which, resting between the bundles of nerve-fibres, increases the appearance of striation. Liebreich has sometimes had opportunities of exhibiting this condition by sections. The fine, red striation appears chiefly on the optic nerve, and the neighbouring parts of the retina, that have more capillaries than large vessels; while the blood effused along the latter shows itself in larger, roundish, dark red spots, that sometimes conceal the veins, and sometimes lie by the side of them, which is an important element in the diagnosis between retinal and choroidal hæmorrhage.

The effusion of blood is rarely so considerable as to make the whole retina to its utmost limits appear of one uniform dark red. In more cases, especially in aged people, Liebreich found the spots apparently large, and so numerous, connected together, and dark, that a small light interstice could only here and there be observed, and the trunk of an occasional retinal vessel seen with difficulty. Moreover, he states that it is only in cases between the most trivial and the most severe, that the characteristic appearance of the vessels, the undefined margin of the disk, the peculiar fine striation, and the small red spots, can be perceived;—these being all intermediate steps in the disease.

It is interesting to observe with the ophthalmoscope the resolution, and the frequently sudden metamorphoses, that occur in this affection.

The fine red striation first disappears, and the larger red spots lose their uniformity, and become marked with brighter yellowish lines and dots, which afterwards increase in clearness and extent, until at last they wholly occupy the places of the red. The optic nerve shows a less uniform striation, and clear portions with bundles of streaks proceeding towards different sides. Soon afterwards the yellow specks themselves disappear, and the nerve again exhibits a defined margin and visible arteries. At last, there is only to be observed slight fulness of the vessels, a peculiar dull white colour of the nerve-disk, and here and there a dark blood-spot that still resists absorption. In other less fortunate cases the original changes may proceed even to carcinomatous degeneration and atrophy of the retina;—fatty degeneration of the retina being a very common termination.

3. RETINITIS PIGMENTOSA.

(*Liebreich's Atlas, Plate* vi.)

(*Pigmentary degeneration of the retina ; pigmented, or tiger-striped, retina.*)

The functional derangements attending pigmentary degeneration of the retina are, according to von Gräfe, so characteristic, that, as a rule, the ophthalmoscopic appearances may be predicted with certainty. The most marked symptoms are, in the first period of the disease, the occurrence of night blindness, and of concentric narrowing of the field of vision. It is especially remarkable that, while the field of vision is contracted, central vision may remain a long time unimpaired, so that persons whose visual field is narrowed to an opening of 10° or 15°, or less, may still be able to read fine type. This is of importance in the differential diagnosis from cerebral amaurosis, in which, as a rule, considerable narrowing of the field of sight is attended by marked impairment of the central vision. In amaurosis with excavation of the optic nerve, good central vision is sometimes found together with advanced contraction of the field; but the contraction, according to von Gräfe, is not concentric, but slit-shaped, with the fixing point of sight lying near the inner margin of the slit. The pigmentary disease is not always hereditary; but it is so in many cases.

The objective signs are as follows:—Between the optic nerve and the equator of the eye are seen irregular lines and figures, distinguishable by their deep black colour from the choroidal pigment. Their forms are very variable and irregular, from simple thin lines to oval spots with fine thin projections, giving the retina a tiger-striped appearance, and often so thickly distributed that the whole fundus appears black.

Their varying numbers in different cases bear little relation to age, or to the development of the disease, but depend, according to Liebreich, upon trivial collateral circumstances, for example, upon the general pigmentation of the individual; while their influence upon sight depends chiefly upon the extent and the position of the parts of the retina involved. In general, the disease is so arranged in concentric circles, that either the optic nerve, or the macula lutea, or most frequently a point near the latter, is their centre. The outer margin is irregular, the inner approaches the centre as the disease progresses.

In this disease, Donders observes that the optic nerve appears small and irregular, often oval or even triangular, not sharply defined. The vessels appear obscured, and cannot be deeply followed. As the disease progresses they become narrower, and are at last wholly obliterated, so as to resemble yellowish-white strings. In almost all cases there occur choroidal complications, such as thickening of the lamina elastica and atrophy of the pigment-layer.

With regard to the essential character of the disease, Donders believes that it depends upon an idiopathic development of black pigment granules in the retina, but that no precise account of the cause or manner of this development can be given. The pigment granules are situated chiefly or exclusively upon the vessels; and, by greater accumulation about the ramifications and anastomoses, produce the appearance of a network of branching corpuscles. Junge, on the contrary, entertains the opinion, based upon the dissection of two eyes affected by the disease, that a spontaneous development of pigment ought not to be assumed. He explained the condition he found (which corresponded perfectly with the ordinary conception of the tiger-striped retina), in the first case by peculiar changes in the retinal vessels, consisting of a condensation of their walls, which he described as "vitrification," with subsequent atrophy. In the second case he regarded the retinal changes as results of three different pathological conditions;—a retinitis dependent upon choroiditis, atrophy of the optic nerve, and atheroma of the retinal vessels connected with the general vascular degeneration. Lastly, Schweigger, who has also had opportunities of dissection in two cases, attributes the disease to an exudation on the inner surface of the choroid, with secondary infiltration of the retina, atrophy of its proper nerve element, and of the optic nerve. He considers the presence of pigment to be only accidental; and believes that a similar process may be carried on without its formation, and that the disease then bears, both in its functional and ophthalmoscopic characters, a deceptive resemblance to cerebral amaurosis.

According to Pilz, the disease is in every case combined with atrophy of the retina, that may be recognized at the papilla nervi optici; and he has discovered it, with the ophthalmoscope, in young persons in whom there was no retinitis. He has seen it supervene without any of the appearances of inflammation; and thinks it certain that the development of pigment occurs chiefly around the vessels, and without bearing the least resemblance to the reddish black spots or flecks of retinal atrophy. "The deposits form such a characteristic network, that, as Donders observes, anyone who had once seen it clearly with the ophthalmoscope, would recognize it with certainty in an anatomical preparation. The white patches of atrophy are also wanting, and the chronic course of the affection is so marked that certain subjective symptoms (intra-ocular pressure, &c.) must be regarded as complications of a co-existing irritation or inflammation, rather than as causes of the principal disease. Its course, moreover, is so gradual that Donders has truly remarked that, in most cases, there is an interval of twenty years or more between the occurrence of the first symptoms and the final extinction of sight."

Stellwag regarded the disorder as only one variety of the many forms of chronic inflammation of the retina.

Liebreich is of opinion that the subjects of this disease, in about half the cases of its occurrence, are the offspring of marriages of consanguinity.

4. RETINITIS ALBUMINURICA.

(*Liebreich's Atlas, Plate* ix., *Figs.* 1 *&* 2.)

(*Fatty degeneration; fatty metamorphosis of the retina.*)

The appearances visible with the ophthalmoscope are thus described by Liebreich :—

At the commencement of the disease there is retinal hyperæmia; the veins appear distended and winding; and, according to their deeper or more prominent position, will vary in colour and distinctness of outline; being now dark red and clearly defined, now concealed by clouded retinal tissue. By the escape of blood, partly in fine radiating streaks between the nerve-fibres, partly in larger oval or roundish spots, the cloudiness rapidly increases, and conceals the thinner and straighter arteries almost completely, so that they can only be perceived with difficulty upon the dark red ground. The papilla also becomes obscured, deprived of its contour and its former characters, and appears of a dull reddish colour, striated, and opaque. In different parts of the fundus, at some distance from the nerve, appear single small white points, and larger, oval or roundish, bright, milk-white, somewhat elevated patches.

The appearances now become characteristic of Bright's disease. The bright spots increase in number and magnitude, and coalesce to form a broad band that surrounds the optic nerve. Between the two, remains a greyish portion of retina, against which the almost equally grey nerve-entrance can scarcely be distinguished. This greyish portion appears regularly circular, and has a diameter twice or thrice that of the papilla. At its periphery commences the elevated, thick milk-white band of granular cells, bounded externally by sharply-defined but irregular longer or shorter curves or points, and extended chiefly in the course of the larger vessels, so that the breadth of the whole zone differs, at different places, from twice to four times the diameter of the nerve-disk. At length, but not always, the band will include the macula lutea, in the neighbourhood of which the retinal changes present a very characteristic aspect. The granule cells in this part appear from the first not as large white spots, coalescing to form an uniform band, but as groups of white points, sprinkled in peculiar radiating lines, while the centre of the macula lutea appears dark red, in contrast to the bright white in its vicinity. In more advanced stages the grouping characteristic of the neighbourhood of the macula becomes concealed by the increasing development of granule cells; the points become larger and larger, and ultimately confluent.

The vessels still appear much as at the beginning of the disease, except that they are partly buried by its increase. In great part, however, they follow the elevation of the surface.

The retina can only remain a limited time in this condition, and great changes in its appearance occur suddenly. First small ecchymoses, and then more considerable hæmorrhages, cover the deposits of fat, and convert the surface into an uniform dark red; and sometimes the retina becomes detached.

As regards the share of the choroid in this process, Liebreich observed towards the periphery, roundish, angular, or irregular spots, partly brighter, partly darker, than the surrounding fundus, and apparently due to changes in the choroidal epithelium. Upon these spots, moreover, there appeared in places an uniform thin film, as if formed by a clear effusion. In one case Liebreich observed the gradual increase of this film, and a small separation of the retina thereby induced. He has also found choroidal changes present in the more central parts, and only concealed from view by the diseased retina; so that, as the retinal changes disappeared, those of the subjacent membrane became visible.

In dissecting eyes that had suffered in this manner, Schweigger found two chief kinds of disorder—alterations in the nerve elements, and in the connecting tissue; the former being the source of the functional disturbance, and the latter of the ophthalmoscopic changes. The alterations in the connecting tissue consisted chiefly of hypertrophy and fatty degeneration, and sometimes of sclerosis. There was also a plentiful development of fine vessels in the papilla, with hæmorrhagic effusions and coagula, the latter appearing partly as compact firm masses, partly as thick coils of clot-fibrine. The changes in the retinal nerve elements were due to thickening of the individual fibrillæ, and were distinct from the thickening produced by serous tumefaction. There were also changes in the choroid and the vitreous body.

Nagel thus expresses the general results of his observations:—Fatty metamorphosis of the retina is a final stage of chronic parenchymatous retinitis. The structural changes produced are not limited to individual layers, but pervade them all. They consist of disturbances of the circulation, especially of punctiform hæmorrhages, of the deposit of amorphous fibrinous effusions, and of fatty changes of the interstitial connecting tissue, as well of the central as of the basic membrane (Müller's fibres and network), with increase of nuclei, transformation of cells, and their retrogression into fatty granule cells. In the advance of the disease the nerve elements of the retina degenerate, and exhibit fatty disintegration of the bacillary layer, degeneration of the ganglion cells, and varicose hypertrophy of the fibrillæ. The chronic inflammation and fatty metamorphosis of the retina that so frequently attend upon Bright's disease are apparently due to imperfect depuration of the blood by the disordered kidneys; and a similar influence is often exerted upon the nervous centres. The retinal apoplexies are not to be regarded as the early stage of the agglomerations of granule cells, and usually stand in no necessary relation with them. Such apoplexies are common to all forms of retinal hyperæmia and inflammation, and are to be considered as symptoms of these conditions, due to the anatomical arrangement of the vessels.

The nature of the causal connection of the retinal disease with that of the kidneys or heart is still an open question; but it should be remarked that a similar or identical disease of the retina is seen in connection with diabetes mellitus, hippuria, benzuria, oxaluria, and so forth; as well as, partially, during pregnancy and lactation, and in syphilis.

Liebreich remarks, with regard to this disorder, that it is only seen in connection with Bright's disease; and that, although the retinal elements may be affected in a similar manner in other pathological conditions, the peculiar grouping and localization of the changes above described are pathognomonic, and allow the kidney disease to be diagnosed with perfect certainty by the use of the ophthalmoscope alone. He states that in syphilitic retinitis the white appearance of the diseased membrane is highly irregular in outline, and less marked in degree, bearing some resemblance to a partial pathological exaggeration of the ordinary aspect of the retina in a darkly-pigmented eye. In Bright's disease, moreover, the hæmorrhages are always in the most internal retinal layer, and the blood effused is ranged along between the fibrillæ, giving a striated appearance to the spots, in a direction corresponding to that of the fibrillæ themselves; whilst the numerous ecchymoses of syphilitic retinitis are found in all the layers of the retina, as well as in front of, or behind, the whole thickness of the membrane.

Liebreich also distinguishes a form of retinitis that he attributes to splenic leucæmia, and that is marked by a peculiar clear, light, almost rose-colour of the vessels and the ecchymoses, by pallor of the optic disk, which is surrounded by turbid and striated retina, and by the presence of numerous small brilliant roundish white spots, resembling those seen in Bright's disease, but differing from them in being peripheral. These various forms of disease are extremely well illustrated in the "Atlas of Ophthalmoscopy," and the student will do well to compare and carefully study the respective figures.

Liebreich holds that idiopathic affections of the choroid are common, but that idiopathic affections of the retina are extremely rare. He considers the diseases of the latter membrane to be almost always due to constitutional dyscrasia or blood-poisoning; and, chiefly, to the three forms of it that are mentioned above. He also calls attention to the fact that, while very conspicuous changes in the retina may be attended by slight disturbance of vision, alterations apparently trifling, in the choroid, usually greatly impair, or even destroy, the sight. He believes that the diseases of the retina, producing obvious alterations in the ophthalmoscopic image, are chiefly seated in the connecting tissue of the membrane; and, moreover, that the nerve fibrillæ, even when much changed in aspect, may still retain their functional integrity. On the other hand, the most trifling alterations in the bacillary layer, such as must arise from very small changes in the contiguous most internal lamella of the choroid, appear to be sufficient to produce very great disturbance of sight.

There are, perhaps, few matters of more practical importance than a knowledge of the appearances that may be considered trustworthy indications of syphilitic internal ophthalmia; and it is impossible to take too much care in the scrutiny of every eye in which syphilitic disease is known to have existed. The cases in which it is only suspected are often extremely doubtful.

5. INFLAMMATORY SOFTENING OF THE RETINA

Presents, according to Pilz, the following ophthalmoscopic appearances :—

The retina, either attached to the choroid or separated from it, exhibits, in greater or less extent, a remarkably bright, yellowish-white appearance, like a thick exudation layer, with sharp, here and there indented, radiating outlines, strongly marked against the neighbouring fundus, and sometimes extending to the nerve, which then presents an ecchymosed and finely red-sprinkled appearance, under which the central vessels may be more or less completely concealed. The position of these patches always corresponds to that of the retina, and they may project somewhat above its normal plane. Upon the portions invaded by the patches no retinal vessels can be seen, although they may be visible in the neighbouring parts of the fundus. The final termination of the disease is always atrophy of the retina, followed, after a time, by atrophy of the optic nerve. The papilla gradually loses its red-sprinkled appearance, and assumes a white shining aspect, in which only traces of the central vessels can be seen.

According to Pilz, inflammatory softening of the retina may supervene upon inflammation of the choroid with exudations from the vasa vorticosa, or upon extensive fibrinous effusion in capillary choroiditis, and simultaneous separation of the retina, with or without corneal perforation, and with or without subsequent shrinking of the globe. It therefore forms part of the changes in phthisis bulbi. Its diagnosis during life is of course only possible, when the ocular media are still transparent.

III. CHANGES OF POSITION OF THE RETINA.

1. SEPARATION OF THE RETINA FROM THE CHOROID.

(*Liebreich's Atlas, Plate* vii., *Figs.* 1 & 2.)

This occurs in all degrees, from the least to the greatest. In the former it has the appearance of a bladder-like prominence, the size of a pea; in greater degrees as a larger bladder, extending over a fourth or one-half of the retina; and in the greatest degree the whole retina is separated from the choroid.

As subjective phenomena, von Gräfe enumerates the following:—There appears, without pain, in the upper part of the field of vision, an apparently sharply-defined dark cloud; and objects appear, especially upon its margin, but in many cases also over the whole field, curved, or interrupted, or oblique. The dark cloud extends itself chiefly towards below, and in a great number of cases has a blood-red colour, which in a few days becomes yellow, and then wholly disappears; although sometimes the original colour will remain. If the central part of the retinal field remain intact, the sight may still be moderately good; but, as soon as the retina around the optic nerve is implicated in the separation, vision will fail. If the upper limit of the detached portion border on the nerve, the sight may vary considerably. In such cases, if the neighbourhood of the macula lutea be intact, there may be good vision in the centre of the field, even though the part of the retina immediately below the nerve be already detached. But in most of such cases, since the upper limit of the detachment is wont to be nearly horizontal, either the macula lutea is at first implicated, or it and the neighbouring parts are involved in secondary changes, so that central vision is impaired, and the patient is compelled, when the diseased eye is used, to direct its axis, not upon the object looked at, but obliquely upwards (Hemiopia). It is also very common in these cases to find diminished perception of light towards below and outwards, depending either upon extension of the separation to both sides of the nerve, or upon the increase of secondary changes. Von Gräfe observed cases in which the retina was detached beneath the nerve, and on both sides of it, as far as to the upper part, but in which a certain portion immediately above the nerve remained attached. There was still a feeble visual power towards below, which was lost as soon as the separation extended itself all round the nerve, although at a greater distance the retina remained attached, and showed an apparently normal texture.

The objective symptoms vary much in different cases. It is common to all, that the retinal vessels present a changed appearance in the inverted image, appearing much bent, and deviating from their normal direction. If the observer make slight lateral movements of the convex lens, he will remark that the parts of the vessels that project towards him show, in relation to this or that side, considerable changes of place, since they are no longer parallel to the sclerotic, but floating in front of it upon a curved and moveable wave-shaped surface.

Upon the colour of the detached portion, the retina itself, as in the normal state, has very small influence. It depends more upon the character of the effusion poured out between the retina and the choroid. If this effusion be clear and transparent, the colour of the detached portion will not differ remarkably from that of the rest of the fundus. If it be opaque, the detached portion may vary from light bluish-grey to dark bluish-green, according to the colour of the fundus and the degree of folding of the loose retina. Upon the upper surfaces or summits of the folds there is often a lustre like that of dirty satin.

The best insight into these conditions is obtained, according to Liebreich, by the study of cases in which the contents of the retinal sac are not homogeneous, but consist partly of clear fluid, partly of solid and opaque coagula. These coagula remain, when the retina is partially replaced by absorption of the fluid, as bluish-white streaks between the retina and the choroid, extending sometimes over a large portion of the fundus, and affording the means of determining the condition that preceded them. If in such a case the observer fix upon some point of the retina (*e. g.* a vessel), that is situated on the line of demarcation between transparent and opaque substance, he may, by moving his head, and altering his line of sight, bring this retinal point to rest upon each part in turn. In this way he will perceive that it is not the retina that affords the dark grey or greenish colour; and he will also easily isolate for inspection the retinal substance itself. If light be concentrated exactly upon the spot to be examined, by forming there an inverted and diminished image of the lamp-flame, and if this spot be then inspected in the erect image with a weak magnifier, the bundles of fibrillæ will be visible as fine streaks, having extremely fine points (granule cells) behind them. Only in rare cases is the retina so thickened and folded that it appears opaque and greyish white, or yellowish; and that the effect upon its colour of the fluid behind it becomes inconsiderable.

The circulation in the detached portions continues entirely normal, even in cases of long standing—those being excepted in which Bright's disease or other complications may be present. Liebreich states, however, that the vessels undergo changes, partly in their course, and partly in their colour. Constrained to follow the retina in all its folds and movements, they deviate more or less suddenly from their accustomed course, and wave about, rising and falling before the observer. It thus happens that they are visible sometimes in their whole extent, and sometimes appear interrupted; that a vascular trunk may vanish suddenly, as if cut off, while on the other side are seen twigs belonging to no apparent stem. In colour the vessels appear as dark red, or even occasionally as black streaks, a colour depending on the tint of the separated retina, as may be seen in cases in which the appearance of the detached portions is not uniform, but partly transparent and partly opaque. On such a ground the vessels appear darker, the darker it is itself; and on the transparent portions they often do not deviate from their natural hue. This only applies, however, when the retinal substance is itself sufficiently transparent; for, if it be very turbid, the vessels will on this account appear dark.

If the retina be detached in its entire extent, its form will resemble that of a funnel, the *ora serrata* corresponding to the wide opening, and the nerve-entrance to the narrow one; or, according to Coccius, the cup of a flower (a convolvulus blossom, Arlt), and will be more or less pointed at the optic nerve. Coccius once saw the lower and outer part of the nerve torn; and resembling a gaping, conical slit in a cloth.

In order to perceive the movements of the retina in the vitreous body, the patient must be directed to make short to and fro movements of the eye. The retinal motion is often small, and its extent must depend partly upon the extent of the disorganization of the vitreous, partly upon the degree of the distention of the sclerotic by effusions, just as the movements of a solid body in a distended bladder are shorter than in one that is less tense.

In respect of the part of the retina most frequently detached, it may be observed, that, in the greatest number of cases, the inferior half suffers. Towards the upper part, the limit between detached and normal retina is apparently sharply drawn by a straight or slightly curved line, either horizontal, or oblique from within outwards. If the separation extend further, the line of demarcation proceeds, even to the optic nerve, and rises, chiefly on the outside, but somewhat on both sides, to the upper part, until by degrees the whole retina becomes detached, excepting the upper and inner portion, where, even in complete separation at the peripheral margin (*ora serrata*), a portion is commonly found adherent, with its inferior limit external to the field of view. Separation of the outer half alone is very seldom found; of the upper half alone, still less frequently; and in old cases scarcely ever, unless caused by *cysticercus telæ cellulosæ*. In a very few perfectly fresh cases, von Gräfe has been enabled to establish the existence of detachment of the upper part of the retina; and hence it is believed that, although nearly all cases of detached retina come under observation with the inferior part affected, it is still by no means certain that the separation first took place there. It is even a fact that in many cases, possibly in most, the separation first occurs elsewhere, and afterwards extends downwards; and, in a certain degree, assumes in that direction a constant form. This change of place appears to be certainly due to gravitation of the sub-retinal fluid to the deepest parts. If the retina, after recent separation, be again applied to its attachments, the questionable or incomplete detachment may be restored; but in old cases this is probably impossible. Complete transparency of the separated parts seems to be, for such reunion, a *conditio sine quâ non*. In such disappearance of retinal detachment at its original seat, with restoration of the portion of the visual field that first was lost, and improvement of the central vision, it is never permissible to anticipate an actual recovery, or to indulge in a favourable prognosis, since, sooner or later, the development of the ordinary form of retinal separation is to be expected.

The complications most commonly to be recognized with the ophthalmoscope are:—partial retinitis in the neighbourhood of the separated portions, shown by the development of very delicate, infinitely fine vascular anastomoses, forming insular spots; by fine, granular, whitish, or reddish-white exudations; circumscribed hæmorrhages; and by opacities in the vitreous body. If, in the elevated portion of retina, there be scattered collections of pigment, extravasations, or crystals of cholesterine, these will impart, in movements of the eye, a very striking and peculiar appearance. There will be complicated changes of position between the different objects, as in a kaleidoscope. If the globe be fixed, these changes diminish and cease; and the separate objects resume their original relative positions. By this circumstance, morbid products attached to the retina may be distinguished from like products that are only suspended in the vitreous. The latter, after floating about, gradually subside, and have no definite or proper locality.

Separation may be produced by various causes:—either by serous (?) effusion between the retina and the choroid, or (according to von Gräfe) by perforating wounds of the sclerotic, or (according to H. Müller) by traction from before. Von Gräfe has repeatedly seen large, apparently widely-gaping, perforating wounds of the sclerotic in the neighbourhood of the equator, with moderate loss of vitreous humour. The healing proceeded favourably, without the least inflammatory reaction; and the vision, although certainly not perfect, during the first weeks remained little impaired. At the period of cicatrization there first occurred a characteristic drawing-in of the sclerotic; and, at the same time, a sudden diminution of vision, contraction of the field in the parts concerned, and lastly, the ophthalmoscopic discovery of a retinal separation, commencing from the neighbourhood of the wounded equatorial portion. Separation of the retina by traction is ascribed by Müller to the contraction of exudations in the vitreous, and in the neighbourhood of the ciliary body.

Separation of the retina is not a very uncommon result of smart blows upon the supra-orbital ridge, or other parts adjacent to the eye. I have seen one very well-marked case, in which it followed a puncture made into the eye by a surgeon, in the neighbourhood of the ciliary muscle, with the idea of relieving simple myopia by the so-called intra-ocular myotomy. I may also mention that, while these pages have been passing through the press, I have seen two quite recent cases—one apparently spontaneous, and the other the result of a blow—in both of which the separation had befallen the *upper* portion of the retina.

2. SEPARATION OF THE RETINA AND CHOROID FROM THE SCLEROTICA.

(*Liebreich's Atlas, Plate* vii., *Fig.* 4.)

This very rare condition has hitherto been observed by Liebreich only. It appears as a smooth, circumscribed, reddish-yellow, spherical tumour, projecting into the vitreous body, and having the retinal vessels continued over it without deviation. As in simple retinal separation, these vessels can be seen from a greater distance than usual in the erect image. The pupil, during movements of the eye, appears sometimes of its normal reddish luminosity, sometimes of a yellowish tint and slightly furrowed by the clearly defined vessels, according as the normal or the projecting portions of the fundus come into view. The chief symptoms of the condition are, the absence of folding and wave-like movement; the red colour in spite of the opacity of the tumour; and, above all, the possibility of seeing the choroid, although feebly, through the retina, in contact with which it rests, giving, according to its colour, different appearances to the fundus. In a woman with blonde hair and blue eyes Liebreich saw the choroidal vessels in clear outline. In her, at the angle formed by the choroidal projection with the neighbouring parts of the fundus, the retina itself was also detached from the choroid; and it was possible, in movements of her head, to see clearly the slow changes of place of the retinal vessels and extravasations in relation to the choroid, and also the light colour of the retina as it appears in simple separation with transparent contents. A separation of the retina and choroid, on account of its peculiar colour, size, and attached position, might be mistaken for a malignant tumour; until the irido-choroiditis, that, in the former, sooner or later occurs, had produced atrophy of the globe.

Separation of the retina may occur also from—

3. TUMOURS IN THE INTERIOR OF THE EYE.

(*Cerebriform Fungus of the Retina, Beer's Cat's Eye Amaurosis.*)

The development of a malignant tumour in the interior of the eye cannot be distinguished, at the beginning of the disease, from simple separation of the retina; but if the affection be farther advanced, and the degenerated and often golden-yellow coloured retina pushed in front of the focal point of the refracting media, then examination by lateral illumination is preferable to ophthalmoscopy, and is attended with no difficulty. According to von Gräfe, the presence of a tumour behind the retinal separation may be suspected, when, coincidently with considerable detachment, there are signs of increasing intraocular pressure. Such signs are,—ciliary neurosis, and hardness of the globe manifest to the touch; especially the latter, as in simple separation the eye usually feels somewhat softened. Moreover, there may be paralysis of the iris, displacement of the iris forwards, anæsthesia of the cornea, &c. &c.

4. CYSTICERCUS CELLULOSÆ.

(*Liebreich's Atlas, Plate* vii., *Figs.* 5 and 6.)

Although earlier observers were aware of the occurrence of cysticerci and other parasites within the human eye, in consequence of their occasional appearance in the anterior parts, it was reserved for our own time, with the aid of the ophthalmoscope, to discover their presence at the fundus. Since von Gräfe and Liebreich made the first exact observations upon this subject, the number of cases has greatly increased; but they all present, under ophthalmoscopic examination, more or less the following symptoms:—

The parasite is found, at least in the first periods of its development, constantly inclosed in a turbid membrane, which in some cases is connected by its greatest breadth with the retina, and seems a continuation of it, since vessels from the retina are continued over it. It appears, therefore, as if the retina were split in the direction of its thickness, and the parasite situate in the pouch thus produced. In other cases, the more prolonged envelope has cylindrical processes at one or both of its ends, and turns one of them towards the fundus oculi, to be either lost to sight in the deeper structures, or visibly united by fibres or membranes to the retina or the optic nerve. The anterior extremity of the sheath is sometimes free, and sometimes terminates in a bundle of transparent fibres, which reach to the posterior surface of the crystalline lens, and appear to be attached there. They are compared by Stellwag to the threads formed in fibrous transformation of the vitreous body.

In proportion to the number and situation of its points of attachment, the mobility of the sheath within the eye may be either very small or very considerable; so that, in the latter case, the parasite may travel over the whole extent of the posterior chamber of the eye. Under such circumstances, the vitreous body must necessarily have become fluid.

The colour of the sheath is greyish-white, which may be changed to bluish or greenish by the transmission through its translucent wall of light reflected from the fundus. At one or the other side the head of the parasite will be visible as a white knot-like appendix, remarkable both by its comparative opacity and by its colour, as well as by variations in its extension, and by changes of its position with regard to the containing vesicle. The details of its formation are of course concealed by the turbidity of the sheath, which also forbids a direct view of the transparent body of the parasite. This, however, is indicated by the expansions and contractions of the vesicle, and especially by a cup-like retraction of its surface that communicates a wave of movement to the surrounding portion, and, in complete stillness of the eyeball, frequently modifies the spherical form of the vesicular body.

In time, however, the investing membrane becomes broken down or torn, and a portion of the vesicle projects, like a bladder-shaped appendix fixed in the sheath, and as if surrounded at its neck. This projection consists of the head and neck, that, no longer confined, move about freely, and are characterized not only by the details of their outline, but by their peculiar expansion and retraction, like the movements of a proboscis. The vessels that traversed the investing membrane gradually disappear, or appear only as very fine lines; and, as the worm advances more and more, the opening in the sheath enlarges, until at last the sheath disintegrates into a system of opaque shreds, that float at the fundus of the eye, and partly cover the liberated parasite. (Stellwag.)

The functional disturbance consists chiefly in the diminution of the field of vision, in which the patient sees a round black patch. The sight steadily diminishes as the retinal separation increases, and the prognosis is always unfavourable.

IV. ATROPHY OF THE RETINA.

This melancholy termination of the most different of the deeper diseases of the internal eye is various in its extent, involving greater or lesser portions of the retina, or even the whole of it; as, for example, in large choroidal effusions, when there may be no trace left of the retina but a few fibres of connecting tissue, proceeding from the simultaneously atrophied optic nerve, and radiating until lost in the choroidal effusion.

Atrophy of the retina is characterized by conversion of its texture into a fine, molecular, more or less clearly striated mass, or into true connecting tissue. Imbedded in this structure, and chiefly near the modified, degenerated, or atheromatous vessels, are found the metamorphosed remains of inflammatory products, and also, in many cases, masses of newly-formed cellular elements, which, during the progress of the inflammation, were often not present, or only in smaller quantity. Among these, pigment cells are especially prominent, and are sometimes developed in enormous numbers; which, grouped in larger or smaller masses, peculiarly modify the ophthalmoscopic and anatomical appearances. Cases sometimes are seen in which commencing atrophy coexists with neighbouring inflammation; the latter declared by the dirty colouring or greyish-yellow turbidity of the fundus, the concealment of the choroidal margin of the papilla, and the distension of the veins, with or without extravasation; the former by the considerable deposition of pigment. If the atrophy be total, the fundus appears in its whole extent of a dirty greyish-yellow or greyish-brown, and covered by numerous black or brown spots, between which the remains of the choroid appear as bluish spots, or even the dirty white of the sclerotic may be visible.

In more advanced atrophy the remains of the retina sometimes become so thin and transparent, that they can only be recognized with the ophthalmoscope by the presence of the almost obliterated blood vessels. The fundus, on account of the visibility of the sclerotic, appears almost entirely whitish-yellow and shining, but marked by dirty clouds, and by larger and smaller collections of pigment. The vessels disappear almost entirely.

Very considerable masses of exudation may sometimes still be recognized, in the atrophied retina, as turbid greyish-white or dirty-greyish yellow dull patches, with indistinct, irregular, ragged, or insular free margins; and sometimes with vessels passing through them.

In the majority of cases there is also atrophy of the optic nerve; and the appearances of the two conditions are combined.

III. THE CHOROID.

The diseases of the choroid were in a certain degree understood, prior to the discovery of the ophthalmoscope, by means of the exact and careful researches of pathological anatomists. It was known that the choroid, as a richly vascular membrane, was the frequent seat of numerous morbid changes, that resulted in the impairment or the destruction of sight. Many forms of amblyopia, of organic amaurosis, and of such plastic exudations within the eye as could be seen without optical assistance, were recognized as the consequences of choroidal disturbance.

Abnormal hardness of the globe, varicosity of the superficial veins, and a peculiar direction of their course, mydriasis, thinning of the sclerotic tissue, &c., were, in a general way, known to be the results of an acute or chronic choroiditis, sufficient to impair, to increase, or to diminish the secretion of the internal humours, to disturb vision in various ways, and to injure the delicate tissues of the retina and of the hyaloid membrane. It was also known that choroidal ossification and posterior staphyloma were the last stages of chronic inflammatory processes. But the direct and immediate examination of the choroid, as of the retina, was then impossible; and the observer was unable to follow the intermediate stages and steps of diseased action from its earliest to its latest phases, to estimate their tendencies, or to connect them with the corresponding functional derangements. The opinions formed upon the nature, the seat, the extent, and the degree of morbid action were therefore uncertain and fluctuating; and the disturbances that had their origin in the choroid were often attributed to the retina, and *vice-versâ.* That was frequently ascribed to dynamic or nervous change, which has been shown, by the help of the ophthalmoscope, to depend upon material or organic processes. Commencing congestion of the choroidal vessels, partial choroiditis, plastic effusions, hæmorrhages with their consecutive opacities of the vitreous body, more or less extensive atrophy from the deposition of different matters in the texture of the membrane—all these things, prior to the discovery of the ophthalmoscope, were not only not known, but were scarcely even suspected. The consequences were, errors of prognosis; and inefficacy of a treatment that was applied to unknown conditions.

As a rule, the appearances proper to diseases of the choroid are easily recognized with the ophthalmoscope; but sometimes a greater familiarity with the instrument and a certain degree of experience will be required, in order to see correctly, and to interpret the appearances that are seen. The greatest aids for the latter purpose are an exact knowledge of the anatomical structure of the membrane, and of its physiological conditions recognizable by the ophthalmoscope. A lighter or darker colour of the epithelial pigment allows us to see the choroidal vessels, now bright red with sharp outlines, and now brown red with outlines obscured, or sometimes, in the latter case, conceals them altogether. A greater or less abundance of pigment in the stroma influences in the most various ways the aspect of the vascular network. If the stroma be sparingly, or not at all pigmented, we see the finest ramifications, which cover the fundus as with an irregular net of narrow meshes; while if the stroma be richly pigmented, there will be only visible a much more regular network of larger meshes, with dark interspaces almost free from vessels. In order to judge, therefore, whether the condition of the choroidal vessels be healthy or morbid, it is necessary always to consider:—1. The degree of pigmentation of the stroma; a matter to which the colouring of the skin and hair of the patient affords a tolerably certain guide. 2. The number, colour, diameter, and elevation of the vessels upon the plane of the choroid, as well as their anastomoses. 3. The condition of the papilla and the retinal vessels, which commonly participate in choroidal changes; and, 4. The appearance of the sound eye as contrasted with the one that is diseased.

The visible diseases of the choroid are chiefly inflammatory, and the inflammations are chiefly chronic. Their most important signs are furnished by exudations, which therefore deserve particular consideration.

I. HYPERÆMIA OF THE CHOROID.

This is a very common affection, occurring to a great number of people, without any remarkable disturbance of sight. For the reasons just stated, it is difficult to recognize with the ophthalmoscope; and its detection is often based upon other grounds, to which especially belong the ordinary habit of the patient, the sluggish movements of the iris, and the remarkably long continuance of pupillary dilatation after the instillation of atropine.

In ophthalmoscopic examination the fundus appears of a dark uniform red, like a strongly inflamed conjunctiva, and the vessels (especially the larger vessels behind the equator) appear strongly injected, often distorted and irregularly enlarged. While Pilz declares, that, in the severer forms, he finds the chorio-capillaris developed into a fine mesh or layer of uniform redness extended over the vessels, Liebreich states, that *"in such affections, even when pathological conditions of that portion were certainly present, he had never been able to recognize their existence with the ophthalmoscope."*

II. INFLAMMATION OF THE CHOROID.

(*Liebreich's Atlas, Plate* iv.)

While in inflammation of the retina the changes produced in the texture of the membrane are early and clearly visible, and are characterized by the changes that they impress upon the aspect of the vessels, the structural changes in the choroid, so long as they are confined to its deeper layers, and therefore at the commencement, or even in the moderate development of morbid processes, are almost entirely concealed by the pigment layer of the stroma. Afterwards, however, in the ready disturbance of the epithelial pigment, and in its common considerable increase, such changes are strikingly and definitely expressed. In other cases, however, in spite of their extent, they may be concealed from view by the development of secondary conditions, and especially by turbidity of the ocular media.

Before proceeding to speak of the appearances characteristic of choroidal inflammation, it is necessary to describe generally the various forms of exudation.

Serous Exudations.—Transparent serous effusions, that interpenetrate the stroma itself, produce very little effect upon the ophthalmoscopic image of the fundus; but, if the effusion be in considerable bulk, it will cause, according to its extent, either partial or total separation of the retina from the choroid, in the way already explained. The colour will be infinitely various, according to that of the effusion, its quality, amount, and the admixture of blood corpuscles it may contain; and it needs only to mention here, that, when the funnel of separated retina retains a certain degree of transparency, the colour of the subjacent fluids, often even the reddish tint of the choroid, and sometimes the occurrence of crystals of cholesterine in the effusion, may be perceived. These appear as shining white, glittering, spherical, cylindrical, or irregular corpuscles, which either retain their places upon the retina, or change them in correspondence with the movements of the eye. If it be necessary to distinguish between such crystals behind the retina and those in a fluid vitreous body, the movements of the former crystals behind any single visible retinal vessel, or, in advanced stages of retinal atrophy, their relation to the shaded folds of the diseased membrane, may serve as points of distinction.

Blood Extravasations (*Hæmorrhages*).—Bleeding from the choroidal vessels may occur in various degrees, from small ecchymoses to a considerable amount; and is a very common phenomenon, that may often be diagnosed from the narrative of the patient. This is generally to the effect that, after headaches, tension and aching of the eye, and momentary weakness of vision, the sight of the eye affected was suddenly lost, usually in the morning at first rising, or after violent efforts, vomiting, &c. In many cases vision is not altogether destroyed, but the patient complains of suddenly occurring black clouds in the field of sight, that interfere with it in this or that direction, or conceal portions of the objects looked at.

Small quantities of blood are found in thin layers upon the inner surface of the choroid, and appear as red spots, that break up under absorption, become pale, and finally disappear entirely, or leave slight alterations in the pigment layer. Sometimes the effused blood extends itself all over the choroid; and the fundus oculi then appears of an uniform dull deep red (*Obscurité de l'œil* of Desmarres); in other cases, the effusion is only partial, and the choroidal vessels can still be perceived between the red spots. By absorption the red colour passes into yellow, and the former position of the blood is shown by spots of a dirty yellowish-white, often with a highly pigmented halo, that may be visible after several years; in rare cases the blood effusion may burst through the retina, and penetrate the vitreous. Effusions of blood in small quantity, and in dark-eyed persons, are, for a certain time, not conspicuous; especially in slow inflammation. In order to become acquainted with their appearance, it is better to produce them in animals, as in brown rabbits, by needle punctures, than to study the most careful descriptions; and such experiments have the further advantage of allowing observations to be made at all periods of the case.

Plastic Exudations.—A transition stage to plastic exudations is formed by those that remain gelatinous, and, in their increase, produce a series of most beautiful reflected colours, from silvery-white to shining golden-yellow. Under favourable positions, the vessels upon the surface of the projecting retina are perceptible to the naked eye. These phenomena were formerly described under the name of cat's eye amaurosis.

Actual plastic exudations are sometimes circumscribed, solitary, and scattered; sometimes more extensive, seldom forming uniform layers, and are found more frequently towards the centre than towards the periphery of the fundus. A thin exudation layer upon the inner surface of the choroid appears like the retina, especially when seen upon a dark ground, as a light grey veil that scarcely conceals the pigment cells. The most solid exudations between the retina and the choroid are of a whiter colour, sometimes yellow, darkly pigmented, and conceal the subjacent textures partly or completely; so that only here and there, with great difficulty, is it possible to recognize pigment or a vessel in the white spots.

Peculiar defined exudation masses were discovered in the choroid by Ed. Jäger, and were shown by microscopic examination to be tubercle, the occurrence of which has been demonstrated more recently by Manz. Observed with the ophthalmoscope, these deposits appear as whitish-yellow, or even deep lemon-yellow, roundish, oval, or irregularly-shaped thick and solid exudation masses, from the size of a small lentil to that of the optic disk, or larger, with sharply-defined margins against the surrounding reddish-yellow fundus, with regular or indented edges, and with spreading surfaces. These tubercles were either isolated or more numerous, and either scattered or collected together into groups.

Single masses of tubercle appear to be developed without important inflammatory symptoms; while in other cases there is a considerable choroidal hyperæmia, with extensive striated pigment destruction, in consequence of serous transudation (œdema). Jäger repeatedly saw tubercle in combination with choroiditis and retinitis, and with coincident, more or less extensive, non-tubercular exudation. Single choroidal tubercles, remote from the macula lutea, appear to exercise no important influence upon the functions of the retina; but, if the tubercle encroach upon the macula, vision will be greatly disturbed. In coincident retinitis and choroiditis the loss of sight will be proportionate to the disease. In the external parts of the eye affected, those visible to the unaided sight of the observer, especially when there is no great degree of retinitis or choroiditis, little or no sign of disease will be apparent.

It is necessary to make mention of choroidal melanosis. The ophthalmoscopic diagnosis of this disease is, at its commencement, very difficult, on account of its resemblance to the conditions associated with displacements and partial accumulations of pigment, or with choroidal apoplexies. According to Cooper, hæmorrhage into the vitreous body may be mistaken for melanotic cancer, and the more readily, since the latter sometimes appears to follow injuries.

Purulent Exudations.—Direct evidence of choroidal suppuration can only be afforded by the ophthalmoscope in the most exceptional cases, since the sympathetic disorder of the other membranes and of the refracting media must always impede the examination by producing opacity.

To proceed now to the actual inflammatory process. It will be evident, from the foregoing, that the chief ophthalmoscopic question will be the diagnosis of the form of choroiditis that is predominant. For this purpose we have chiefly to consider—

1. *The Appearances produced by the Exudations.*—These are seen as sharply-defined patches, not elevated, and of the most various outlines,

recognizable by their accumulations of pigment and their peculiar colour. Their point of origin is commonly either in the neighbourhood of the macula lutea, or to the inner side of the optic nerve, and at some distance apart from it. According to Jäger, they may either appear immediately at their place of origin, or dispersed at several isolated points in nearer or farther distance around the macula; and may spread from thence more uniformly towards the equator of the eye, following the ramifications of individual choroidal vessels. Their extension, whether towards one side only, or more uniformly over a great portion of the fundus, may be explained by their progress from their centre, or point of origin, the macula lutea. Even the originally more limited and local forms of peripheral choroiditis commonly follow the ramifications of the choroidal vessels. In this way the inflammation spreads from the region of the macula to, or nearly to, the optic disk; and when originally more peripheral, and therefore situated about the circumference of the nerve, it still approaches it gradually, and at last partially or entirely surrounds it. The margin of the effusion is usually very sharply defined; and the choroidal effusions generally, unlike the more cloudy and indefinite opacities of the retina, follow in their outlines the characteristic course of the choroidal vessels. Extravasations in the retina exhibit by their indented contour the radiating course of the nerve fibrillæ; but in the choroid, by their defined margin, usually the course of a large circumscribing choroidal vessel, the winding course and net-like ramifications of which are defined by the changes in the pigment layer. The shape of the patches is sometimes very regular; circular, triangular, rhomboidal, or the like; but commonly very irregular. The colour differs, according to the degree of turbidity of the effusion, and according to the degree of participation of the pigment layer; and may be brighter or darker, whitish-red, greyish-red, whitish-yellow, or dirty brownish-yellow, with or without darker clouds and shadings. Frequently the appearance is of brownish-yellow or brown patches, separated from each other by a bright network corresponding to the vessels.

2. *The Changes in the Pigment Layer.*—These, which will be described more fully hereafter, are almost constant in their occurrence in cases of long standing, and appear as larger or smaller collections of pigment, scattered very irregularly within the exudations. Their colour is black, but they may appear blue, or greenish-grey, when covered to any depth by very turbid effusion.

3. *The Changes of the Optic Nerve.*—Reddening of the nerve disk is almost a constant symptom, even in the early stages of the disease. It is characterized, according to Jäger, by its greater uniformity and deeper situation in comparison with the more superficial and striated redness of retinitis; and also by its peculiar tint, which is like that given to the

vitreous body by post-mortem blood staining, or even like blood itself. It is, therefore, by some attention, generally possible to see clearly the nerve boundaries against the fundus; while in retinitis, from the extension of the superficial redness and turbidity over the whole surface, the disk becomes by degrees completely concealed.

Jäger explains the reddening of the ocular termination of the nerve in choroiditis, on the ground that deeper portions of the trunk receive the continuations of fine choroidal vessels, and therefore share in the disturbed nutrition of the membrane.

In copious effusions, and in severe cases, the retina always becomes involved, earlier or later, in the inflammation, and produces modifications of the ophthalmoscopic image, until turbidity of the media, or iritis and closed pupil, prevent the possibility of further examinations.

The special forms of inflammation of the choroid are:—the sclerotico-choroiditis posterior, presently to be described as a complication of congenital scleral staphyloma with choroiditis; the disseminated choroiditis; and glaucoma.

Of the disseminated choroiditis (*Forme pointillée de la choroidite exsudative* of Follin, *Choroidite tigrée* of Desmarres) Liebreich gives the following description:—

This disease never commences in the parts of the choroid immediately about the optic nerve, or in a single circumscribed spot, but develops itself simultaneously in more points than one, at some distance from the papilla, in the form of small, roundish, diffused, or wholly irregular spots, of brighter colour than the surrounding fundus. Upon these spots the epithelium appears faintly pigmented or altogether absent, and the choroidal vessels allow themselves to be clearly seen, in the beginning even, with sharper contour and brighter redness than natural. As the disease progresses, the spots continually become larger and more numerous; they partly coalesce, and partly separate themselves more and more from the normal parts; they become paler, and the vessels gradually disappear; while dark pigment streaks border the spots, and separate them from one another, giving to the parts of the choroid attacked a marbled or variegated appearance. In old cases, and in the highest grade of the disease, the originally separated spots coalesce, and cover the greater part or the whole of the fundus with an uniform white surface.

Von Gräfe considers the affection to be a symptom of secondary syphilis; but possibly it is only one of the numerous aspects presented by partial or extended atrophy of the choroid, with wasting of pigment.

With regard to glaucoma, von Gräfe considers that a simple choroiditis is insufficient to explain its occurrence; and Stellwag expresses himself as follows:—"If all the bearings of the case be considered, and all the older as well as the more recent observations, both with the microscope and the ophthalmoscope, be taken into account, it will appear that glaucoma consists essentially of a venous hyperæmia, and an inflammatory process extending to all the internal parts of the eyeball—a process that is followed by very considerable increase of intra-ocular pressure, by early excavation of the optic nerve, and by a decided tendency to atrophic degeneration of the interior structures. The conjoint participation of all these internal structures, especially of the ocular extremity of the optic nerve, is essential to the idea of glaucoma. The disease is therefore distinct from morbid processes analogous in kind, but limited to one of the three chief vascular systems of the eye—to the uveal, the retinal, or the nerve vessels. Glaucoma is, therefore, neither a serous choroiditis, nor a hyalitis, nor a dictyitis, nor an inflammation of the optic nerve; but requires the combination of all these conditions in one and the same eye."

The most frequent ophthalmoscopic appearances are excavation of the nerve, choroiditis with preponderating serous effusion, and pulsation of the arteria centralis retinæ, either spontaneous or easily produced by gentle pressure. Hæmorrhages in the retina and choroid, and turbidity of the vitreous body and crystalline lens, are frequently seen as complications.

The pathology of glaucoma may be made tolerably clear, if we assume that its essential phenomena are the venous hyperæmia, and the increase of the fluid contents of the eyeball. The symptoms presented by different cases will then be governed chiefly, if not entirely, by the rate of increase of the disease.

The continued existence of excessive intra-ocular tension necessarily produces compression of the retina, and consequent loss of sight. The whole surface of the retina suffers; but the peripheral portions earlier than the central. Consequently, the field of vision becomes gradually contracted; and, although central vision is always impaired in some degree, it may remain comparatively good up to a late period of the disease. In the end, however, unless the tension be relieved, total blindness is the inevitable result.

For some reason that can only be conjectured, but probably either from weakness of the ciliary muscle through interference with its supply of blood, or by the production of a premature hardness of the lens, the early stages of exalted tension are usually attended by rapidly increasing presbyopia. Where this symptom presents itself, a careful examination of the degree of hardness of the globe should never be omitted.

Moreover, it is not uncommon for the impaired nutrition of the distended eyeball to find expression in cataract, as well as in other degenerative internal changes. It is not difficult to believe, therefore, that a large proportion of the unsuccessful cataract operations of the pre-ophthalmoscopic period were performed upon eyes the retinæ of which were perishing from compression; and that most of the cases of so-called "amaurosis," in persons past the middle period of life, were simply instances of gradually increasing tension, in which the lens had retained its transparency.

The ocular tunics, like other textures of the body, show a marked tolerance of pressure that is only very gradually increased; and a decided intolerance of the same degree of pressure when suddenly or quickly produced. While, therefore, in cases of very gradually increasing tension, the only symptoms may be presbyopia, dimness of sight, contraction of the field of vision, cupping of the optic disk, pulsation of the central vessels, and eventual complete blindness, it is much more common to meet with patients in whom a more rapid rate of increase is productive of more or less inflammatory reaction. In such cases the dimness of sight is liable to be increased suddenly for short periods, which may be followed by partial improvement; and it is common for the exacerbations to be attended by ciliary and orbital neuralgia, by the appearance of coloured fringes around a flame, by congestion and inflammation of the ocular tunics, and by morbid opacities in the vitreous body. When the increase of tension is very rapid, the symptoms are correspondingly severe.

The more typical examples of these three gradations of rapidity are called respectively, simple chronic glaucoma, sub-acute glaucoma, and acute glaucoma. They possess common characters, depending upon exalted tension; differential characters, depending upon the rate at which that tension has increased, and upon the degree of resistance opposed to it by the sclerotic. They fade into one another by imperceptible degrees, and they are all successfully treated by timely iridectomy.

The ingenuity of ophthalmic surgeons has been taxed to measure and express the different degrees of tension; but, hitherto, with very little result. The instrument contrived by v. Gräfe is painful to the patient, and of small value to the observer; and the recently invented "Spannungsmesser" of Prof. Donders has not yet been sufficiently tested for its merits to be known. The simple scale of nine T's, devised by Mr. Bowman, is open to the objection that there is no standard to which any of them can be referred. The tension of normal eyes varies within rather distant limits, and the T−1 of one observer might be the T+1 of another. It is probable, moreover, that one retina might endure T+2 while another would perish under T+1. Perhaps the best method is for each surgeon to take his own eye as a standard, and to trust to practice and a cultivated touch for the general accuracy of his judgments.

The mode of examination is to feel the upper portion of the eyeball, as far under the orbital margin as possible, with the tips of the two fore-fingers. The eyelids should be gently closed, the centres of the finger-tips placed about half an inch apart, and then, pressure being made with one of them, the other will estimate the degree of resistance.

III. CHANGES IN THE PIGMENT LAYER AND LAMINA ELASTICA.

The pathological changes seen in the choroidal pigment (maceration of pigment) show themselves, according to Jäger, either as partial or more extensive diminution, or as simple displacement. Diminution, which necessarily presupposes a loosening of the pigment layer and a destruction of the cells, is characterized by an irregular or sharply-defined, partial or more extensive, decrease or absence of pigment from one part of the fundus; by changes of the normal colouring; by the visibility of deeper structures or parts, as well as of deposited pathological formations, without perceptible accumulations of pigment elsewhere. In displacement, on the contrary, together with partial absence or deficiency, collections of pigment are found near or about the denuded spots, in the form of brownish-red, dark-brown, or black stripes and masses.

Such changes in the condition of the pigment are most commonly caused by effusions and extravasations into the choroid and the retina. If the diminution of pigment be only obscurely defined, or if it be nearly co-extensive with the visible fundus, Jäger attributes it to a serous infiltration of the textures, produced by slight hyperæmia of the choroid or of the retina. It is then limited to the continuous inner (epithelial) layer, and allows the deeper membranes to be seen. If it be clearly and sharply defined, and limited to a locality (in which case it is commonly united with displacement), it is occasioned by a thicker and more abundant exudation. If the effusion which produces the loss of pigment be transparent, or translucent and slightly coloured, the subjacent textures will be rendered more or less visible; but if it be opaque and strongly coloured, it conceals completely the parts upon and among which it is deposited; and instead of the loss of pigment being manifest, there is nothing seen but the effusion, with its own peculiar colour, limitation, situation, and surface. Even when the pathological product, that has occasioned pigment atrophy, is itself no longer visible, its nature may usually be discovered, according to Jäger, by the position, shape, and outline, and other secondary appearances of the part affected. Thus pigment atrophy produced by retinal apoplexies, long ago absorbed, is marked by citron-yellow patches, in which the retinal vessels and the radiation of the nerve fibrillæ may be recognized. A deficiency limited to the epithelial layer, with visibility of the subjacent textures, indicates serous effusion; a sharply-defined deficiency indicates destruction of the stroma pigment by deeper choroidal exudation; a circular deficiency around the nerve disk indicates glaucoma; and one more or less conical, extending from the disk over the fundus, affords evidence of posterior staphyloma.

In cases of displacement of pigment, in which the retina remains transparent, the inner surface of the choroid no longer presents a brighter or darker tint of uniform brown, but is dotted over with brighter spots, having dark margins, and variegated by dark streaks and points. In these spots a greyish colour will be visible at points where the pigment is as much as possible destroyed; and in many cases the grey becomes decidedly whitish, more or less marbled with brown.

The appearance of choroidal vessels in defined outline, and their evident visibility, are believed by Pilz to be indications of little value. These appearances, when present, he attributes to an uniform choroidal hyperæmia; since, in that condition, the vessels sometimes become visible without any essential change in the pigment, and the degree of hyperæmia will produce various modifications of their colour. He found, moreover, that in cases of increased development (thickening) of the lamina elastica, the reflecting power of the fundus was so much increased that this cause alone rendered difficult a clear recognition of the choroidal vessels; while, on the other hand, these vessels became most conspicuously manifest in cases in which diminution of vision and simple atrophy of the pigment epithelium were associated with an increased development of the pigment lying between the choroidal vessels in the stroma of the membrane.

Pigment changes that are limited to the peripheral portions of the fundus have little influence upon the sight; but, during their development in the centre of vision, the patient usually observes a decrease in the apparent blackness of printed characters, and a tendency to their coalescence, sometimes in a horizontal, sometimes in a vertical direction. Many patients observe that printed letters appear to have a convex surface; and, eventually, they lose perception of such small objects entirely. Objective examination disclosed to Coccius a small white spot in the centre of the macula lutea, produced by destruction of the subjacent pigment, and sometimes bounded by abnormal pathological pigment collections.

In simple atrophy of the epithelial pigment layer we see dark interspaces, in the form of light brown or greyish-red spots, which become more and more sharply defined, and assume a darker and darker tint, until they become deep brown or nearly black, and which separate bright red spaces, corresponding in shape to the peculiar distribution of the choroidal vessels. If the pigment of the stroma be very plentiful and dark, both filling the interspaces and covering the vessels, the latter will appear reddish, and the former dark, or even black. If the pigment be plentiful and dark, but chiefly occupying the interspaces, and scarcely covering the vessels, the latter will be yellowish or yellowish-red, and the former of a lighter or darker reddish-brown. Where the stroma pigment is only moderately dark, and is limited to the interspaces, these will appear of a light reddish-brown, and the vessels will be more yellow. And lastly, in cases where atrophy of the pigment layer is attended by atrophy of the pigment of the stroma, the interspaces present a lighter colour than the vessels; so that while the latter are of a dark orange-yellow, the former will be of a bright light yellow. Such appearances seldom extend over the whole fundus, and it is usual to find more than one of the above conditions existing in different parts of the same eye.

The lamina elastica undergoes peculiar changes, first described by Donders as colloid formation of the nuclei of the pigment cells; then by H. Müller as thickening of the lamina elastica. This process has, with few exceptions, been seen only in the eyes of persons of from 70 to 80 years of age; the chief exception being recorded by Liebreich, who found, in the eyes of an individual of 26, peculiar, only very faintly marked figures in the choroid, that, in more careful examination, showed themselves as dark circles, inclosing smaller bright spots. They were formed of pigment cells, full of granules, collected round others that were less filled, and were scattered over the whole of the visible choroid. In section there were found bowl-shaped thickenings of the lamina elastica, extended equally over a great part of the choroid. These, at their greatest prominence, had pressed together and destroyed the pigment cells, and had diminished the pigment in front of them while increasing that at their circumference.

IV. COLOBOMA CHOROIDÆ, VAGINÆ NERVI OPTICI (ET IRIDIS).

(*Liebreich's Atlas*, *Plate* xii., *Figs.* 4 and 5.)

In almost all cases of this kind examined by Liebreich, he found, in different degrees, the same ophthalmoscopic appearances.

An oval white patch, with its upper extremity directed towards, or even inclosing, the optic nerve, and its inferior extremity approaching the ciliary processes. Over this patch were seen a few retinal, and some very slender, abnormally-directed choroidal vessels, that were lost laterally in the deeply-pigmented margin of the fissure. The optic nerve, when only just involved in the coloboma, was sharply defined above, but laterally was only imperfectly distinguishable, by its somewhat more reddish or greyish colour, from the bluish white sclerotica. Its form was elliptical, with the long axis horizontal.

The distribution of the vessels of the papilla has been extremely abnormal; and the greater number of branches are directed upwards in curved lines, while only a few slender twigs pass downwards.

Liebreich has repeatedly seen cases in which an oval, indistinctly defined optic nerve was associated with a defect of the choroid at its lower aspect, like a posterior staphyloma, and in which he has assumed, from the vascular configuration characteristic of coloboma, that this arrest of development was the cause of the appearance.

V. ATROPHY OF THE CHOROID.

The ophthalmoscopic appearances presented by this condition may be inferred from anatomical considerations. With regard to these appearances, it is important to observe that the retina, even in normal transparency and tension, reflects a certain amount of white light, especially if the cone of rays afforded by the mirror be allowed to fall obliquely into the eye. In turbidity of the retina the quantity of light reflected from it increases, and attains its maximum when the membrane is uniformly folded. It is self-evident that, at the same time, the choroidal reflection must be greatly diminished. The data necessary, in order to estimate the degree of diminution, are afforded by the intensity of the light reflected from the interspaces between the retinal vessels, and by the extent of the changes of level of the retina itself. Only where the retina has entirely perished, can the ophthalmoscopic image of the fundus be accepted as the simple optical expression of the changes in the choroid. Absence of the retinal vessels, and their striking changes of level upon the fundus in nearly normal form of the globe, are the indications from which such a loss of the retina, or of part of it, may be inferred. The quantity of blood contained in the choroid, together with the presence of the pigment layer, cause the normal fundus to reflect a yellowish-red light; which, in great development of the pigment layer, becomes more or less intermixed with brown. The unequal distribution of the pigment upon and in the choroid, is also productive of faintly-shaded lines, which give to the image some resemblance to watered silk. Diminution of the pigment to almost entire disappearance, loss of its colour, destruction of the thick vascular network, with the exception of a few trunks, and dwindling even of these, constitute the anatomical characters of choroidal atrophy. It is evident, therefore, that the colour of the light that is reflected from the atrophied parts of the choroid and from the sclerotic, must deviate in a high degree from the normal standard. Such parts, in small degrees of atrophy, return yellowish-red light, in higher degrees, dirty-grey or yellowish-grey, and in the highest degrees, even dirty-white; and are, therefore, conspicuous against the surrounding choroid, that still contains blood, and retains its natural redness. In wasting of the central portion of the choroid, the limits of the brightly-yellow reflecting nerve-entrance become obscured; although black pigment is often left, around the margin of the posterior choroidal opening, in the form of an irregular circle, composed of dots and little masses. This condition is not infrequent; and only represents a special form of that reticulated or arborescent, striated or patchy aggregation of black or brown pigment granules, that is so often scattered over the surface of an atrophied choroid, and separated by heaped or isolated granules. The ophthalmoscope exhibits these variously-shaped collections of dark granular pigment with great clearness. They furnish, in connection with the grey or dirty white reflection from their background, a pathognomonic indication of choroidal atrophy. Pigment collections, that are due to metamorphosed extravasations of blood, present neither the same aspect nor the same colour; and, in the retina, in which accumulations of dark-brown or black pigment may occur, there are no morbid conditions, that, even in the most extreme alteration of the ophthalmoscopic image that they can produce, present the most distant resemblance to the condition above described. It is evident that any remaining choroidal vessels, after loss of the pigment that naturally covers them, will appear against the bright background in clearer outline. Their course and comparative limitation will distinguish them sufficiently from those of the retina. (Stellwag.)

IV. THE SCLEROTICA.

Within the structure of the sclerotic some small vascular twigs form a kind of wreath of vessels around the nerve-entrance. According to the observations hitherto made by Jäger, this vascular wreath is not completely developed in every eye, since the two ciliary vessels that form it, often ramify in an abnormal way after their entrance into the sclerotic; or are extremely delicate, and penetrate but a short distance. Frequently one of them is absent; and cases are not rare in which both are wanting. If, however, the sclerotic vascular wreath be fully developed, as is usually the case, it surrounds the optic nerve closely at birth; and, in the adult, forms a corona of size corresponding to the enlargement of the globe, and usually farther distant from the nerve.

I. INFLAMMATION OF THE SCLEROTIC.

It is doubtful whether sclerotitis ever occurs as an original disease; but it is common as an accompaniment and consequence of inflammations in the neighbouring more vascular structures. In this place we are only concerned with the inflammation occurring at the hinder portion of the eye, and designated sclerotitis posterior by E. Jäger, who gives the following description of it:—

Inflammatory processes in the posterior vascular region of the sclerotic would usually be concealed from ophthalmoscopic observation, were it not that the portion of the nerve within the sclerotic canal, sometimes also the immediately surrounding portion of the choroid, and even the nerve-surface itself, are nourished by the same system of vessels.

In a generally normal condition of the eye this system is very small, and extends but a short distance beyond the optic disk. But, if the vessels of the sclerotic pierce that membrane farther than usual from the nerve, and surround it in wide curves; or if there exist an ectasia (staphyloma posticum), the territory they supply undergoes a corresponding extension beyond the papilla. The ophthalmoscopic signs of inflammation in their region are chiefly a deep redness of the nerve disk, and changes in the portion of choroid immediately surrounding the papilla—changes which, at least in their commencement, indicate more or less clearly the course of the sclerotic vessels.

These changes of texture either develop themselves earliest and most clearly in the immediate vicinity of the papilla, and form a more or less broad, bright, variously-coloured or pigmented band, surrounding the optic nerve either in great part or completely (nerve halo of glaucoma), and usually broadest either downwards or towards the macula lutea, and narrowest in the opposite direction; or they appear as single, isolated or grouped, smaller or larger, differently-coloured patches or bands, of the most various size, number, and shape, situated at a small distance from the nerve (upon the curves of the above described sclerotic vessels), and gradually increasing and coalescing until the disk is nearly or completely surrounded.

Such patches usually increase eventually in a peripheral direction towards the macula lutea, and the other parts of the fundus; and thus more or less exceed the boundary of the posterior sclerotic vessels.

In this way the textural changes of sclerotitis posterior, unlike those of choroiditis, form patches of various size and shape upon the fundus immediately around the nerve disk, and either remain confined to the region of the posterior sclerotic vessels, or extend into the choroid in one or in several directions, always with the nerve disk for a centre. It is from this extension, especially in the more intense degrees of sclerotitis, that choroiditis is so often developed, either simultaneously or as an immediate consequence.

The textural changes of sclerotitis posterior occur usually in the same place and to the same extent as the cone visible with the ophthalmoscope in posterior staphyloma. It is extremely rare, however, for the two conditions to group themselves in precisely similar forms.

II. SCLERECTASIA POSTERIOR.

(*Liebreich's Atlas, Plate* iii.)

(*Sclerotico-choroiditis posterior of von Gräfe. Staphyloma scleroticæ posticum of Scarpa. Retrogressive metamorphosis of the fibrous tissue of Pilz. Atrophic choroiditis of Follin.*)

The recognition of this disease, so common as to be the cause of four hundred and twenty cases of amblyopia in a thousand, is so far easy, according to von Gräfe, that the observer has usually to direct his attention only to the entrance of the optic nerve.

He will there remark a white figure inclosing the outer margin of the nerve. In the early stages this figure is sickle-shaped, its concave margin in a certain degree coincident with the margin of the nerve-disk, while its convex margin looks towards the posterior pole of the eye-ball. As the disease progresses, the white figure continually increases, so that its outer border extends farther from the nerve, and the whole patch changes its sickle-shaped outline in various ways; sometimes extending itself outwardly, and assuming the aspect of a horizontal band proceeding from the papilla; sometimes spreading upwards and downwards, and appearing as a white figure of very variable outline surrounding the outer border of the nerve, and separated from the surrounding fundus by an angular and indented margin. Lastly, the degeneration may also encircle the inner side of the nerve-entrance, so that the latter appears as an island inclosed in a white or sometimes a bright green-coloured surface, the outer part of which, however, is always more developed and broader than the inner. The light reflected from the diseased surface exceeds every other ocular reflex in its intensity, and is much brighter and whiter than that from the optic nerve; so that the latter appears comparatively less illuminated, and of a dull grey or reddish tint.

The retinal vessels can be distinguished upon the white diseased surface more clearly than in the normal state; and, since the observer can perceive even the finest branches, it is very easy considerably to over-estimate the actually existing hyperæmia of the retina. Another error dependent upon the illumination is that the retinal vessels appear to vanish at the periphery of the white figure, and to be lost either in the deeper parts of the textures or in accumulations of pigment, an error depending upon the fact that the vessels become less evident as they pass over to a darker background.

The degree of ectasia, according to Liebreich, cannot be correctly estimated from the size of the bright figure alone. It is necessary to scrutinize its periphery, and the whole circumference of the nerve. There is sometimes a very extensive staphyloma, when, nevertheless, the bright crescent around the nerve is but narrow. In such cases, upon close inspection, and by a comparison of the parts immediately beyond the crescent with the more peripheral portions of the fundus, it may be seen that, beyond the white figure upon which the choroidal atrophy has already reached an extreme, or, at least, a very high degree, there is a second zone, within which the texture of the membrane is much disturbed, and the pigmentation of the stroma diminished, although not sufficiently so to give, at first glance, the appearance of atrophy. If the more peripheral portions be examined and compared with this second zone, the difference between the two will be easily perceptible—a difference that is sometimes sharply defined, and sometimes passes away through intervening gradations. When defined, the boundary sometimes coincides with the course of a curving choroidal vessel, passing to a vortex near the papilla. The boundary is more difficult to define, when the epithelial layer is still darkly pigmented. It is then best to examine by the side of the retinal image of the flame, by means of transmitted light; and in this way only can be recognized, in other cases, the commencement of sclerectasia, at a period when, to ordinary observation, the choroidal texture appears perfectly normal up to the margin of the nerve. If a bright image of the flame be cast upon the choroid, the observer sees the parts, that this image illuminates, by reflected light; but the parts lying next to the image, and also luminous, are seen chiefly by transmitted light, returned from the structures beneath them. The latter kind of illumination, while the epithelial pigment-layer remains, is the best for the detection of textural changes in the stroma. In this way may be discovered a crescent of the ordinary form, on the outer side of the nerve, covered by stroma already considerably wasted and deficient in pigment; while the epithelial layer remains perfect, and, in examination by reflected light, conceals the subjacent changes.

In the vicinity of the chief figure may often be seen smaller insular white spots, of entirely similar character, but of a less degree of development. By their accumulation about its margin, the chief figure assumes an irregular, notched, or indented appearance. The latter indicates a rapid progress of the disease; while, on the contrary, a distinct limitation and pigmentation of the chief figure show a stationary condition.

The appearance of the pigment is highly characteristic. In lesser degrees of development of the white figure the pigment commonly disappears entirely from within its boundary, but collects at its outer margin in greater amount than on the surrounding parts of the fundus; so as to render the belief possible that its collection depended upon its being pushed onwards by the development of the white figure, around which it often appears as a bright brown band. In cases of extensive disease there is usually abnormal pigmentation within the limits of the figure, which then appears broken by brown and black spots and irregular marks of all kinds, over which the retinal vessels proceed undisturbed; these marks being chiefly towards the posterior pole of the globe, and at the prominences of the angular margin of the white figure.

The retina usually presents no abnormal appearance, although in isolated cases it is marked by small greyish spots, both over the white figure and in other portions of its surface. The choroid, on the contrary, is never natural in the neighbourhood of the disease, and at least presents an abnormal difference between the luminosity of the vessels and of the intervascular spaces—the former appearing of a brighter red, the latter darker, bluish, or even violet; appearances depending upon alterations in the pigment. The aspect of the choroid becomes still more variegated, when, as often happens, it becomes the seat of ecchymoses.

Liebreich found the shape of the optic nerve to be oval, in all the cases in which the atrophied choroid formed a sharply-defined crescent, situated exclusively upon one side of the papilla, but only seldom in cases in which the nerve was surrounded on all sides. "The oval of the papilla deviated from a circle sometimes more and sometimes less; and in one case I found, by micrometric measurement, that the vertical diameter was twice the length of the horizontal. The extension of the ellipse bears no constant proportion to the size of the ectasia; so that a very much elongated nerve-disk may be found with a small ectasia, and *vice-versâ*. The direction of the greatest diameter appears, however, to be essentially dependent upon the ectasia; in such a way that it is perpendicular to its chief direction. It is therefore in the majority of cases vertical, since the ectasia is commonly directed horizontally outwards. On the contrary, I have seen the long diameter of the nerve-disk horizontal, when the crescent was situated at its lower margin; and, in some few cases, I have seen the disk completely oblique, its long diameter passing from downwards and inwards upwards and outwards, while the white figure was at its outer and lower side." Of this appearance Jäger gives the following explanation:—"In examining in the erect image an eye rendered short-sighted by a high degree of staphyloma posticum, and still more in the inverted image, the observer is often led to think the nerve-disk longer and more oval than it is in reality.

"The reason of this is, that the plane of the nerve-surface is often situated very obliquely to the axis of the examined eye, especially in those staphylomatous ectasiæ in which the nerve-disk is excentric. The disk, in such a case, only appears to be long or oval; and would appear more circular, if its plane could be rendered perpendicular to the visual axis of the observer. A further source of error is that the margin of the choroidal pigment, which in a healthy eye coincides with the margin of the choroid itself, and therefore exhibits the same outline as the nerve, in cases of staphyloma posticum often presents a more flattened curve, on the side opposite to the crescent, than that of the actual choroidal margin. Opposite the centre of the crescent the choroidal pigment reaches nearly to the nerve; but its boundary line recedes from that of the nerve on both sides of this central point, and thus the disk appears elongated in a direction perpendicular to the greatest width of the crescent. And, in an opposite direction, in the direction of the width of the crescent, the observer is often led to under-estimate the transverse diameter of the nerve; since, in consequence of the peculiar textural changes of the choroid, the outer margin of the ring of connecting tissue becomes more or less completely obliterated. The observer is then easily led to mistake the inner edge of the ring of connecting tissue for the outer margin of the disk; and therefore, in judging of the diameter of the latter, to under-estimate it, in the direction of the width of the crescent, by the whole width of the connecting tissue."

Another frequent source of error with regard to the shape of the nerve-disk is that the choroidal pigment, on the side opposite to the crescent, may actually cover the nerve-surface to some extent. The unpigmented, bright, normally-coloured portion of the disk thus obtains a decidedly oval or elongated aspect, which in no way corresponds with the actual outline, as it would be revealed by dissection.

A sclerectasia posterior, in a certain degree established, always produces a myopic condition of the eye; and to the myopia, a certain grade of amblyopia becomes soon superadded—showing itself first by the imperfect correction of the myopia that can be obtained by concave glasses; and next, by diminished power of vision, even for the nearest distance. Many patients are very susceptible to wind, which produces dazzling, and sometimes subjective sensations of light; and feelings of pressure and tension in the depths of the eye are seldom absent. The patients may often possess tolerably good sight, until the white figure reaches the macula lutea, when they perceive a black spot in the field of vision, which considerably interferes with seeing, and especially with reading.

There may occur as complications:—1. Opacities in the vitreous body. 2. Separation of the retina. 3. Turbidity of the posterior pole of the lens, ophthalmoscopically indicated by a spotted opacity, that in movements of the eye appears to belong to the corneal reflection—this has its seat in the posterior cortical substance, and may remain a long time stationary. 4. A gradually-occurring glaucomatous condition, about which von Gräfe observes: "I have seen in old persons, who have suffered from posterior sclerectasia for an indefinite time, the occurrence of lateral contraction of the field of vision, with increasing weakness of sight. Further experience taught me that in such cases excavation of the optic nerve, and signs of increasing pressure, usually develop themselves. The excavation of the nerve is never so clear and strongly marked as it is in the absence of sclerectasia posterior. This may be easily understood from the anatomical condition of the parts, inasmuch as the sclerotic immediately around the nerve, when somewhat loosened, does not present its natural power of resistance, but yields to pressure, so that a sharp cupping of the optic nerve cannot be produced, but only a gradual sinking, the margin of which will show little dislocation of the vessels. This depression may be distinguished from a strongly-marked physiological concavity of the disk (H. Müller), by its extending to the periphery of the nerve, while the latter only affects the centre, the part immediately around the vessels. The aspect of such a nerve is sufficiently characteristic. In common sclerectasia posterior its margin is almost obliterated, and the disk and its surrounding parts present a similar appearance; so that the limits of the former can often only be determined by the aid of the nerve outline still visible, perhaps, on the inner side, by the appearance of the vessels, or by the recognition of atrophied choroidal tissue over the sclerotic. In the cases under consideration, however (*i.e.* sclerectasia with excavation), the nerve-disk is clearly marked in the middle or to one side of the white figure. This alone may excite suspicion; and more exact examination in the usual manner will discover the surface of the disk to be hollowed. In these cases a considerable deviation of the vessels is not to be expected, but only a small displacement; and the kind of illumination of the disk characteristic of cupping will be only moderately conspicuous. With the occurrence of excavation in sclerectasia posterior, the previously soft globe becomes more tense, the pupil somewhat dilated and sluggish, although not fixed, and the cornea somewhat insensitive. The field of vision becomes contracted, sometimes concentrically, sometimes laterally, and the disease may proceed to almost complete blindness." Von Gräfe's cases were chiefly those of sclerectasia posterior in persons more than 50 years old, with high degrees of amblyopia, and with neither disease of the vitreous body, separation of the retina, nor cataract, to explain it. They had in some cases central scotomata, in consequence of extension of disease to the macula lutea.

5. If choroiditis should attack an eye suffering from staphyloma posticum, there will be produced, according to Jäger, usually first in the region of the macula lutea, or in its immediate vicinity, one or more patches of effusion, separated from the bright surface of the staphylomatous cone by broader or narrower strips of normally-coloured surface. By degrees these effusion patches enlarge, and fresh ones appear in their vicinity, at more or less distance from the nerve, and also towards its inner side. These constantly increase in magnitude, gradually approach one another in all directions, coalesce, and form a circular patch upon the fundus. By this enlargement, and by its continued progress, the unchanged cone is continually approached, the bridge of normal texture separating it from the effusion is constantly diminished, until the latter at last surrounds and joins not only the cone, but the whole outline of the nerve.

The cone itself remains unchanged; but the continued increase of the effusion-patches at last obliterates its margins, either by the coalescence of the white surfaces, or by the destruction of the band of pigment surrounding the cone; and at last the nerve appears as a faintly-reddish disk, situated in the centre of an irregular yellowish-white brightly-shining surface, more or less broken by extravasations and pigment masses. In rare cases the effusion-patches appear at first in the immediate vicinity of the cone, and immediately destroy its characteristic appearance. The choroidal inflammation displays itself chiefly by destruction of the epithelial pigment layer, in consequence of which the larger choroidal vessels and the pigment of the stroma are rendered more visible. Hence the dark pigment boundary of the cone is often long preserved, and, after the development of other appearances, remains as an indication of the original disease.

6. If a sclerotitis posterior should be developed in an eye that is the subject of a cone, the invasion is marked, according to Jäger, chiefly by disturbance and extension of the boundary of the original mischief. The cone enlarges, not uniformly, and retaining its former shape, as it would do in physiological increase; but it spreads, by the destruction of its pigmented margin, either chiefly towards one direction, or simultaneously in several, and thus obtains an extremely irregular appearance, its boundaries conforming more or less to the course of the larger choroidal vessels, and the characteristic aspect of the surface of the cone being destroyed. In this way the extension of the sclerotitis to the choroid may surround the nerve-disk with a white surface, like that described in the foregoing paragraph.

With regard to the essential nature of the morbid process in sclerectasia, it is attributed by von Gräfe to a chronic inflammation of the choroid; and, as the disease involves the back part both of this membrane and of the sclerotic, he assigned to it the name sclerotico-choroiditis posterior. Liebreich considered the first stage to be the deposit of a thin exudation layer on the inner surface of the choroid, with subsequent absorption of its stroma and progressive changes in the effusion; Follin believed the chief conditions to consist in removal of the pigment with obliteration and absorption of the choroidal vessels; while Pilz regarded the disease as a non-inflammatory disturbance of the nutrition of the choroid, showing itself—1. In such an extreme partial contraction of the connecting tissue of the membrane about the nerve-entrance, that the vessels in that situation become obliterated; and, 2. In the disappearance of the pigment from the affected localities, and an accumulation of it, as if it were pushed forwards, upon the boundary of the disease. Lastly, After very numerous and careful examinations, Jäger has arrived at the conclusion that the peculiar anomaly of formation is usually congenital, very often hereditary, and then associated with no functional disturbance of the retina, and never to be considered as the result of an inflammatory process.

According to von Gräfe, pathological observation reveals:—A remarkable elongation of the eyeball from behind forwards, with bulging of the posterior hemisphere (especially pronounced, in extreme cases, at the region of the posterior pole), while the vertical and horizontal diameters are scarcely increased. A considerable thinning of the posterior segment of the sclerotic, and a bluish tint of the thin portion, which is not to be referred to a transpicuity of the choroidal colour, but is the optical expression of the semitransparent portion of sclerotic itself. The stroma of the choroid, in the locality of the white figure seen with the ophthalmoscope around the optic nerve, is greatly thinned, so that it appears changed into a lax web of connecting tissue, adherent to the inner surface of the sclerotic, and exhibits no trace of the vessels peculiar to the proper choroidal structure. Near the boundaries of the white figure, the choroidal stroma becomes again more distinct; but still the membrane, beyond the apparent disease, and usually over its whole extent, is thinner than natural, and its pigment-layer extraordinarily defective. The latter is entirely removed from over the limits of the white figure, except that occasional black patches may be seen. These are pathological pigment accumulations, and always lie close to the points of entrance of the posterior ciliary arteries, which sometimes in the neighbourhood of the white patch are found completely obliterated, and sometimes they mark the receding angles of the white figure, and thus form divisions between its several projections. The retina, of normal aspect, covers the white spot with all its elements, and only occasionally presents small knot-like thickenings. The vitreous body, in cases of advanced development, is somewhat fluid,—the lens opaque at its posterior pole.

V. THE REFRACTING MEDIA.

The condition of the refracting media plays a highly important part in ocular pathology, since it often depends entirely upon their healthy or diseased condition, whether the parts lying behind them can be examined with the ophthalmoscope or not. They require, therefore, in every ophthalmoscopic examination, the most careful study, based, generally speaking, upon the following considerations.

The examination must always be made with a fully-dilated pupil, since otherwise a large part of the anterior portion of the vitreous would escape observation, and the field of vision would be contracted by the narrowness of the pupil, as often happens, unfortunately, in cases of synechiæ after iritis and anterior choroiditis.

The method of illumination deserves particular attention, since, for example, opacities of the lens and vitreous body are seen, by transmitted light, as black bodies upon a red ground; while, by incident light, they appear in their true colours. If we seek the reason of this difference, it depends only in small part upon the opacities being insufficiently illuminated from before, and chiefly upon the following considerations:—The opacities that present only small surfaces, as dots, granules, threads, or streaks, are those that appear dark against the illuminated fundus, since their small surfaces can reflect but little light, and, even collectively, can intercept but little, so that, notwithstanding their presence, the fundus becomes thoroughly illuminated, and they appear black by reason of the contrast between their reflection and that of the fundus. On the contrary, they are seen in their true colours when they are lighted up, the fundus being in shade, as in lateral illumination. Both kinds of light should therefore be employed, and by preference the ophthalmoscope for bodies in the posterior half of the globe, and lateral illumination for bodies in the anterior half.

Furthermore, it is important in many cases to determine the depth at which opacities are situated; for which purpose the following methods are used. For examination of the erect image, the application of concave and convex glasses. All objects, placed in or behind the focus of a dioptric apparatus, can only be seen in an erect position by the aid of a concave lens; while objects that can be seen with the unaided eye, or with a convex lens, must lie within the focus. Our judgment upon the precise position of the examined objects may therefore be guided by the strength of the concave or convex lens through which they are clearly visible. For examination, in the inverted image, of objects lying near the retina, we have recourse to the same slight movements of the convex lens, in a direction perpendicular to its axis, the eyes of both observer and patient being at rest, that have been described already under the head of excavation of the nerve-disk. Objects lying near the observer appear to follow the movements of the lens; and objects more distant to move in an opposite direction. For example, if a thread-like opacity were to proceed from the posterior pole of the lens, straight through the vitreous to the centre of the retina, it would appear punctiform when seen from before. If the convex lens were now moved slightly right and left, the anterior and posterior extremities of the opacity would appear to make, respectively, the movements above described, and it would be seen no longer as a point, but as a line, of a length depending upon the extent of the lens movement. As a further means to the same end, in observation of the inverted image, we may observe the changes of place of the objects in movements of the patient's eye. If, for example, the observer look in such a direction that his line of sight passes through the turning-point of the patient's eye, this point alone, in all movements of the eye, will remain stationary, while all other points move in relation to it; those lying in front of the turning-point moving in the same direction as the cornea, those lying behind it in the opposite direction, and passing over a greater distance, the farther they are remote from the turning-point. The corneal reflection (of the mirror) remaining stationary in the axis of vision, the pupillary margin, and, for deeper objects, the image of the fundus, even when somewhat obscure, assist in the exact determination of the movements described.

Lastly, it should be mentioned, that certain changes in the refracting media produce an appearance as of misty spots upon the retina, and obscure the images of the apparently turbid portions. These appearances are independent of the retina, and are projected upon it by turbidities of the refracting media, connected with irregularities of their surfaces. The observer must, therefore, be upon his guard against misinterpreting them, in cases of commencing cataract, and of changes in the cornea (facets with or without important opacity).

1. THE VITREOUS BODY.

In examination of the vitreous body, it must never be omitted to make the patient's eye move upwards, downwards, inwards, and outwards; movements that should be short and quick, and many times repeated. This is necessary, partly in order to form a correct judgment with regard to the consistence of the vitreous, and partly in order to shake up and bring into view opacities that may have sunk as far as possible in the fluid humour. It should be observed here, that even a complete fluidity of the vitreous will escape observation, unless attended by some small opacities; and further, that in a perfectly normal condition of the humour, opacities still have some mobility, showing itself in a slight, scarcely visible trembling, corresponding in its precise degree with the precise consistence of the vitreous.

1. OPACITIES IN THE VITREOUS BODY.

Besides the opacities produced by effusion of blood, which will be described hereafter, there are found, in the mostly fluid vitreous, opacities of the most varied kind and shape, in various conditions, such as congestive and inflammatory diseases of the retina and choroid. These opacities are apparently due to inflammation of the vitreous body.

With regard to form, they appear, according to von Gräfe, as :—

a. Punctiform or diffused opacities, which are the most difficult to recognize, since they produce a fine veil over the retina, and obscure the sharp outlines of the nerve entrance, the retinal vessels, and so forth. By more accurate examination, this veil may be resolved into an innumerable multitude of fine points, a proceeding particularly difficult when the points are situate not in the same, but in different layers of the vitreous. In such cases, the highest attainable magnifying power must be used, and the observer, with due regard to the strength of the convex lens, and his own distance from the objects, must by degrees accommodate his eye for different depths in the vitreous body. If the opacities lie in one layer, they present the appearance of a finely-sprinkled translucent membrane, which, through shifting of its different portions, seems sometimes collected together and sometimes spread out, and appears to draw a net, or fine web, here and there before the fundus. If they lie in different depths, they appear collectively as an infinitely fine dust or spray, that in movements of the eye collects in parts into somewhat denser masses, and in a fixed position either remains uniform, or sinks to different depths in different regions of the eye.

These opacities disturb the sight far more than large but circumscribed bodies, so long as the parts of the vitreous body between the latter remain perfectly transparent. In this respect there is resemblance to what is seen in the cornea and lens, in either of which structures dense defined opacities, when they leave part of the area of the pupil free, produce far less disturbance than opacities that are finer and more diffused.

b. Filamentous opacities show themselves with the ophthalmoscope as apparently dark, simple, or sinuous threads, that in movements of the eye shorten and again elongate themselves. The patients are accustomed to compare them to snakes, the legs of insects, and so forth.

c. Membranous opacities form strongly-translucent, finely-sprinkled membranes, which may either roll themselves up or unfold, and therefore present very varied aspects. Their shadows produce to the patient the appearance of a cobweb that is suddenly developed, and that again falls suddenly into separate threads.

d. Flocculent opacities form single masses of various extent, and are compared to snow flakes, small clouds, coagula, &c.

e. Cholesterine crystals are often found near any of the above-described, or near wholly irregular opacities, and constitute the disease of the vitreous known as sparkling synchysis. This presents with the ophthalmoscope a particularly beautiful and interesting appearance when membranous opacities are also present, as these are then strewn over with shining particles, and shot in the most varied colours; while in movements of the eye the crystals scatter themselves in all directions, looking like a golden rain, or a shower of sparks from a firework.

The colour of all the opacities is, in most cases, greyish-blue; they are rarely like pigment, but are frequently tinged by blood, from a bright rust-yellow to a dark red-brown. Desmarres described, as *état jumenteux* of the vitreous body, a condition in which it had, from the presence of a more or less considerable number of microscopic corpuscles, a tint resembling that of the urine of a herbivorous animal, through which the papilla nervi optici had the appearance of the sun seen through a mist. The sea-green or bottle-green colouring of glaucoma disappears in examination with the ophthalmoscope; and therefore depends on the optical effect produced by the presence of yellowish tints, or tints intermediate between yellow and red, from blood colouring of the refracting media.

To this section belongs also a turbidity, equally colourless both by reflected and by transmitted light, and not occasioned by the presence of solid matters, but to be recognized by the following indications, according to Coccius, as being produced by a homogeneous fluid:—The retina appears turbid and indistinct, as if washed out, whether the eye, before the occurrence of the disorder, was normal-sighted or not. Since the volume of the contents of the globe has been increased, the refracting power has been increased in like proportion. An emmetropic eye would in this way be rendered myopic. In myopia, the increased refraction can be diminished by concave lenses, until the objects of the fundus are seen in sharp outline, and at the same time more brightly illuminated; since the focus of rays will be no longer in front of the retina, but upon it. If the same proceeding be attempted with an eye suffering in the manner described, the details of the fundus will certainly appear in sharper outlines, but the turbidity will not be removed, and upon this circumstance the diagnosis may be based.

2. FOREIGN SUBSTANCES IN THE VITREOUS BODY.

1. *Blood Effusion.*

Effusions of blood in the vitreous occur chiefly after wounds, after great bodily exertions, or in diseased conditions of the choroid and retina (especially sclerectasia). With the ophthalmoscope a recent effusion appears as a dark mass, that chiefly occupies the lower portion of the eyeball, and completely conceals the parts of the fundus that lie behind it, and that by degrees again become visible with the progress of absorption. After the breaking up and partial dissolution of the clot, there may be seen little lumps, spots, or threads, varying in colour from rusty-yellow to dark reddish-brown, floating in the vitreous, and, as they readily sink in the fluid humour, often escaping the observer, if he neglect to cause the quick movements already described.

Spontaneous effusion of blood commonly makes itself known, subjectively, by the sudden occurrence of a dark spot, a cloud, or a mist, in the field of vision, as if from the intrusion of some foreign substance, and often leading to endeavours for its removal. Sometimes there is also a feeling of pressure, as from the presence of a foreign body. Later, the impediment to sight reveals its character by its reddish or greenish tint, by a certain degree of mobility in the field of vision, and by an outline that could only be assumed by a fluid specifically heavier than the vitreous body, lying in front of the retina. Such a limited effusion appears to the patient as a black, circular, or oval disk in the field of vision, differing in different cases in its apparent size and distance from the eye; but, on the whole, always retaining the same relative position in the field, except that in course of time it sinks, appearing to the patient to rise higher. Afterwards, when breaking up of the clot and absorption are in progress, and the specifically heavier parts have sunk, and in quick movements have lost their sharp contour, and appear translucent, thinner, reddish, rust-brown, dark green or grey; these parts in repose of the eye are seen towards below, and in quick lateral movements, for instance, in rapid adduction of the globe, they pass like tails from without inwards.

2. *Solid Foreign Bodies in the Vitreous.*

Bodies penetrating the vitreous from without are seen at first, with the ophthalmoscope, according to Ed. Jäger, lying upon the yellowish-red fundus perfectly clear, sharply defined, and in proper colour. After some days, coincidently with the development of local retinal or choroidal inflammation, there occurs slight greyish opacity of the vitreous in the immediate neighbourhood of the foreign substance. This opacity, apparently spreading from the periphery towards the centre, and increasing in density, first surrounds the substance in the form of a strongly-shining, yellowish-white, broad border, and, in the beginning, only obscures its outline, while its surface, by its darker colour, remains strikingly apparent. By degrees the opacity of the vitreous gains ground, and closes in from the periphery to the inner surface of the foreign body, so as to cover it and wholly withdraw it from sight. The subsequent changes depend upon the diminution or increase of the local inflammation. In the former case, in from one to two weeks, under diminution of the inflammatory processes in the choroid and retina, the circumference of the exudation inclosing the foreign body diminishes; and after the turbid vitreous has become clear, there remains only a dense membrane inclosing the foreign body, so that the observer sees only a well-defined yellowish-white capsule or cyst, reflecting light strongly, having a general correspondence with the shape of the substance, and somewhat larger dimensions. In the latter case, atrophy of the eyeball will be the result. Von Gräfe has lately observed cases in which no process of secretion from the inner membranes occurred, and in which small or even middling-sized bodies reached the inner membranes without inflicting any damage, and remained in them free and not encysted. The track by which a foreign substance has reached the interior of the eye, shows itself as an opacity, bluish-grey by reflected, and black by transmitted light.

Foreign bodies in the vitreous, like blood effusions, produce a defect in the field of vision corresponding to their size and their position.

3. *Entozoa in the Vitreous.*

Cysticerci in the vitreous body usually present exactly the same appearance as when under the retina, except that they are often more easily and clearly recognized when floating in the humour without investing membrane. For perfect certainty of diagnosis, it is absolutely necessary to see the movements of the creature. Unfortunately, this is not always possible, since a system of concentric membranes often surrounds it like a bladder, and renders it less apparent. This appears to be always the case when the parasite has attained a certain degree of development. The ultimate result, according to von Gräfe, is invariably phthisis bulbi.

A case unique of its kind was described by Quadri to the Ophthalmological Congress at Brussels, in which a living Filaria oculi humani (Rudolphi) had been observed in the vitreous body of a woman thirty years of age. She possessed with this eye completely normal sight, except that the movements of the entozoon across the field of vision produced a momentary opacity like that of a common flocculus. The Filaria had before been found only in the anterior chamber of a horse, and in the human crystalline lens after death.

4. *New Vascular Formations.*

Coccius has had one opportunity of observing a new formation of vessels proceeding from the retina into the transparent vitreous. He has also seen a similar formation upon the white surface of an organized exudation formed within the vitreous body. In the former case—

"The patient had suddenly perceived a smoke-like cloud before her sight, and the eyes had been somewhat reddened. At the time of consultation they appeared natural, the irides bright green, the pupils somewhat sluggish. Ophthalmoscopic examination showed that the vitreous was completely infiltrated with small punctiform opacities, and was in great part fluid. Single particles floated behind the lens across the whole vertical and horizontal diameters of the eye, and the central mass of the vitreous moved together in such a manner that a relaxation of its tissue was necessarily assumed. At the fundus were seen a number of vessels, which, in the different positions of the eye, moved gradually to and fro. They were most developed in the right eye; and the longest vessel reached forward into the middle of the vitreous, where it ended in a long pointed white thread, that was lost in the upper portion of the humour. In the right eye, towards the inner and lower portion, I observed such threads proceeding from several shorter vessels, that were, after careful inspection, identified as capillary loops. The vascularity of the retina was extraordinary; and when the eye made quick movements the observer could see move, in small curves, vessels which, when the eye was at rest, appeared to be lying upon the retinal surface. The veins of the retina were remarkably winding, and in many places completely concealed by the turbidity of the membrane. The patient was placed under antiphlogistic treatment, and examined almost daily. After some weeks the vitreous body had become visibly clearer, and the patient could discern print, as dark lines, with both eyes. After one more weekly examination, I arrived at the conclusion that the vessels in the vitreous were offshoots from the retinal vessels. At the beginning, I could not discern their origin clearly, prior to the partial clearing of the turbidity. The new vessels were connected partly with venous, partly with arterial retinal vessels, and were equal in diameter to the medium sized arterial twigs of the equatorial region of the eye. They all arose from the neighbourhood of the optic nerve, the margin of which was wholly obliterated. The vessels of the lower half of the right eye passed perpendicularly into the vitreous. In the left eye the retinal vascularity was less, and the capillary loops were much shorter; but the degree of turbidity was the same as in the other. On the morning of the thirty-fourth day of treatment, the patient complained of an increase of blindness in the right eye. After dilatation of the pupil an examination was made, and it was found that a considerable hæmorrhage had taken place from the capillary loop that extended farthest forwards into the globe, and that no clear view of the retina could be obtained. After further treatment, the vitreous again became clearer and the vision better; but a short red streak, with a clubbed extremity, remained for weeks at the end of the capillary loop. The patient then discontinued treatment."

2. THE CRYSTALLINE LENS.

It would be superfluous to attempt to give a complete description of all the possible morbid changes in the lens that can be seen with the ophthalmoscope, and I shall therefore be content to point out the most important matters in the ophthalmoscopic examination, and briefly to mention the chief forms of lenticular opacity.

While these opacities are, for the most part, discernible by examination in daylight with a magnifying glass, yet the inspection with the ophthalmoscope has these great advantages, that it shows the presence of opacities which, on account of their fineness, could not be recognized by the examination with incident daylight; and that, in opacities of greater degree, their depth and extent can be more accurately seen against a brightly-illuminated background, and the degree in which the subjective sight-disturbance is due to their presence can be more certainly determined. The means for this are afforded partly by the ophthalmoscope, and partly by lateral illumination; which is, in such cases, of paramount advantage, inasmuch as it displays the smallest changes in the transparency of the lens or its capsule, of whatsoever natúre they may be, with the greatest accuracy that is attainable in the living subject. In the application of the ophthalmoscope only a weak illumination should be used, which is best furnished by a plane mirror alone; although a convex lens may with advantage be placed behind it, so as to make objects appear larger and clearer.

In complete absence of the lens, it is naturally impossible, even when no concave glass is used, to bring the mirror close to the eye of the patient; and, on account of the absence of this strongly refracting medium, the observer must place himself several inches distant. The nerve surface and vessels, through the remaining refracting media, appear comparatively small. The focal point of the conjoined refracting apparatus is placed, in such a condition, so far behind the retina, that this membrane is seen only slightly magnified; and such an appearance of marked diminution should produce suspicion of the absence of the lens. On account of the strong divergence of the emergent rays, a short-sighted observer must in such a case use a very weak concave glass, or generally even none; and a far-sighted observer must use a convex glass, in order to see the retina clearly.

Opacities in the lenticular system are distinguished from those in the vitreous, partly by their shape and appearance; partly by the kind of glass with which they can be accurately seen; partly, after some practice, by the conscious exercise of the power of accommodation which is necessary in order to measure their distance from the cornea and from the retina, and to see these points clearly one after another.

1. OPACITIES OF THE CAPSULE OF THE LENS.

a. Plastic exudations and pigment deposits on the anterior surface of the capsule are very frequent after previous iritis:—the former, which may either lie free upon the capsule, or may unite it with the pupillary margin (posterior synechiæ), exhibit very clearly, by lateral illumination, their whitish colour and the finest details of their surfaces;—the latter are seen in their natural colour; while both, with the ophthalmoscope, appear only as black spots upon a red ground. They are often arranged in a circular figure corresponding to the margin of the pupil, and with the unaided eye are scarcely perceptible.

b. Opacity of the capsule itself, or deposits upon its inner surface, also appear with the ophthalmoscope as black spots upon a red ground; and by lateral illumination as milk-white, roundish, uneven, often slightly projecting spots—the capsule itself, where elevated by these spots, being sometimes very regularly wrinkled.

c. Secondary cataracts, according to von Gräfe, appear either as small, very fine, glistening, and almost completely transparent pellicles; or as opaque, milk-white membranes, formed by the thickened capsule itself, often incrusted by calcareous particles, or loaded with lens fibres in a state of fatty degeneration, or with a greater or less amount of still transparent lens substance; or, lastly, as opaque, shining white, tough threads and membranes, the results of considerable exudations.

2. OPACITIES OF THE LENS SUBSTANCE.

The chief of these are, according to von Gräfe:—

a. The laminar cataract (lamellar cataract, S. Wells), (stationary nuclear cataract of young people, Arlt), (cataract with isolated opacity of the fibrous layers, Jaeger), the most common form in childhood, exhibits behind the pupil a somewhat sodden turbidity, which, after the instillation of atropine, is seen to be divided by a sharp marginal line from a peripheral zone of transparent lens, and to present a circle having a diameter of from 2‴ to 3½‴. Unless, as is almost constantly the case, the anterior pole of the opaque stratum be dotted by small white points, the degree of opacity, from the margin to the centre, will be completely uniform. In ophthalmoscopic examination the opaque circle appears dark, sharply defined, and, with light falling perpendicularly, the central parts, if not too turbid, have a brownish-red translucency. The margin of cortical substance, in stationary cataracts, is perfectly clear, so that it is usually possible to examine the objects of the fundus, although with a contracted field of illumination. But if the cataract be slowly progressive, there will be fine punctiform opacities of the cortical substance, or short radiating streaks near the equator.

b. The cortical cataract; broad, radiating, crystalline streaks uniting in the poles of the lens, and the substance lying between them turbid, cloudy, and spotted. A riper cortical cataract, of from two months to a year's duration, often shows pigment spots upon the strongly-distended capsule; the cortical substance, interspersed with glistening streaks, is grey with a tendency to bluish, not absolutely opaque, but in a certain degree translucent, so that one can see into deeper strata. Between the streaks are commonly small segments, in which the transparency is still greater. Sometimes there may be seen in the cortical substance single spots of a grey colour passing into blue, but never a trace of the yellowish reflection of a hardened nucleus. The ophthalmoscope shows, in the clear reddish pupillary field, black wedge-shaped shadows, their broad ends towards the periphery, their points turned towards the centre. In cases that in other respects present the aspect and bulk of soft cortical cataract, the appearance of a weak yellow tint, not confined to the central portion, but extended over the middle and external cortical layers, is not an evidence of a harder nucleus. Such cataracts are not altogether pulpy, but are formed of harder sectors, separated by interspaces of soft matter.

c. Punctiform opacities of the lens, even when present in considerable numbers, are often only to be seen with difficulty upon the red ground. By lateral illumination, on the contrary, they appear as small, excessively fine and bright drops upon a dark ground, scattered irregularly throughout the whole lens. In the opacities of the cell layer, between the lens margins, black radii are seen from the periphery to the centre; in opacities of these cells at the summits of the lens, Werneck's star-shaped figures become visible as dark appearances, which, by lateral illumination, reflect a peculiar bluish light.

In order to distinguish whether these opacities are situated in the anterior or posterior cortical substance, Desmarres gives the following directions:—"If they are numerous, the observer, when seeing them clearly, should direct the patient to bend his head strongly backwards. If the opacities are near the posterior surface, they will then in great part disappear behind the lower pupillary margin, and leave the anterior layer to be recognized as transparent. If there be, near the posterior layer, only a single opaque streak, the observer, whilst looking at it, directs the patient, for example, to look upwards; upon which the streak, instead of going upwards also, as it would do if it were near the anterior surface, goes downwards, and disappears behind the inferior pupillary margin. Inversely, a posterior spot would move upwards, when the patient himself looked down.

An extended, uniform opacity of the lens, that almost entirely prevents the entrance of light into the eye, so that the pupil appears dark when looked at from before with the ophthalmoscope, may be recognized by the appearance, in the whole circumference, of a faint reflection of light from the fundus, when, the pupil being widely dilated, the observer looks from either side, between the iris and lens, in the direction of the ciliary processes.

3. OPACITIES OF THE NUCLEUS OF THE LENS.

a. The nuclear cataract of young subjects appears as a grey, sometimes whitish suffusion behind the pupil, of a depth increasing from the periphery to the centre. Sometimes the proper nuclear region is indicated by a somewhat sodden and more whitish colour, with an obscure margin separating it from the greyish or slightly smoky cortical substance, which in its outer layers usually remains translucent, but not completely transparent. The ophthalmoscope, with widely-dilated pupil, shows the cortical substance, even to the capsule, to present a diffused or finely-dotted turbidity. In this, as well as in the increasing saturation, consists the most important distinction from the laminar cataract, with which this rare form is liable to be confounded.

b. The senile cataract is distinguished by the yellow colour of the nucleus, the size and tint of which may be learned by using lateral illumination, in the following manner:—The convergent pencil of light is first thrown upon the anterior surface of the nucleus, which is marked by a strong greyish-blue reflection, and then through the lens to the posterior surface, so that the nucleus appears of its proper amber tint. If the surrounding cortical substance be fluid, the yellow nucleus may be found not in the middle, but shining yellowish through the diffuse opacity at the lower part of the capsule, to which it has sunk.

There are certain conditions of the eye in elderly people (in whom the nucleus of the lens is usually more or less tinted) that are often mistaken for cataract by the inexperienced. The most deceptive of these is produced, I think, by slight detachment of the retina. The pupil will then sometimes present a peculiar uniform cloudiness that is due to reflection from the fundus, and that, in examination by diffuse daylight, under atropine, would be liable to deceive many persons. Its distinctive character, however, is its perfect uniformity. In focal illumination, the pencil of light passes over the crystalline without a break, and this is never the case where there is cataract. The ophthalmoscope, of course, would clear up the question immediately; for, by the use of the mirror alone, the faintest opaque line becomes conspicuous as a dark streak against the illuminated background. If the object lens were also used, and the details of the inverted image rendered visible, it is possible that these details might obscure or conceal the very finest striæ. To show that the caution contained in this paragraph is not unnecessary, I may mention that I have lately seen a patient who had just undergone an unsuccessful operation for cataract in a provincial hospital. He was told by the operator that his remaining eye was also cataractous, but not ripe, and that he must wait three months for an operation upon it. I found the remaining eye precisely in the condition described above; the lens tinted, but perfectly transparent, and the retina slightly detached. The pupil presented a peculiar amber-coloured cloudy reflection, and the ophthalmoscope had not been used prior to the operation. I have very little doubt that the operator made the same error of diagnosis with regard to the first eye that he manifestly made with regard to the second.

III. THE CORNEA.

Opacities, losses of substance, and other changes in the cornea, having defined margins against the bright ground of the pupil, are not only characterized by the peculiar refraction of light that they usually occasion, and that is easily seen by inspection of the eyes by daylight, but are particularly distinguished from lenticular opacities by their position in relation to the iris, and by their visible movements. If, for example, there be in one eye a small opacity in the centre of the cornea, or nearer to the inner margin of the dilated pupil; and, in another eye, in the same position, an opacity of the anterior cortical layer, or of the anterior capsule of the lens, and if the two eyes are both turned inwards, or are looked into from the outer side, the corneal opacity will also move inwards over the bright disk of the pupil, and finally disappear over the iris; while the lenticular opacity will be approximated to the outer pupillary margin, so as to leave a free space between the opacity and the inner pupillary margin; and opacities that were formerly concealed behind this latter margin will so be brought into view.

Facets upon the cornea are frequent causes of distorted retinal images, and are most frequently seen in combination with opacities. The latter become very manifest against the brightly illuminated fundus, even if inconspicuous when examined only by a magnifier. Inequalities of the cornea, which, if present in great numbers, give to its surface the appearance of a polyhædron, may be discovered by reflected daylight, either with or without a lens. Their influence upon vision, however, can be in no way better observed than by the aid of the ophthalmoscope.

Among other corneal inequalities, mention should perhaps be made of conicity; which, in its earliest stages, may be detected by the ophthalmoscope more readily than by any other method of examination. The mirror only is required, and should be so held as to afford no image of the fundus. One half of the base of the corneal cone will then be cast partially into shadow, and the slight semicircular shading thus produced will play around the base, in obedience to movements of the mirror.

IV. AMETROPIA AND ASTIGMATISM.

The ophthalmoscope furnishes data, sometimes of considerable value, for the diagnosis of these affections; which, as they depend upon anomalies of refraction, may be properly considered in this place. In my account of them I shall chiefly follow Professor Donders.

The refracting apparatus of a normal eye, in repose of the accommodation, has its principal focal point upon the bacillary layer of the retina, and unites parallel rays in this situation. Rays mathematically parallel are such as proceed from infinitely distant luminous bodies; but, for all practical purposes, the rays proceeding from objects merely remote may be considered and treated as parallel. Such objects are furnished by Dr. Snellen's test types, when placed at a distance from the observer equal, in Paris feet, to the number by which each size of type is distinguished.

Inasmuch as clear vision is possible only when the rays of light are brought to their focal union upon the bacillary layer of the retina, it is evident that the refracting power of the normal eye must be increased when vision is required for near objects. Such objects furnish divergent rays, which, without an increase of power, would be first united at a point behind the retina.

In the human eye, the necessary increase of refraction is afforded by certain internal changes of adjustment, the most important of which is an increase of the curvature of the anterior surface of the crystalline lens, effected by the action of the ciliary muscle. This change may be rendered visible by the ingenious experiment of Professor Cramer.

It is well known that the eye returns to a spectator three images of a candle-flame held in front of it: one from the cornea, one from the anterior surface of the crystalline, and one, inverted, from its posterior surface. By means of an ophthalmo-microscope the two latter images may be seen to approach and recede from one another, as the eye is directed alternately to a distant or a near object.

With the change in the crystalline are associated other movements of less importance, but conducive to the same end. The pupil contracts, so as to cut off the most divergent rays; and the axes of the two eyes converge, so as to meet upon the near object that is inspected. The first movement diminishes the amount of change required from the crystalline, and the second allows each eye to receive the image upon the most sensitive portion of its retina.

Extreme contraction of the pupil would alone be sufficient to afford distinct vision of near objects, by admitting only the central and nearly parallel rays of the cone of light, were it not that the loss of illumination would be too considerable. This may be seen by looking through a capillary opening in a metal disk. Through such an opening small type may be read as close to the cornea as it can be brought, but the background of white paper appears of a dirty grey.

The sum of these ocular changes is expressed by the word accommodation; and the eye is said to accommodate when it adjusts itself for the divergent rays that proceed from near objects. The refraction of the eye denotes its natural physiological action upon light when perfectly at rest; and the accommodation, the power of altering the refraction by voluntary muscular effort.

The normal eye, when at rest, would unite parallel rays upon its retina. Such rays proceed from infinitely distant objects, and such objects should, therefore, be clearly visible. The normal eye, it follows, has really no "far point," no distant limit of its power of sight. Its far point is said to be infinitely distant; and its range of vision is only limited by the failure of light from distant objects, in consequence of atmospheric dispersion.

To the power of accommodation, however, there is a distinct limit. As the object of vision comes nearer and nearer, the rays from it increase in divergence, and the accommodation effort increases in like ratio. When the divergence attains a certain degree, the accommodation can no longer conquer it, and the object becomes indistinct. Immediately prior to this change, the "near point" of distinct vision has been attained. The interval between the far point and the near point is called the range or territory of accommodation.

In early life, when the crystalline lens is comparatively soft, the ciliary muscle is able to modify its form considerably, and the near point is then at its shortest distance from the cornea. As the lens hardens with advancing years, it yields less and less to the peripheral pressure, and the near point recedes in proportion. This change occurs in all eyes, and is always gradually progressive; but its rate of progress is very different in different persons. In time, it usually reaches such a degree, that small type can only be read at a distance inconveniently remote; and, in consequence of this distance, under an unusually strong illumination. Convex spectacles are then required, in order to supplement the failing power of accommodation; and the patient is said to suffer from presbyopia. It must be borne in mind, that presbyopia is a purely physiological condition; that it occurs, more or less, in all persons; and that it affects the near point only.

An eye that, in repose of its accommodation, unites parallel rays upon the bacillary layer of its retina, is said to be *emmetropic*.

There are two directions in which the ocular refraction may deviate from this normal state, and cause the eye to be *ametropic*.

The focal point of parallel rays, in repose of accommodation, may be situated either in front of the retina or behind it. In the first case, the eye is short-sighted, myopic, or brachymetropic; in the second, it is hypermetropic. In the former, the far point is situated at a finite distance in front of the eye; in the latter, at a finite distance behind it. In other words, the refraction of a myopic eye will only unite upon the retina divergent rays proceeding from a point in front of the cornea; and that of a hypermetropic eye, rays already converging to a point behind it.

Myopia and hypermetropia are, therefore, two diametrically opposed conditions. They have this much in common, that both are caused, most frequently, by a deviation from the proper length of the ocular axis, which in the myopic eye is longer, and in the hypermetropic eye shorter, than in the emmetropic.

Myopia has long been studied by ophthalmologists, on account of its connection with many diseased conditions (sclerectasia posterior, atrophy, retinal separation, næmorrhage, &c.). Hypermetropia has only lately received any considerable attention, since it has been ascertained to be the cause of most cases of asthenopia and of strabismus convergens. It must be remembered that hypermetropia may be concealed by constant exercise of accommodation, and that then it will not become evident until the ciliary muscle is paralyzed by atropine. With this precaution, hypermetropia is declared when vision for distant objects is improved by convex spectacles, and myopia when it is improved by concaves.

The degree of ametropia is ascertained by the strength of the spectacle lens which corrects it, and renders the eye emmetropic. The strength of a lens is inversely proportional to its focal distance F, and is expressed by $\frac{1}{F}$. The value of F is stated in Paris inches. By lenses of $\frac{1}{6}$, $\frac{1}{8}$, &c., we therefore understand convex glasses, that have a positive focal length of six and eight Paris inches respectively. Lenses of $-\frac{1}{10}$ or $-\frac{1}{20}$ are concaves, having a negative focal length of ten or twenty inches. The same are written without the fraction, as 6″ or 8″, −10″ or −20″. The same expressions are used for the ametropia. $M = \frac{1}{9}$ signifies a myopia that is neutralized by a lens of −9″, and $H = \frac{1}{12}$ is a hypermetropia that is neutralized by a lens of 12″. Every case of ametropia belongs to one of these two classes.

It is found, moreover, that the same eye may possess different powers of refraction in its different meridians. The same eye may be emmetropic in one meridian, and ametropic in another; or the two meridians may present ametropia of different degrees, or even of different forms. This asymmetry is usually so slight as not to interfere with vision; but it sometimes becomes considerable, and the sight then suffers in a marked degree. It has received the name of astigmatism.

The ophthalmoscopic diagnosis of ametropia rests upon the consideration already stated, that the rays of light leaving an eye return along their path of entrance. Rays leaving a myopic eye are therefore convergent, and those leaving a hypermetropic eye are divergent.

In the ophthalmoscopic examination of an emmetropic patient, the eye under examination is usually accommodated for some point short of infinite distance, say for the other side of the room, and the rays returning from it (unless in perfect paralysis of the ciliary muscle) are therefore converging to a focus at a distance of twelve or twenty feet from the cornea. If the observer be emmetropic, and bring his eye and mirror close to the eye of the patient, he will, if the mirror perforation be not too large, receive only the central rays of the emerging cone, and will unite them on his retina into an erect virtual image of the fundus. As he retires from the patient the cone becomes smaller, its outer and more convergent portions pass through the mirror opening, cannot be united by the observer, and the image becomes confused and ultimately lost. In most cases, however, the emerging cone will have such convergence, even in its central portions, that a very weak concave lens, —30″ or —40″, placed behind the mirror, will sharpen the details of the image.

If, however, the observer withdraw to a distance of 12″ or 14″, he will obtain from the emmetropic eye no image at all, except by the interposition of the inverting object lens.

In ametropia the case is widely different. When either of its forms is present in a marked degree, the observer, looking through the mirror alone, without the object lens, and without approaching very near the patient, sees at once the details of the fundus. In myopia, the emergent converging rays have already united, without an object glass being required, to form an actual inverted image; and, in hypermetropia, the divergent rays still afford an image that is virtual and erect. If, therefore, the details of the fundus can be seen at ordinary visual distance without an object lens, the observer should make a slight lateral movement of his head. If the image appear to move in an opposite direction, it is inverted, and the patient myopic; if in the same direction, it is erect, and the patient is hypermetropic.

A further test is supplied by the inverted image given by the object lens. In myopia, the details of this image are smaller and brighter; in hypermetropia, larger and less bright than in the normal condition under equal illumination.

In myopia, moreover, the emerging rays are so convergent that an erect image cannot be obtained without the aid of a moderately strong concave lens behind the mirror; while in hypermetropia, a convex lens in the same position will be, if not necessary, at least advantageous, by its effect in magnifying the image.

The question of the existence of myopia is one that often presents itself to the military surgeon in the examination of recruits, or on other occasions; and that may occasionally arise in connection with civil jurisprudence.

It was formerly a common practice to simulate myopia in order to obtain discharge from the army. The old test was to place strong concave spectacles before the eyes, and then to try the vision by various objects. Malingerers trained themselves by previous practice with such glasses, learned to overcome their refraction by strenuous accommodation, and often passed the examination successfully. The ophthalmoscopic examination, however, affords unfailing evidence of the true state of the refraction.

The observer may use his own distance of clear vision as a standard for shortness of sight (*see* page 83), by holding concave lenses now nearer to his own eye, now nearer to the eye examined, and by determining experimentally what power exhibits the retinal vessels most clearly in each position. Of two lenses, if that which requires to be held nearer to his own eye be stronger than the other, which must be held nearer to the eye under inspection, then the examinee is of shorter sight than the examiner; and the more so, the greater the difference in the focal distance of the lenses. A focal difference of two inches is sufficient to show a very great difference of visual distance.

Lastly, any doubt about apparent or actual myopia is changed to certainty when the observer discovers, in the eye examined, any of those morbid conditions which are commonly associated with, or consecutive to, shortness of sight. Such are opacities of the vitreous, injuries of the retina, sclerectasia posterior, and so forth.

Prof. Ed. Jaeger has given directions for determining the adjustment of the eye by means of the ophthalmoscope. He recommends for this purpose the erect image, as shown by a concave mirror of 7″ focal length, or by the ophthalmoscope of Helmholtz. In order to obtain the necessary experience and dexterity, the observer must train himself by repeated and careful examinations of healthy and normal eyes, in repose of their accommodation, and must accurately study the characters of the images he sees. He must especially observe the degree of enlargement of the parts; the size of the field of view, both absolutely and in proportion to the pupil; the quantities and tones of light and colour; the sharpness of outlines; the adjustments of his own eye; the apparent distance of the image; the kind and power of correction lens that affords the clearest picture; and lastly, at what distance of his own eye from that of the patient the examination can be most comfortably made and continued. All these particulars afford to each observer a standard, for himself alone, by which to judge of eyes that depart from the normal condition.

Compared with such a standard, a myopic eye affords a smaller field of view, and an image nearer to its actual position, a less intensity of light and colour, and a greater enlargement of details; insomuch that the whole of the nerve disk will perhaps not be visible at once. It will also be necessary to use a concave lens of a strength corresponding to the degree of myopia, and to approach the examined eye very closely.

In an hypermetropic eye, on the contrary, the field of view will be strikingly enlarged; the image will appear to be considerably in front of the actual position of the retina; its intensity of light and colour will be increased, and the size of its component details diminished; so that every part of it will gain in sharpness, and the whole in general effect. In a high degree of hypermetropia, it will even be possible to include at a glance nearly as much of the fundus as commonly in the inverted image. In further contrast to myopia, in will be necessary to use a convex correcting lens, and the distance between the observer and the patient may be considerable.

These differences between the appearances presented by normal, myopic, and hypermetropic eyes respectively will depend, in their degree, upon the degree of the ametropia. After some practice, therefore, it is not difficult to estimate the latter with tolerable accuracy; and to prescribe, within one or two numbers, the spectacle lens required for its correction.

Stellwag observes that, in order to obtain a clear image of the retina of a myopic eye, either a convex or a concave glass will be necessary, according as the image of the retina, formed by the refracting media of the examined eye, be situate in front of the ophthalmoscopic mirror or behind it, and therefore also behind the lens, which intervenes between the mirror and the eye of the observer. In the latter case, if we assume, with him, p as the focal distance of this lens, a as the accommodation distance of the examined, and b that of the examining eye, then:—

$$p = \frac{a\,b}{b-a}, \text{ and } -p = -\frac{a\,b}{b+a}, \text{ whence } a = \frac{p\,b}{b+p}$$

by which the visual distance of the examined eye can be determined. It is so much the less, the greater the strength of the glass that is required, in stationary accommodation of the observer, in order to afford a sharp and clear image of the retina.

The diagnosis of astigmatism rests upon many circumstances which it would be foreign to the scope of the present volume to discuss; and in the myopic forms of the affection, the subjective signs afforded by the state of vision will be the most trustworthy. In both forms, however, but especially in the hypermetropic, the ophthalmoscope affords very certain evidence of the condition.

In a normal eye, or in one that is simply ametropic, in the erect image, the emmetropic observer, in repose of his accommodation, sees all the vessels upon the nerve disk at once, with equal distinctness, in whatever direction they proceed. In an astigmatic eye this is no longer the case, and the observer must vary his accommodation in order to see alternately, with equal clearness, the vessels that proceed in different directions. As a rule, the observer, in repose of accommodation, will see the horizontally directed vessels clearly, and will require an exercise of accommodation, or the aid of a lens, to see those that are directed vertically. This condition will be reversed in the rare cases of preponderating hypermetropia in the vertical meridian; it will also be reversed in the inverted image, in which, moreover, the difference will be much less remarkable, and may even be altogether destroyed by the inclination of the axis of the object lens.

Dr. Knapp suggested to the Heidelberg Conference of 1861, an ophthalmoscopic test of astigmatism, based upon the apparent shape of the nerve disk, the diameter of which, as seen in the erect image, would be elongated in the meridian of greatest, and diminished in the meridian of least, curvature. This appearance would be reversed in the inverted image. Professor Donders points out the obvious difficulty, that the diameters of the nerve disk are often actually unequal, and would, therefore, appear so in eyes that were not astigmatic.

SECTION THE FIFTH.

THE OPHTHALMOSCOPE IN ITS RELATIONS TO FORENSIC MEDICINE.

On account of the great advances made during late years in the public administration of justice, and of the consequent demands upon the medical practitioner, it appears expedient to discuss certain circumstances in which the ophthalmoscope may furnish medical jurists with important aid in the formation of their opinions.

It would be of the greatest utility to forensic medicine if the ophthalmoscope should afford a means of determining with certainty the presence of death by the turbidity of the refracting media; or of deciding, by the degree of this turbidity, what time had elapsed since death took place. Unfortunately, it is of no avail for these purposes; and Professor Coccius, who first propounded and considered the question, thus states his conclusions:—"These grave problems do not allow me to solve them positively, however well I know the value and importance that would attach to an opposite decision. But questions of such nicety do not require answers that only balance doubts. For example, in a case where the transparency of the ocular media of a dead body was tested, it still would not be known what had been the transparency during life, unless this had been formerly ascertained. Moreover, in animals chloroformed to the point of death, the cornea may be seen to grow pale, and, with the returning consciousness of the animal, to be restored to its natural state. In corpses, also, that have been dead for the same period of time, there are remarkable differences in the transparency of the media; those of persons that have died from exhausting diseases retaining their clearness longer, in general, than is the case with the victims of acute illness. Among the latter, however, must not be included persons killed suddenly by accident, in whom, as in slaughtered beasts, the transparency remains longer. Furthermore, various collateral circumstances, such as constitution, temperature, and mode of death, exert an influence upon the earlier or later occurrence of changes in the media; so that, after taking all the conditions into account, we must say that the ophthalmoscope may certainly, in particular cases, and with due regard to all connected circumstances, throw light upon the time that has elapsed since death; but that, in general, it only teaches that the media in mankind appear turbid within a few hours after dissolution; and that the degree of turbidity is dependent upon various contingencies."

While, therefore, for the purposes above mentioned, the ophthalmoscope is of little or no value, it may be applied with more decided utility to cases in which the medical jurist is called upon for an opinion about injuries to the eye; and especially about their permanent consequences. If the injuries have been so severe as to rupture the cornea and sclerotic, and to cause the escape of the vitreous and aqueous humours, or if, some hours afterwards, a so-called traumatic cataract makes its appearance, then, indeed, the ophthalmoscope is not required. Cases occur, however, in which, after blows upon the eye or in its vicinity, sudden total or partial loss of vision follows; and in these the ophthalmoscope is of value for the determination of different questions, and affords evidence either positive, as of the existence of hæmorrhagic effusion, retinal separation, &c., or negative, to the effect that no changes or abnormalities are discoverable in the eye, and that therefore the injury in question has probably affected the brain itself. And the medical jurist, moreover, is guarded against deception in cases where an injured person simulates loss of vision as a result of injury; or, possibly, having before laboured under some disease of the eye, first discovers it after the blow, and supposes that the blow has produced it. If the surgeon, under such circumstances, find the traces of old disease, old choroidal exudations, old destruction of pigment, posterior staphyloma, and so forth, the examination places him in a position to compare the disturbance of vision with the injuries.

The detection of simulated ametropia has been sufficiently noticed in the preceding section, and a few paragraphs, given by Dr. Zander on this part of the subject, have been incorporated with the observations on pp. 200 and 201.

Cases will sometimes occur in which it is desirable to test the reality of a professed partial or total blindness of one eye. This can scarcely be done with certainty, except by the ophthalmoscope, since the merely external signs are insufficient.

It is true that squinting of the affected eye, mydriasis, smoky turbidity of the fundus, or immobility of the iris, would lead to the conclusion of real blindness. These signs are wanting, however, in cases of amaurosis, in which the retina retains a slight sensitiveness to light; or they may be present, independently of amaurosis, in paralysis of the oculo-motorius, or in idiopathic mydriasis, or even in mydriasis artificially produced.

In persons, moreover, who suffer from hemiopia, or almost total annihilation of sight, dependent upon retinal separation, effusion of blood in the neighbourhood of the macula lutea, scattered small hæmorrhages, or serous exudations in the retina, the pupil almost always retains its regularity and mobility; and, in such cases, except by the aid of the ophthalmoscope, no certainty could be attained.

In many other cases the pupil remains regular and movable, notwithstanding complete amaurosis, as from advanced atrophy of the optic nerve, or through disease of the nerve-trunk itself. In such cases, by displaying concavity of the papilla, mother-of-pearl tinting of its surface, obliteration or atrophy of the retinal vessels, or other changes, the ophthalmoscope would afford conclusive evidence of the reality of the disorder.

As a rapid test of monocular blindness, von Gräfe recommends the use of prismatic glasses, which have the advantage of being applied to the eye that is professedly sound. A prism should be held before this eye, preferably with its base upwards or downwards, and the patient be asked whether he sees one or two images of a light placed in front of him. If he see two—one above the other—one of which moves round the other when the prism is rotated, the stationary image belongs to the other eye, and the imposture stands confessed:—as may be proved to the patient himself, by covering the eye that is professedly blind. With regard to the detection of simulated weakness of sight, von Gräfe says,—"If we take objects of different sizes, arrange them at different distances, and then try the effect of glasses, a malingerer will soon give answers that will convict him of simulation. It is especially useful to employ convex lenses. A malingerer will commonly think to make himself safe by protesting that he cannot see through any of the glasses; and since a convex lens only shortens the visual distance, and does not impair the sight, this protestation will afford the evidence that is required."

Whether the ophthalmoscope will hereafter assist the medical jurist in the investigation of mental diseases, is a question that only time can solve. The foregoing observations are intended to show that, in the cases referred to, it will at least not be useless, and that it will therefore deserve more consideration than it has hitherto received.

SECTION THE SIXTH.

THE INFLUENCE OF THE OPHTHALMOSCOPE UPON THE TREATMENT OF OCULAR DISEASES.

THE title of the present section opens a wide field for inquiry. The great invention of Helmholtz has been a source of new life to every branch of ophthalmology, and has not only directly modified the treatment of the conditions it has actually exposed to view, but indirectly, perhaps, although not less truly, that of other conditions also, with which its connection is at first sight less apparent. We are directly indebted to the ophthalmoscope for the modern treatment of detached retina or sclerectasia posterior; but we are indebted to it almost equally for the recognition and relief of astigmatism, or for the modern operations for the removal of cataract. Its influence upon curative measures can therefore only be described by a sketch of the existing state of ocular therapeutics. The present volume affords no fitting opportunity to render such a sketch complete in matters of detail, and I shall therefore content myself with endeavouring to place a general view of the subject before the reader. This general view will be illustrated by cases, so far, and so far only, as they seem to me to be typical in their characters and results, and to afford the means of describing actual occurrences in the smallest possible number of words. As an additional aid to conciseness, and in order to avoid repetition, it seems desirable to commence by some account of the principal means of treatment, and of the nature of the influences which they respectively exert. These means of treatment may be enumerated, with some appearance of order, under the five following heads, namely: 1. Iridectomy; 2. Depletion; 3. Internal Medication; 4. Counter Irritation; 5. Local Applications.

The operation of iridectomy was first brought prominently forward by von Gräfe, in 1857. I shall first describe the method of performing it, and shall then speak of its effects.

The instruments required for iridectomy are a spring speculum for opening the lids, proper forceps, toothed at their extremities, for holding the globe, a triangular knife, of a size proportionate to that of the anterior chamber, set at an angle upon its handle, fine forceps for seizing the iris, and keen scissors for cutting it. The surgeon should also provide himself with a scoop, a fine spatula, some cotton wool, and a bandage.

It is quite possible to perform iridectomy without chloroform. Still, the restlessness of the patient, and the spasm of his ocular muscles, are serious sources of danger, and entail not only increased risk of wounding the lens, but also of the occurrence of retinal or choroidal hæmorrhage upon the sudden diminution of intra-ocular pressure. Unless there be some very cogent objection, complete anæsthesia should be regarded as an essential preliminary.

I may here observe, by the way, that the dangers of using chloroform in ophthalmic surgery have been greatly exaggerated by many writers. The effect most dreaded, vomiting, will rarely follow if operations be performed in the morning, when the patients have had neither food nor drink since the evening before, and if a suitable dose of brandy and water, strong and hot, be administered to adults, a few minutes before inhalation is commenced. Some operators prepare their patients for chloroform by a day or two of moderate meals, and a few hours of abstinence. The brandy, which is very useful for adults, should seldom be given to children, in whom it is more apt to cause sickness than to prevent it. If vomiting should, after all, be threatened, the surgeon should desist from manipulation, remove the speculum if it were inserted, close the eye, cover the lids with a ball of cotton wool, and support the whole with the palm of his hand, while the patient's head is turned to one side, and the matters vomited are received and cleared away. This done, the former position should be restored, the inhalation renewed, and the operation, in due time, proceeded with. I have repeatedly performed extraction of cataract under chloroform; and, as a rule, use it generally in all other operations upon the eye; and, strictly observing the above precautions, have never had reason to regret its employment.

The middle third of the upper half of the iris is the portion that should usually be removed. The resulting deformity being partially covered by the upper lid, is not only less unsightly, but also less disturbing to vision, than it would be in any other portion of the circle. Still, there are special circumstances that may render another situation desirable, and some of these will hereafter be enumerated.

For all operations upon the eye, partial anæsthesia is worse than none at all. The surgeon having satisfied himself that no muscular spasm will be produced by the forceps or knife, and the patient being upon his back, in a good light, and with a suitable inclination of his face towards the window, the next step is the gentle introduction of the speculum.

The size and strength of this instrument should be accurately adapted to the requirements of the case, so as to hold the lids apart without too much tension, and without pressure upon the globe. The improved speculum of Mr. Bader, which can be fixed at any required width of opening, should generally be preferred. If pressure upon the globe cannot otherwise be obviated, the speculum used should be slightly lifted by an assistant.

The surgeon, standing behind his patient, seizes the conjunctiva and its sub-mucous tissue with toothed forceps, at a small distance from the cornea, and at a point opposite the centre of the intended incision. If necessary, he slightly rotates the globe, imitating the action of the corresponding rectus muscle; but never lifts or pulls it, and simply holds it still when the desired position is attained. The point of the knife is then placed on the conjunctiva, about a line from the corneal margin, and is made to pierce the sclerotic, and to enter the anterior chamber immediately in front of the iris. It is pushed steadily onwards until the external incision attains a length of 6^{mm} or 8^{mm}, which will correspond to 4^{mm} or 6^{mm} of internal wound. It is then very gently and quietly withdrawn, so as to allow a gradual escape of the aqueous humour. If the blade be too narrow to make a wound of the desired length, the external angle may be enlarged in the act of withdrawal.

In cases of glaucoma, it is of essential importance to remove a sufficiently large piece of iris, and to remove it in its entire width, tearing it from its ciliary margin. For this purpose a sufficiently large wound is required, and its position must be sufficiently far back. In endeavouring to fulfil these conditions, an inexpert or careless operator may enter the globe behind the iris, may wound the iris at his first puncture, may lacerate the capsule of the lens in traversing the pupil, or may entangle the point of his knife in the opposite pupillary margin. All these accidents have occurred even where there has been a good anterior chamber.

It happens, however, in some cases of intra-ocular tension, that the anterior chamber is almost abolished, and the iris and the anterior capsule are nearly in contact with the lining of the cornea. Under such circumstances it would be very difficult, even if possible, for the most skilful surgeon to make the ordinary section without wounding either the lens or the iris. Various suggestions have been made in order to overcome this difficulty; and the best of them all, perhaps, is that of Mr. Bowman. He uses a small cataract knife, and makes his incision as if for extraction, but smaller. In this way the point of his knife does not traverse the pupillary space, and the only difficulty is to guide it between the iris and the cornea. In such cases, the previous application of Calabar bean, as suggested by von Gräfe, may also help to secure the lens from injury.

It has been recommended by some surgeons to withdraw the knife suddenly, so as to allow the aqueous humour to escape in a gush, by which practice prolapse of the iris is commonly produced, and the introduction of forceps into the anterior chamber rendered unnecessary. To this plan there are two objections—1st, that the sudden diminution of pressure is liable to produce retinal or choroidal hæmorrhage; and 2nd, that there is some reason to believe that the shock to the lens may be a cause of cataract. However the knife is withdrawn, its back must come in contact with the anterior capsule, and great care is necessary to save this from being scratched by the receding point. The method I practise is, first to loosen the knife in the incision, so as to allow the gradual escape of the fluid, and afterwards to withdraw the blade quickly, with a slight inclination forwards of its point.

An unpractised operator will sometimes find it difficult to give his attention to both knife and forceps, and, while engrossed by the former, will unconsciously exert pressure or traction with the latter. This error should be most carefully avoided.

The section being completed, and the knife withdrawn, the eye may be freed from tears and blood with a bit of soft rag. An assistant then takes the forceps, and is careful gently to rotate the globe in any required direction, without suddenly dragging it. If the iris be not prolapsed, the surgeon passes the fine forceps into the anterior chamber; and, wherever it is, he seizes it near the pupillary margin, at a point nearly corresponding to the middle of the section, cuts it through with scissors close to the forceps, from the pupillary to the ciliary margin, and then tears the piece still grasped by the forceps away from its ciliary attachment, up to the angle of the wound, renders it tense, and cuts it off close to the conjunctiva. The other half of the prolapse is treated in the same manner, and the cut extremities usually retract within the chamber. This method of excision is due to the ingenuity of Mr. Bowman.

If any portions of iris remain within the lips of the wound, they must be displaced by the spatula, and the wound may also be made to gape, in order partially to empty the chamber of blood. The speculum being withdrawn, all coagula must be removed, not only from the incision, but from the general surface of the conjunctiva. The lids are then closed, covered by an elastic compress of cotton wool, retained by a bandage; and the patient is left in bed. An anodyne is occasionally required; and by the third day the section will usually be healed, the aqueous humour again secreted, and the anterior chamber free from blood.

When iridectomy is practised in order to diminish the danger of cataract extraction, it is not necessary to remove the whole width of the membrane. It is probably even safest to leave a portion of the ciliary zone, since this may afford support to the delicate hyaloid membrane. Dr. Waldau, in his scoop operation, recommends a corneal section, and that the iris should be cut through a little in front of its attachment; and, in practising iridectomy as a preliminary to flap extraction, or immediately after the removal of the lens, I have found such a partial excision fulfil every purpose.

Mr. Bowman has performed iridectomy in various ways—as by tearing a portion of the iris from its ciliary attachment through a corneal wound. I learn from him that it is his purpose to publish his experience of the different possible methods of operating, and of the circumstances under which one or other of them should be preferred; but, in the meanwhile, the method described above will be found well adapted for all ordinary purposes.

The effects of iridectomy are far more easily described than explained; for which reason I will here content myself with their enumeration.

1. The operation diminishes intra-ocular tension in a degree that bears some proportion to the size of the piece of iris removed.

2. In many cases where there is no evidence of morbid tension, as well as in others in which this condition is very apparent, iridectomy produces a marked and favourable change in the state of the ocular nutrition, so as to promote the resolution of inflammation and the repair of injuries.

By virtue of this twofold action, it produces the following effects:—

In acute glaucoma, if performed sufficiently early, it will almost certainly cure the disease; and, if the blindness be already complete, it will still relieve the pain.

In 1860, I was consulted by a hale man, sixty-five years of age, on account of pain and blindness in his left eye. The attack had commenced three days before I saw him, and his sufferings were very great. The globe was of stony hardness, the conjunctiva much injected, the cornea steamy, the aqueous humour turbid, the pupil somewhat dilated, fixed, and of an oval outline. With the affected eye, the patient could barely discern the position of the window before which he was seated. A large piece of iris was immediately excised, and his recovery was speedy and complete. Ten days after the operation he could read pearl type with the affected eye, and it has ever since remained in an equally good condition.

In chronic glaucoma, either simple, or complicating sclerectasia posterior, iridectomy will usually arrest the disease, and will sometimes arrest other morbid changes, such as cataract. It will seldom, or only slightly, improve vision under such circumstances, but will preserve it from further impairment.

In the month of November I was consulted by a lady, fifty years of age, suffering from simple chronic glaucoma of the left eye. There was steadily increasing presbyopia, contraction of the field of vision, increased tension of the globe, and progressive failure of sight. The media were transparent, and the excavation of the optic disk was well marked. There were also striæ of commencing cataract in the lens. Iridectomy was performed forthwith.

In December of the following year I saw this lady again, in consequence of her right eye being affected in a similar manner. Both from her statement, and by tests, I found the sight of the left eye to be a little better than before the operation; and the cataractous striæ, of which, thirteen months previously, I had made a careful diagram, had undergone no increase.

In irido-choroiditis, iridectomy not only produces speedy resolution, but it removes the tendency to the recurrence of the disease that is produced by the gradual contraction of effused lymph.

If practised sufficiently early after an injury, iridectomy will usually prevent the occurrence of traumatic panophthalmitis, and will arrest it at any stage in which recovery is still possible. It will also arrest the course, and procure the healing, of the rapidly destructive corneal sloughing that often follows contusion of the eye in elderly or feeble persons.

A few months ago, I saw a young man whose eye had been punctured by a thorn about thirty-six hours previously. The thorn had penetrated the cornea, pierced the iris, and wounded the lens, and had been immediately withdrawn. The lens was, of course, opaque, the aqueous humour had escaped, and the anterior chamber was half filled by viscid pus. There was much injection, severe pain, and little or no perception of light. Guided by the corneal puncture, iridectomy was so performed as to remove the wounded portion of the iris. Forty-eight hours later the wound had healed, the pain and inflammation had subsided, the aqueous humour was re-secreted, and the lens was in a fair way to be quietly absorbed.

In the *Medical Times and Gazette* for 1863, vol. i. p. 503, I have reported the history of a man in whom impending destruction of the cornea after injury was at once checked by iridectomy; and the case is curious—because, by an accidental error on the part of the patient, no other treatment of any kind was employed. When the operation was performed, the cornea was the seat of a large sloughing ulcer, was opaque over its whole surface with the exception of a small crescentic portion, and vision was limited to a perception of the situation of the window. Sixteen days later, the patient could read No. 16 of Jäger's test types.

The beneficial effect of iridectomy upon the general nutrition of the globe is further illustrated by certain cases of chronic irido-choroiditis, in which softening, instead of tension, is a result of the disease. After excision of a portion of the iris it is common, in such cases, to see a more active secretion of the humours, and a return towards a normal state of tension. Iridectomy will also promote the absorption of blood effused into the vitreous body; and will, in some cases, arrest the progress of conicity of the cornea. Its influence upon the intra-ocular circulation was conspicuously manifested in the case of ischæmia retinæ recorded by Dr. Alfred Gräfe (*see* page 139); and, partly in consequence of that history, I have lately performed the operation in a case of atrophy of the optic nerves. The result of this experiment will be hereafter declared.

As a preliminary to the extraction of cataract, or as a proceeding to be executed immediately after the removal of the lens, iridectomy has now been very largely employed. It not only promotes healing, and places the eye in a condition generally favourable to recovery, but it removes the special danger of iritis from compression of the iris by the lens during its exit. The piece removed should correspond to the central portion of the corneal flap; and the iridectomy will so far diminish the dangers of extraction that a favourable result may, in almost every case, be confidently anticipated. Extreme age, constitutional debility, or persistent cough, need no longer be considered insurmountable impediments to success.

The effect of the artificial coloboma iridis upon vision is very small. In cases of wound, where it is desirable to remove the injured part, and in cases of cataract extraction by an external or inferior corneal section, it may be necessary to make an iridectomy in such a situation that the resulting deformity, especially if the iris be light-coloured, will be extremely visible. But, in the majority of cases, the coloboma may be placed under the shadow of the upper lid, and will there be scarcely seen. Many of the patients who require iridectomy are elderly people, and most of them, either from age or disease, have retinæ by no means hypersensitive; so that they perceive little dazzling or inconvenience from the enlargement of the pupil. In one case of double senile cataract, I performed extraction on one eye without, and on the other with, an iridectomy. The patient reads pearl type equally well with either, and finds no difference in their utility for general purposes. In a similar case I made a very large inferior iridectomy, and extracted the lens by an inferior corneal flap, in the right eye; and made a superior iridectomy and a superior extraction in the left. In this case, also, the two eyes were equally useful.

It might be supposed, however, that iridectomy would destroy or impair the power of accommodation; and hence that its hurtful influence upon vision, if any, would be chiefly apparent in cases where the lens was retained. I have not seen anything to justify this supposition; for, although the accommodation of an eye that has undergone iridectomy is usually somewhat impaired, there will often be an explanation of the impairment either in the age of the patient, or in the disease for which the operation was performed. In any case in which the deformity, or the dazzling, or the failure of accommodation, was sufficiently evident to require relief, it would not be difficult to obtain it by the use of spectacles, tinted, or partially opaque, and adapted to the optical requirements of the patient.

From graver ill consequences, even by virtue of its antiphlogistic action, iridectomy is almost wholly free. I have preserved notes of fifty-seven eyes upon which, for various reasons, I have performed the operation during the last three years; and with none of them has there been any mischance. In two cases of confirmed glaucoma, in which the sight had long been destroyed, but in which iridectomy was indicated to allay the distressing pain occasioned by extreme tension, the operation afforded complete relief, but set up changes that ultimately produced wasting of the globes. In every other case the operation has been followed by sound and speedy healing, in many cases it arrested disease that seemed almost beyond the reach of treatment, and in only a very few were my expectations of benefit entirely disappointed.

I have entered into this question at considerable length, partly because iridectomy is an operation that has, I think, in some degree, passed out of the domain of the special ophthalmic surgeon into that of the general practitioner;

and partly because it has recently been assailed by a good deal of rather irrational invective.

The diseased conditions that most urgently require iridectomy are acute glaucoma, sloughing ulcer of the cornea from injury, and traumatic suppurative iritis. In such cases, under any other treatment, vision will be almost inevitably lost; and, by timely iridectomy, it will be almost certainly saved. An immediate operation for strangulated hernia can never be more essential to the preservation of life than an immediate iridectomy frequently is to the preservation of eyesight. The time during which it can be usefully performed is often very limited, and the patient whose case requires it has a right to expect relief at the hands of the nearest practitioner. There can be no doubt, I think, of the correctness of the opinion advanced, a year or more ago, by the Editor of the *British Medical Journal*, to the effect that any surgeon who neglected iridectomy, in the presence of certain indications for its performance, would incur great risk of being mulcted in very heavy damages as the defendant in an action for malpraxis. In chronic or sub-acute glaucoma, although the necessity for the operation would in one sense be equally great, it would not be equally urgent; and the patient would usually have time to seek the assistance of a special practitioner.

Among English ophthalmologists there are, almost of necessity, some men of high position and great attainments, endowed with qualities of mind that cause them to be slow in estimating the value of that which is new. There are others who, either more sanguine than the first, or less cautious, or, it may be, gifted with a greater rapidity of discernment, form their conclusions and act upon them, while men of more tardy minds are still occupied in collecting and examining evidence. In the dialect of familiar professional intercourse, the two classes of surgeons are superficially distinguished as the "brilliant" and the "safe;" although the propriety of the latter designation may be very fairly questioned. It would appear that one who fails to appreciate and practise a remedy, the necessity of which time confirms, can hardly be called the more "safe" adviser.

It naturally happened that the new operation was first performed and advocated, in this country, by distinguished members of the "brilliant" school. Their accounts of its effects were met by considerable incredulity—by unwilling trials upon cases of hopeless disease, and even by point-blank denials of the utility of the procedure. In spite of such opposition, iridectomy steadily gained ground in the opinion of every man who practised it skilfully upon carefully-selected cases, or who had opportunities of observing such practice in the hands of others. More or less tardily and reluctantly, often in direct opposition to their earlier preconceptions, and sometimes in direct opposition to their previous writings, but nevertheless in fair and honest deference to manifest truth, the "safe" ophthalmologists who are indebted for eminence to their intellectual capacity, are now, almost to a man, beginning to admit the prodigious importance and value of the operation.

Within the last few months, however, the operators who practise and advocate iridectomy have been assailed by a clamour that has scarcely even parodied the tone of a scientific discussion. A professor eminent in general surgery, but hitherto unknown in connection with ophthalmic practice, and an ophthalmic surgeon whose reputation is supposed to rest upon the manual dexterity associated with great bodily strength, courage, and activity, rather than upon unusual powers of judging and comparing—and in some degree, also, it may be, upon the memory of the convincing argument by which, several years ago, he proved the ophthalmoscope to be an useless and a dangerous instrument—have combined with a number of wholly unknown "Surgeons" and "Constant Readers" in an endeavour to establish the position that iridectomy cannot do any good,—because they themselves neither practise it, nor understand the principle on which its action depends. The general effect of their letters would be to leave the impression, upon many minds, that there is, about iridectomy, a difference of opinion among competent judges. Such an impression would be erroneous. The controversy (if, indeed, it may be called by such a name) has proved the existence of surgeons who are not acquainted with the benefits that result from the operation; but it is an abuse of language to describe the absence of knowledge as an opinion.

It is, of course, quite possible that a failure to obtain the good effects described may be due to a want of the dexterity and knack required for the proper performance of the necessary manipulations. If the knife be carried behind the iris, if the lens be wounded, or if the sudden diminution of tension be followed by choroidal hæmorrhage, the condition of the patient will seldom be improved. Such accidents, although not difficult to produce, are not included within the proper programme of the operation; and their occurrence, in any case, destroys its value as an illustration of the results of iridectomy.*

It would be improper to leave wholly without notice an operation that has been advocated, in slightly varied forms, by Mr. Hancock, of London, and Mr. Vose Solomon, of Birmingham. These gentlemen have employed section of the ciliary muscle as a substitute for iridectomy; and Mr. Solomon, especially, has practised his method for the cure of myopia. My own experience of this "intra-ocular myotomy" is very limited. In a severe case of irido-choroiditis, with increased tension, I made a radial section of the ciliary muscle, on the temporal side, with much temporary benefit. The eye became very nearly well, but underwent speedy relapse. I next made an oblique section on the nasal side, with no other effect than to increase the irritation. The patient then wished to go to London, where she underwent iridectomy at the hands of Mr. Critchett, but I have never heard with what result. Shortly afterwards I met with a case in which "intra-ocular myotomy," performed by a very skilful surgeon, had been followed by extensive detachment of the retina; and, since then, I have wholly abandoned the operation. The cases of myopia, published by Mr. Solomon, have not, as far as I have seen, been described with sufficient precision to convey a clear idea of the state of vision, either before or after the section; and there are

* Iridectomy, like any other surgical procedure, would be liable to suffer in professional estimation if it were performed in cases for which it was not required. Under the impression that such an abuse of the operation might have led to its being undervalued, I asked Mr. Bowman to favour me with his opinion upon this part of the subject; and he has kindly permitted me to publish the following letter, dated Dec. 7th, 1863:—

"You ask me whether I think the operation of iridectomy for glaucoma has been abused. I will answer for myself. I do not remember to have performed it in any case of glaucoma in which, with all the experience of its efficacy I have since acquired, I should not now recommend it, or be ready to perform it again. I can call to mind a very few instances in which it might have been in some particulars more perfectly accomplished; but they were nearly all among the earlier examples. I am very unwilling to express any decided opinion as to the operation in the hands of others. The knowledge of the diagnosis of cases of glaucoma has been a gradual acquisition, and it is possible that some operators may have imperfectly distinguished the conditions of disease to which they applied this remedy; and that some may have been induced by the urgency of symptoms to operate without an exact acquaintance with the method, rather than allow their patients to forego all benefit it might confer. From the first introduction of iridectomy into England in 1857, it has proved the source of the greatest blessings to numerous sufferers; and now that the indications for it, and the mode of performing it, are generally understood, there will very shortly, in my opinion, be no excuse for any one, oculist or general surgeon, who shall neglect either to perform it himself in suitable cases, or to pass on his patients to some one who will. Least of all is there even now an excuse for any oculist professing to have inquired into the subject, and who, at this somewhat mature period of our experience, not merely rejects it himself, and allows his patients to go blind in default of it, but *abuses it*, in a different sense from what you intend, when you ask whether the operation has been abused."

probably few surgeons who would feel themselves justified in performing, on account of uncomplicated myopia, any operation whatever. On the whole, I think it may fairly be said that intra-ocular myotomy is neither so efficacious, nor so free from danger, as it was believed to be by its first advocates.

Depletion.—In the present state of professional feeling with regard to the lancet, there would perhaps be no case of eye disease in which general depletion would be considered necessary. The local abstraction of blood, however, is a remedy of the greatest value, and may be advantageously practised either by means of leeches, or by the artificial leech of Baron Heurteloup.

The application of leeches to the eyelids or temple is attended by the disadvantage that their prolonged suction produces congestion of the neighbouring parts, and of the very organ they are intended to relieve. They are therefore ill suited to cases in which it is wished to unload the ocular vessels at the smallest possible cost of blood.

Dr. Jacobson, of Berlin, employs leeches in a very heroic manner, in the treatment of cases in which inflammatory reaction is threatened after extraction of cataract.* He commences by applying four; and every leech, as it falls, is replaced by a fresh one, until the pain and heat, or other alarming symptoms, are decidedly relieved. He has applied, in this way, from forty to eighty leeches to a single patient.

The instrument of Baron Heurteloup consists of a small cylindrical drill, and a glass exhausting-tube with an air-tight piston. The drill can be set to make its incision to any desired depth, and the piston works with a screw. In applying the instrument, care must be taken to accommodate the screw movement to the rate of bleeding, so as not to make a vacuum above the column of blood. By this precaution, the instrument gives little pain; and, by its use, a few ounces of blood may be rapidly drawn from an incision carried into the temporal muscle.

In whatever mode local depletion be practised, it is necessary for its beneficial employment that all causes of local congestion should be carefully avoided for some time afterwards. For at least 24 hours, the patient should be kept at rest in a darkened chamber, and the eyes cooled, from time to time, by the use of cold compresses, or by the douche. The water pulveriser, made by Mathieu, of Paris, affords a shower of fine spray, that is, in such cases, extremely grateful and beneficial.

The symptoms that justify the abstraction of blood may depend either upon the acuteness and severity of the disease, or upon its prolonged duration.

The more acute inflammations of the eyeball are usually the results of injury, either surgical or accidental, and are only in rare cases idiopathic. However arising, they require active depletion in their earliest stages; and, when traumatic, they should be anticipated rather than followed. The best evidence of the necessity of commencing or repeating the abstraction of blood will be furnished by increased heat of the eye; apparent, at first, as a subjective sensation to the patient, and subsequently recognizable by the touch as a distinct elevation of temperature. In cases of a more chronic character, the surgeon will be guided in depletion by the ophthalmoscope—not only by the actual state of the ocular vessels, but also by the degree in which this state is seen to be influenced by the loss of blood. It will be proper to bear in mind that a good deal of congestion of the eye is often caused by fatigue of the internal or external ocular muscles, due either to excessive exercise of the accommodation in cases of hypermetropia or astigmatism, or to the habitual demand for a degree of convergence of the optic axes that is painful to the internal recti. In such cases, to practise depletion would mostly be to increase the evil.

Internal Medication.—In the selection and use of internal remedies it is necessary to distinguish, with some care, between those that are directed against the local

* "Ein neues und gefahrloses Operations-Verfahren zur Heilung des grauen Staares." Berlin: Peters. 1863.

affection, and those that are directed against the constitutional state of which the local affection is only a single evidence. Beer and his followers, in pressing the doctrine of the remote origin of ocular diseases, were guided by a principle, the truth of which has outlived their somewhat fantastic applications of it. We no longer speak of "abdominal ophthalmia," but we recognize that many of the disorders of the organs of vision arise from constitutional conditions, and are diseases affecting the eye, in the sense in which we speak of diseases affecting the skin. In all chronic morbid states of the internal ocular tunics, and especially in the absence of marked syphilitic taint, or gouty or rheumatic diathesis, it becomes the duty of the surgeon to scrutinize with great care the general condition of the patient, and especially the action of the more important excretory organs. Of these, the skin, the kidneys, or the uterus will very commonly be found at fault, and will always deserve the most sedulous attention. The means of stimulating torpid excreting organs, and of restoring their healthy tone, fall too much within the domain of general medicine to admit of special notice here; and it is sufficient to point out the indication, and to dwell upon the imperative necessity of fulfilling it. Bathing, frictions, general tonics, appropriate exercise and diet, are resources of treatment the employment of which should be familiar to every practitioner. Besides these, the special internal remedies of chief importance in ophthalmic medicine are mercury, opium, and iodide of potassium.

Admitting fully that of the numerous preparations of mercury there are many of nearly equal clinical value, I still think that the surgeon will usually find it advantageous to confine his choice among them within narrow limits, and to practise himself in the frequent observation of the effects of the same agent, rather than to vary his preparation for every patient. For this reason, I am accustomed, in acute cases, to prescribe blue pill almost exclusively; and, in chronic cases, the corrosive sublimate.

In the treatment of acute inflammations within the eye, it is important, above all things, to lose no time. The delicate structures affected may so speedily be injured in properties essential to their usefulness, that any unnecessary delay or postponement of resolution would of itself be a serious evil: hence it is usually desirable to treat the internal ophthalmiæ by the prompt and free use of mercury, up to the point of commencing ptyalism, and then to maintain the influence upon the system by such doses as may be required. I believe it is never necessary, or even proper, to carry mercurial action to such an extent as to inconvenience the patient. The slightest possible swelling of the margin of the gums is a sufficient proof that the drug is influencing the system; and this barely visible effect may be produced and maintained, in most patients, without being suffered to increase. If the doses of blue pill be combined with opium, and guarded by chlorate of potash, they may be given at short intervals—say two grains every four hours, even to a delicate person. After the first day or two, it is usually more prudent to lengthen the intervals, even although no constitutional effect of the medicine be perceptible.

In acute intra-ocular inflammation, in which mercury has checked the morbid process, its action should usually be maintained until recovery is complete, or as complete as the circumstances of the case will allow. The propriety of continuing its use should be determined, not only by the amount of vision and the state of the anterior parts of the eye, but by the transparency of the vitreous body and by the general condition of the posterior ocular membranes.

The corrosive sublimate possesses great advantages in many chronic diseases, not only because it will produce all the good effects of mercury, as against either simple inflammation or syphilitic taint, with very little risk of ptyalism; but also because it admits of being combined with tonics and sedatives. In doses of from the sixteenth to the twenty-fourth of a grain, combined with sulphate of quina, tincture of sesquichloride of iron, and a little hydrochlorate of morphia, it may often be administered thrice daily, for months together, with great benefit. I am accustomed very slightly to acidulate the mixture with hydrochloric acid, and to recommend that the tincture of steel employed should at the least be three years old. It undergoes certain changes by keeping—which, without detracting from its efficacy as a ferruginous tonic, render it much more grateful to the stomach. The obvious precaution of administering the dose immediately after food is one that need scarcely be mentioned. Where the corrosive sublimate will alone fulfil the requirements of the case, there are few better vehicles for it than the compound tincture of bark, with a very small quantity of tincture of opium, to correct the griping pain sometimes caused by the salt itself. The Liquor Belæ, so highly recommended as a vehicle by Mr. White Cooper, does not, I think, at all surpass the tinctures of bark and opium in utility.

The corrosive sublimate is chiefly useful in diseases of syphilitic origin, and generally in the chronic inflammations of cachectic or weakly persons.

The preparations of opium, of which I can only speak as invaluable adjuvants, are relied upon by many practitioners as their principal remedies in the treatment of ocular inflammations. Mr. J. Zachariah Laurence was the first to advocate, in this country, the "morphia treatment" of iritis, an inflammation that is now known to be most frequently associated with like mischief in the choroid. In the case of a patient possessing an idiosyncrasy hostile to mercury, I should not hesitate to place my chief reliance upon some of the preparations of opium; but it may fairly be questioned how far such reliance is justifiable in ordinary cases. The effect of mercury in subduing intra-ocular inflammations is so clear, and the duty of using the most rapid and certain means to this end so binding, that there may well be a very intelligible reluctance to abandon a tried and trusty servant, however favourable the antecedents of the proposed successor. The cases reported by Mr. Laurence (*Ed. Journ.* Dec. 1862) certainly seem to establish the position for which he contends; but, at the same time, our earlier knowledge of the effects of mercury will probably render surgeons indisposed to abandon it, even in favour of a remedy perhaps equally useful, but not yet sanctioned by the accumulated experience of many generations.

In using this language, and in expressing a very decided opinion about the present state of what may be considered a pending controversy, I do not for a moment lose sight of the views of those surgeons who denounce mercury. I am quite ready to admit that further evidence may hereafter justify practitioners in abandoning its use, in favour of opium or of some other medicine; and I do not forget that there are cases on record, well authenticated, in which a second eye has been attacked by inflammation while the patient was under the influence of salivation produced for the cure of the first. I cannot here enter into a discussion about the mode of action of the mercurial treatment, or debate whether it produces actual resolution of inflammation, or only the absorption of the scarcely organized inflammatory products. If even the latter view be adopted, it must be remembered that the presence of such products has a powerful influence in maintaining inflammatory action, and their removal, in subduing it. But to sum up the matter in few words, and to express exactly what is on my mind, I would say, that I think there is a certain degree of art in the management of a mercurial course, so as to obtain its full benefits, and to exclude its possible dangers; and I think the cachexia induced by the excessive administration of this powerful agent, and the various diseases to which that cachexia entails an increased liability, afford no sound argument against the proper employment of a valuable means of treatment. There are many morbid conditions in which we habitually prescribe low diet, and find our account in doing so, although daily experience teaches us that the liability to such conditions is increased, and their actual severity is augmented, in persons who have, for any lengthened period, attempted to maintain life upon an insufficiency of food.

In painful diseases of the eye, of whatever nature, the use of opium as an adjuvant should seldom be omitted. It must not be forgotten that exalted tension is a frequent source of pain; and that, when this is present, the cause should be removed by iridectomy, instead of the effect being masked by anodynes. But, wherever the source of pain cannot be reached, the pain itself should be subdued; and the opiates required for this purpose should be measured by their effects, rather than by their quantity. Local pain is, as a rule, hurtful to the nutrition of the suffering part, and while it is urgent, no process of repair can be actively carried on. To give opiates in quantities insufficient to afford relief, even although the doses may be absolutely large, is merely to add the injurious effects of a drug to those of the pre-existing malady; and it is only by pushing the remedy until ease is obtained, that any advantage can be anticipated. For this purpose, the preparation selected should be given liberally at first; and a smaller dose be repeated, at short regular intervals, say hour by hour, until pain is effectually controlled.

With regard to the forms of administering opium, the drug itself will be found the most generally useful. The preparations of morphia, or the various officinal and non-officinal solutions, may have their special advantages in certain cases; but the pill of solid opium will usually fulfil all the indications. For local application, as a fomentation to the closed lids, a strong warm watery solution of opium is to be preferred to all other preparations. The hypodermic injection of a solution of morphia is, however, a highly valuable means of giving the first dose, and of producing its effects with a rapidity not otherwise attainable. The solution used for this purpose may contain one-third of a grain in ten minims of distilled water; and the loose skin of the temple should be the place selected for the puncture.

The iodide of potassium has a wide range of usefulness in ophthalmic medicine. In most cases of inflammation, either acute or chronic, it may be given together with mercury—or alternately with it, or may even be substituted for it; and it may be combined with carbonate of ammonia, or with syrup of iodide of iron, or with ammonio-citrate of iron. In the very numerous cases that are immediately or remotely dependent upon syphilis, it is, of course, one of the chief resources of treatment; and its well-known property of controlling nocturnal headache extends, in some degree, to the nocturnal exacerbations of pain so common in diseases of the eye. For adults, the most useful doses range from three to ten grains given three times a day; and the irritant action of the drug upon the stomach may be prevented, in nearly every case, by the use of a sufficient quantity of barley-water, say from four to eight ounces, as a vehicle. The larger doses will be most useful in syphilitic patients, and the smaller in cases of simple inflammation.

In the eye, as in other organs, it is often necessary temporarily to excite the reparative powers of the system, not only by the employment of nutritious diet and alcoholic stimulants, but also by the use of suitable medicines. For this purpose, the carbonate of ammonia, given with decoction and tincture of bark, will very frequently be found efficacious.

Counter irritation, in diseases of the eye, must be used and controlled on the same principles as in medicine generally, and will be found useful in the waning stage of acute, and throughout the whole course of chronic inflammatory disorders. It may be effected most conveniently by the frequently repeated application of blistering liquid, or blistering tissue, at the back of the ear, or to the temporal region. It will seldom be found desirable to produce a very severe effect by a single application, or to repeat the blistering more frequently than at intervals of four or five days. Too active a vesicant may produce œdema of the eyelids and conjunctiva, as well as irritation of the deeper parts of the globe; and the good influence of blisters upon the eye, as well as elsewhere, is usually most manifest at, and shortly after, the period of their healing. The action of blistering tissue is easily regulated, by varying the time during which it is in contact with the skin, and this agent is therefore more manageable than most other vesicants.

In chronic or recurrent superficial disease, affecting the conjunctiva or the epithelial layer of the cornea, Mr. Critchett employs, with very great advantage, small setons in the hairy scalp, just above and in front of the ears. They are inserted by lifting up the scalp, so as to remove it from the temporal vessels, and by passing a large suture needle, carrying a piece of thick silk, through the resulting fold. The needle is then cut off, and the double thread knotted together by its ends. The seton track may be an inch or more in length, and should be completely concealed by the hair. Unless passed deeply, these threads are liable to ulcerate out, especially in strumous subjects; but their employment is, nevertheless, most advantageous in a great variety of cases.

The Local Applications required for diseases of the internal eye will not include the various agents known to all practitioners as valuable means of treating disorders of the conjunctiva or of the corneal epithelium. They will include cold, warmth, various anodynes, and the compress or *Druckverband*.

The application of cold admits of being graduated with great exactness; and may be effected in the gentlest manner by the fine spray of Mathieu's water pulveriser. The ordinary douche, first with a rose, then with a jet, and supplied with water of any required temperature, affords the means of more energetic refrigeration; and the sedulous application of iced poultices, or small waterproof bags of freezing mixture, changed every few minutes, will meet the requirements of the most acute and dangerous cases. Sustained cold may also be applied by allowing water, iced if necessary, to drop continually upon a piece of lint or linen laid upon the closed lids. A vessel of water placed above the patient, and furnished with a skein of loose thread to act as a siphon, forms a suitable apparatus; and the water that drains away from the linen should be caught in a gutter of oiled silk, and conducted to some convenient receptacle. Before arranging such a contrivance, the surgeon will do well to remember that the measure is a severe one, and that its self-acting character will cause it to be neglected by nurses, or people in attendance. It is therefore very likely either to become deranged in its working without detection, or else to be allowed to produce a greater effect than is desired. The iced poultice, changed every few minutes, and requiring constant care, is less perfect in theory, but is in many respects better adapted to human frailty.

The water pulveriser, or the douche with a rose, will be found useful after depletion in chronic cases. The douche with a jet is a highly beneficial application in most chronic ailments of the eye, and should be allowed to play upon the closed lids for ten minutes or so, twice daily. Sustained cold is only required in the most acute inflammations. It should usually follow depletion; and should be regulated, in great measure, by the sensations of the patient.

The form of douche employed is a matter of little importance; but the reception of the water in a small glass, applied to the margin of the orbit, is a practice to be condemned, because it interferes with the refrigerating effect that is the chief benefit of the application. A continuous stream is preferable to an interrupted one; and therefore a siphon is better than a syringe. A very good form is made by attaching a piece of metallic gas pipe, of the size and shape of a common horse-shoe magnet, to one end of a piece of india-rubber tubing four feet in length, and carrying a rose or jet at the other end. The metal tube will hang over the edge of a jug of water placed on a high shelf; and, the stream being once set going by suction, will continue until the water falls beneath the level of the short arm of the siphon. If a more elaborate apparatus be required, it is easy to make an ornamental table fountain, with a compressed air chamber, and to arrange that it shall play for ten minutes without requiring adjustment.

External warmth, by poultices, simple or medicated, spongio piline, bags of boiled camomile flowers, and so forth, is very soothing and useful in a great number of superficial ocular diseases. It is of less value in the more deep-seated affections—but cases will now and then occur in which it is indicated. As Sir Henry Holland has pointed out, temperature is a matter about which the sensations of the patient are usually safe guides; and we shall meet with persons, every now and then, to whom cold is painful, and warmth, with moisture, soothing. There can be no doubt that our practice should be modified accordingly.

Among locally-applied anodynes, atropine stands almost alone, by reason of its paralysing action upon the ciliary muscle and sphincter pupillæ. The agents that resemble it in this respect, such as daturin, have not been sufficiently tested in practice to furnish us with certain proofs of their value, and their action is supposed to be wanting in permanence. Thanks to the labours of Mr. Hilton, the utility of rest, as a therapeutic agent, has become an axiomatic expression; and atropine secures rest to the internal eye. There is, therefore, scarcely any form of internal ophthalmia in which it should not be used, and in which its use will not secure one of the most important conditions of recovery. A solution, containing four grains of atropine to an ounce of distilled water, is a convenient form; and a large drop of this should be placed between the lids every four hours, until the pupil is fully dilated, and afterwards with sufficient frequency to maintain the dilatation. If the atropine should irritate the conjunctiva, Mr. Bowman advises that it should be omitted; or else that its irritant effect should be counteracted by nitrate of silver (1gr. ℥j). The elaborate argument once published by Mr. Dixon, against the use of atropine in iritis, would hardly, in the present state of knowledge, be reproduced by its author; and therefore does not require any special refutation.

The application of other anodynes, in fomentations or medicated poultices, or in ointments, has only a limited utility, and falls within the range of general medicine. It would be improper to leave unnoticed the Calabar bean, which is found useful in wounds of the cornea attended by prolapse of the iris. Its power of contracting the pupil serves to reduce the prolapse, and to prevent its recurrence. For this purpose, the best application is the solution of the extract in glycerine, placed upon the palpebral conjunctiva. It was at one time hoped that the Calabar bean would be useful in removing the effects of atropine, after ophthalmoscopic examination. The atropine is, however, so much the more powerful of the two opposed agents, that this hope has hitherto scarcely been realized. When the active principle of the bean can be obtained in sufficient quantity, a different result may reasonably be expected.

The compress (*Arlt's compress*, or the Druckverband), is composed of a small piece of fine soft linen, some charpie or cotton wool, and a bandage an inch and a half wide and four or five feet long. The middle third of this bandage should be made of knitted cotton, and the ends of highly elastic flannel. The closed lids being first smoothly covered by the piece of linen, the surgeon lightly fixes the nasal extremity of the upper lid with the tip of a finger, and with the tip of the next finger draws the skin of the temporal extremity of the lid against the margin of the orbit, in such a manner that the lid itself is gently tightened over the surface of the globe. Charpie is then carefully packed in, so as first to fill the depression immediately within the margin of the orbit, and then to cover uniformly the whole surface of the lids, until no central elevation can be felt by the surgeon. The end of the bandage is applied to the temple of the affected (say the right) side, and secured by a single turn at the same level. From the right temple it then passes over the left ear to the occiput; and from the occiput the knitted cotton centre passes over the padding, with firm gentle pressure, to the left temple, from which the flannel continuation makes a second turn, like the first one, round the head at the temporal level, and is secured by a pin over the right temple, at the point of commencement. The perfect adaptation of the charpie to the orbit must be maintained by the hand, until the bandage replaces it; and before fixing the pin, the surgeon must satisfy himself that the degree of pressure is adapted to the requirements of the case.*

The compress, thus applied, fulfils a great variety of purposes. By restraining the movements of the intraorbital muscles, it secures absolute physical rest to the eye and eyelids; and, by its opacity, it affords rest to the iris and retina from the stimulus of light. It affords all the benefits of firm and equable support or pressure, so valuable in many inflammatory or congestive states. It maintains uniformity of tem-

* The above instructions for applying the compress are taken from a paper by von Gräfe, in the Arch. f. Ophth. Band IX. Abth. 2, S. 111, and afford a good illustration of that carefulness about matters of detail which so greatly promotes the success of treatment.

perature against all external conditions, and it absorbs discharges with great rapidity. It has the disadvantage of being somewhat heating, and of placing a difficulty in the way of inspection of the eye.

From the above description it follows that the compress should be applied after almost all eye operations—especially after cataract extraction and iridectomy, and the removal of staphylomatous corneæ—in all cases, in short, in which there is danger of intra-ocular hæmorrhage. It is also indicated in cases in which such hæmorrhage has occurred spontaneously; in ulcerations, wounds, and abrasions of the cornea; and, as a protection to the eye, in corneal anæsthæsia, and in paralysis of the orbicularis. It is contra-indicated in all disorders attended by elevation of temperature, and wherever other kinds of local treatment are required. For further information on the subject I must refer the reader to the essay by von Gräfe, already mentioned in a foot-note.

The foregoing general remarks have been intended to supersede the necessity of any detailed account of the methods of treating many of the morbid conditions described in the Fourth Section. The surgeon will find it desirable to bear in mind the observations, already cited, of Dr. Liebreich, upon the more idiopathic and acute character of the disorders of the choroid, as contrasted with the constitutional character, and comparatively chronic course, of the diseases affecting the retina. The former will manifestly demand a more active and local, the latter a more persistent and general plan of treatment; modified, of course, in either case, by the special symptoms, condition, and requirements, of the individual sufferer. Indeed, it may even be worth while to remark that philosophical medicine, which aims at curing the patient, differs from empirical medicine, which aims at curing the disease, more widely perhaps, in ophthalmic practice, than in any other department of the healing art. The display of physical changes effected by the ophthalmoscope, and the attention given, of late years, to the evil consequences of intra-ocular pressure, have some tendency to lead the student to the belief that, in the eye, he can see and feel the whole of the forces against which he is required to strive. It is impossible to learn too soon, or to remember too continuously, that intra-ocular physical changes are something more than mere deviations from the physiological status of a single organ. They form, in every case, a pathological superstructure, resting upon some special foundation of diathesis, of temperament, or of acquired dyscrasia; and, although this may be true in a greater degree of the retina than of the choroid, or of one patient than of another, it is true in some degree of each and all; and is never more conspicuously manifested than in the different results that, in two apparently healthy persons, may follow from the infliction of similar wounds or injuries upon both. In order, therefore, to treat ophthalmic diseases with success, it is necessary to look for something more than even the most exact physical diagnosis, and to study the subjective and the constitutional symptoms with as much care and accuracy as the objective. Thus much being premised, I may pass on to a brief notice of some of the morbid changes described, a few of which appear to demand the mention of special therapeutic indications.

Excavation of the Papilla, when acquired, must always be regarded as a mechanical result of increased intra-ocular tension, and as a reason for the performance of iridectomy. Upon this subject, and upon the signs and effects of morbid tension, sufficient has already been said elsewhere.

Atrophy of the Optic Nerve is a condition against which all the resources of treatment have been exhausted in vain. The perusal of Dr. Alfred Gräfe's case of ischæmia retinæ (page 139) has determined me to perform iridectomy in any case of apparently idiopathic atrophy that I may see at a sufficiently early stage. At present, I have tried the operation in a single case only, in which the disease was already far advanced. For a short time the patient declared that his sight was improved, but I could never satisfy myself that it was so; and the improvement, if it ever took place, has certainly not been maintained. Among the methods of treatment that have utterly failed, the most important have been depletion and the use of mercury on the one hand, and of nervine stimulants and tonics on the other. Electricity, quinine, phosphorus, strychnine, and a host of other agents, have all been equally barren of results; and the obscurity that overhangs the nature of the disease, the uncertainty whether the nervous fibrillæ, the vessels, or the connecting tissue, be the structure primarily affected, must necessarily tend to interfere with the persevering employment of any remedy whatever. In cases apparently due to excessive smoking, there seems to be no doubt that the abandonment of tobacco has been highly useful; and I have lately heard from Mr. Wordsworth of a case in which the disease was arrested by the reduction of the daily dose of tobacco from forty cigarettes to six. In the present state of knowledge, therefore, the only indications are purely general, and require the abandonment of any vicious habits or debilitating practices, in which the patient may be found to indulge.*

In the cases of Hyperæmia of the Retina that are apparently due to mechanical pressure behind the eye-ball, the surgeon will often find it impossible to interfere with

* Some months ago, when the influence of tobacco in producing atrophy of the optic nerves was much discussed, it occurred to me that the experience of the Egyptians and Turks, who are perhaps the greatest smokers in the world, would be of some value as evidence in the case. In 1855-6, I was myself for many months resident in various parts of Asiatic Turkey, and had opportunities of becoming acquainted with the prevalent diseases of the country, among which, as far as I saw, amaurosis could not be numbered. In order to obtain more exact information, I applied to Mr. Farquhar, who was for many years surgeon to the British Consulate at Alexandria, and to Dr. Dickson, the physician to Her Majesty's Embassy at Constantinople. I requested these gentlemen, if they could give me no trustworthy evidence about tobacco, to state their opinions about the prevalence of amaurosis; because I considered that the frequent occurrence of tobacco disease, if not recognised as such, would at all events make itself felt by increasing the number of amaurotic persons. The letters written by Mr. Farquhar and Dr. Dickson reached me too late to be incorporated with the note on page 131; but they seem to me to be too important to be omitted. I need only say further, concerning them, that the tobacco to which they refer is not so strong as even the mild varieties used in this country.

Mr. Farquhar writes:—

"In answer to your inquiry respecting amaurosis, I can only say that, during the whole of my residence in Egypt, and among the many thousand diseased eyes that I examined, it was always a mystery to me that I saw so very few cases of this affection. The Egyptians, if it be possible, smoke even more than the Turks."

Dr. Dickson writes:—

"Amaurosis, taking the term in its widest sense, is not a common complaint in Constantinople, or in Turkey generally; and yet smoking tobacco is so prevalent a vice, that it is practised by the whole population, Mohammedans, Christians, and Jews, with hardly a single exception. The usual amount of tobacco consumed by one person, per month, may be estimated at an oke, equal to 1,283 grammes; or about 2⅘ lb. avoirdupois.

"In addition to my own testimony on this head, I add that of Dr. Millingen, one of the oldest and most celebrated physicians here, who declared to me that amaurosis was a rare affection in Constantinople.

"Dr. Hübsch, our principal oculist, in reply to my inquiries on this subject, says:—'Si l'on désire savoir, sous la dénomination générale d'amaurose, s'il y a beaucoup d'aveugles à Constantinople, en exceptant les *Cataractes*, je suis à même de répondre que Constantinople, comparé aux autres centres de populations, présente un chiffre d'aveugles de beaucoup inférieur à celui des autres capitales; ici les affections oculaires sont plus rares, et n'offrent aucun caractère particulier digne d'être noté.

"'Il y a des amauroses dépendantes de vice syphilitique, en nombre assez considérable; il y a quelques amauroses cérébrales dépendantes de lésions des centres nerveux; les maladies advantage, unless circumstances should permit the removal of some exostosis, or other growth, from within the orbit, or should demand the removal of the globe. It occasionally happens, however, that inflammation and suppuration of some of the soft parts within the orbit may be causes of mechanical ocular congestion, and may admit of relief by deep incisions into the orbit, above, or to the sides of the eye itself; and that by such procedures vision may be saved. The cases are extremely rare; but the fact of their occasional occurrence should not, on that account, be forgotten.

Separation of the Retina, when first recognized by the aid of the ophthalmoscope, was regarded as an incurable affection. Latterly, however, it has more than once been successfully treated. Dr. Liebreich has succeeded in the cure of two recent cases by the use of evacuant remedies, and by maintaining, by the aid of some mechanical contrivance, complete immobility of the head of the patient. The effused fluid has been absorbed, the detached membrane has been restored to its proper place, and vision has returned. Guided by the occasional occurrence of a spontaneous

du cerveau et de la moelle ayant dans ces derniers temps pris un developpement en rapport avec l'activité fébrile de notre siècle, et l'agitation permanente des esprits; il y a quelques cas très rares d'amaurose albuminurique. J'ai observé des amauroses chez les femmes grosses, disparaissant avec la délivrance (trois cas).

"'J'observe actuellement cette forme d'amaurose dépendante d'une rétino-choroïdite postérieure; elle est très fréquente surtout chez les personnes qui s'occupent de travaux fins qui fatiguent la vue.

"'Quant à l'action du tabac sur les yeux, elle est très problématique; ici tout le monde fume du soir jusqu'au matin, et du matin jusqu'au soir; les hommes fument beaucoup, les femmes un peu moins que les hommes; et les enfants fument dès l'age de sept à huit ans. Je n'ai jamais pu attribuer l'amaurose à l'abus du tabac; le nombre des fumeurs est immense, le nombre des amauroses est limité. La fumée détermine souvent, chez les personnes qui ont la peau et la conjonctive très délicates, des irritations chroniques, des congestions locales, ou des blépharites ciliares avec perte des cils, larmoiment continu, et rougeur plus ou moins intense. Voilà pour l'action du tabac.'

"On the other hand, I may add that during a ten years' extensive practice at Tripoli, in North Africa, I found that amaurosis (I speak generally, for I had no ophthalmoscope then—1847-57) was a very common affection there; and yet the natives, particularly the Bedouin Arabs, never smoke.

"Hence I infer that smoking tobacco has no influence whatever on the development of amaurosis. What I believed to be the proximate causes of this infirmity were, Egyptian ophthalmia, in consequence of the violent congestion it excites in the eye; strong glare of light, such as you meet with on the naked desert, or issuing out of a forge, or glass furnace, and straining the sight upon microscopic objects, as exemplified by watchmakers, &c. The climate and locality of Constantinople must be very congenial to the eye; for the inhabitants are noted for the fine development, expression, and beauty of this organ.

"I may mention an example of amaurosis, arising from violent mental emotion, which came under my care in 1844.

"When the Turkish Expedition, under the command of Koord Ahmed Pasha, were taking possession of the Jabel, a mountain district to the S. W. of Tripoli, Hadj-Goónus, one of the Pasha's agents, was ordered to exact tribute from a certain tribe of Maraboots, whose sole occupation consisted in affording gratuitous hospitality to the wayfarer, and charity to the poor; and who, on this score, had ever before been exempted from taxation. The Sheïk of these good people refused to acknowledge the tax; and pleaded that, their revenues being solely disbursed for the benefit of the needy, the property was held sacred, and could not be taxed. Hadj-Goónus persisted in his demand, got very angry, and even threatened to use violence on the Sheïk, if he refused any longer to pay. Upon which the venerable old man rose from his seat, outstretched his arm towards Hadj-Goónus, and, while retiring from his rent in the detached portion, through which the sub-retinal effusion has passed into the vitreous body, so as to allow the subsidence of the retina, von Gräfe has in a few cases punctured the prominence by a cutting needle, introduced into the eye-ball behind the crystalline lens, and guided by the judgment of the operator, after careful study of the exact seat and extent of the detachment. Mr. Bowman also, since 1862, has not unfrequently used one or two needles for puncturing or tearing open the separated retina; and his experience is, on the whole, favourable. (*See Ophthalmic Hospital Reports, May,* 1864.) These procedures cannot yet, however, be considered as among the ordinary resources of treatment; and can only be safely undertaken by a practised operator, whose fingers and whose muscular sense are thoroughly habituated to the degree of resistance offered by the different ocular textures. It is not necessary, therefore, to give in this place any specific directions about the method of performing such operations.

Tumours in the interior of the Eye may either be cystic, tubercular, or malignant. I have found the first, between the choroid and the detached retina, in a disorganized eye-ball, that I removed because it was a source of pain; and the two last kinds are sufficiently common. I am not aware of any characters by which, in an early stage of development, and in the living eye, they can be distinguished apart with certainty; and, in the absence of such characters, it is clearly the duty of the surgeon to enucleate the affected organ without unnecessary delay, in order to prevent, if possible, the threatened infection of the system by a malignant tumour. For the purposes of sight, the eye would in any case be lost; so that, if the microscope showed the morbid growth to be tubercular, no harm would be done; whereas, if it were found to be malignant, the patient would have some prospect of being rescued from a miserable death.

At the Kent County Ophthalmic Hospital, in January, 1863, I removed the eye of a young child, acting on the principle laid down above, on account of a new formation that was supposed, both by myself and others, to be tubercular. Microscopic examination, however, fully established its malignant character. It had commenced at the lower portion of the retina, and had not reached the optic nerve. The patient made a good recovery; and, up to this time (March, 1864), has had no return of the disease. The case is reported at length in the *Medical Times and Gazette* for December 5th, 1863.

Removal of the eye-ball may be effected, within its fibrous capsule (commonly called the capsule of Bonnet, but really first described by Dr. O'Ferrall, of Dublin), with very little disturbance of the other intra-orbital textures. A spring speculum being placed between the lids, and the conjunctiva being snipped all round, near the cornea, with scissors, the muscles should be taken up, one by one, on a strabismus hook, and divided close to their ocular attachments. A slight, gentle pressure, between the sides of two contiguous fingers, will make the globe start forwards; and, the optic nerve being then cut through, the eye will fall into the hand of the surgeon. A pair of sharp-pointed scissors, not too large, and curved on the flat, a pair of toothed forceps, a spring speculum, and a strabismus hook, are the instruments required.

The operation is usually attended and followed by very slight hæmorrhage, but some of the blood effused is apt to make its way into the lax cellular tissue about

presence, spoke these words:—'Since you insist in carrying out your evil design upon the funds of the poor, may the Almighty curse you with blindness.' These words were hardly uttered when I observed (for I was present) Hadj-Goónus suddenly place his hand upon his head, and moan aloud from the intense pain he felt there. This was not all—for he had become totally blind!

"I did what I could to relieve his sufferings, but to no purpose. He quitted the camp, and I heard that he died a short time afterwards, at his own home, suffering greatly all the while."

the orbit, where it produces great discolouration of the eyelids and cheek, so that the patient is disfigured for many days. To obviate this occurrence as much as possible, it is desirable to stop the bleeding by pouring a small stream of cold water upon the exposed surface (receiving the water as it flows away in a basin or large sponge). The speculum may also be left between the lids for half-an-hour, to facilitate the escape of blood outwardly; and the conjunctival wound may be left unclosed. Some surgeons unite the edges by a suture or sutures; but their use does not appear to be attended by any advantage. I once had occasion to remove, at the same time, both eyes of the same patient, and I used sutures on one side and not on the other. There was no difference either in the period of healing or in the condition of the stumps.

In one instance, in which sutures were used, the operation was followed by very rapid and considerable distension of the eyelids and conjunctiva, apparently from venous hæmorrhage among the textures within the orbit. Cold was applied, the effused blood was speedily absorbed, and the wound healed as well as usual.

Enucleation of the eyeball is said not to be wholly free from danger. Cases are recorded (two of them by von Gräfe) in which the operation was followed by inflammation of the orbital textures, that extended to the brain, and terminated fatally. I have never heard of such an instance under circumstances that permitted me to investigate its history; and I have performed the operation more than one hundred times, without ever seeing an alarming symptom produced by it.

The fibrous capsule of the eye, after being perforated by the tendons of the recti muscles, passes forwards nearly to the margin of the cornea, and is then reflected upon the conjunctiva. This anterior portión is commonly known as the capsule of Tenon. It would be theoretically possible to prevent the effusion of blood into the cellular tissue, by dividing the conjunctiva in front of the reflection of Tenon's capsule, and by pushing back the capsule to get at the muscles. I much doubt, however, if this could be accomplished in practice.

After enucleation of the eyeball, a stump is formed by the muscles, covered by the conjunctiva. This stump will bear an artificial eye, but will only impart to it very limited movements; and is therefore inferior, for this purpose, to the stump left in cases of abscission of the front portion of the globe.

In cases of intra-ocular tumours that showed signs of having already extended themselves beyond the limits of the globe, the surgeon would, of course, expect little benefit from any operation; but, in cases of growths advancing from the deeper parts of the orbit, the removal of the eye may afford much relief to the patient. The pain occasioned by the eye being pushed forwards is often agonizing; and, when blindness is once produced, this pain may with great propriety be removed by the removal of the suffering organ.

The operation is also indicated in all cases in which a blind eye, whether blinded by disease or injury, but more especially in the latter case, becomes a source of continuing pain or irritation. Removal affords the only security against sympathetic inflammation of the other eye; and such inflammation, if it should occur, is usually very intractable and injurious.

The presence of Cysticercus Cellulosæ, or of a Foreign Body, either behind the retina or in the vitreous chamber, is a condition that seems naturally to call for some effort to remove the intruder; and that seems to justify any attempt, in this direction, that the circumstances of the case may suggest. The well-known instance in which Mr. Dixon removed a fragment of metal is, perhaps, the most successful of this kind on record. Von Gräfe has operated several times, for the removal of cysticerci, metallic fragments, and depressed lenses, and has used sometimes a corneal incision, sometimes an incision through the sclerotic, parallel with the periphery of the cornea, somewhat in front of the equator, and so planned as to divide partially two contiguous recti muscles without completely dividing either of them. The results of these operations have not been very brilliant; and such procedures could only be attempted with propriety by an ophthalmic surgeon of great experience. Dr. Liebreich has extracted a cysticercus, by means of canula forceps, through a scleral incision, aided by an ophthalmoscope fixed to his head, so that he was able to illuminate, and observe, both the parasite and the instrument. He mentions that the base of the neck of the parasite, which is less transparent than the rest of its structure, and is dotted with fine white calcareous particles, is the part that is most resistent, and that affords the most secure hold to the forceps.

Sclerectasia Posterior is a disease that may be chosen to illustrate the general management required by chronic ocular inflammation. Its treatment has been very well described by Mr. Soelberg Wells, in his treatise on "Long, Short, and Weak Sight;" and the description may be summed up as embracing rest, protection from strong light, and from the red and yellow rays of the spectrum, by means of blue spectacles, depletion, derivatives, improvement of the general health, the use of the eye douche, general tonics, corrosive sublimate, and iodide of potassium. To this I may add, that the action of the internal recti seems to increase the protrusion of sclerectasia; and that it is therefore often desirable to provide the patients with weak prismatic spectacles, the bases of the prisms being turned towards the nose. Such glasses render pencils of light less divergent, and hence diminish the convergence of the eyes that would otherwise be required in order to direct both optic axes upon a near object.

Opacities of the Vitreous Body, when recent and diffuse, are usually inflammatory, and may require mercurial treatment; membranous opacities are usually the results of former inflammation; and flocculent opacities, when not the remains of blood clots, are mostly dependent upon impaired nutrition.

Ann L., aged 24, domestic servant, consulted me on the 26th of October, 1863. She was a well-formed young woman, somewhat anæmic, with light hair and blue irides; and she stated that she had become suddenly blind of her right eye on the day before. The same eye had been "bad" two years previously; and she had been two months under medical treatment, but the sight had never been entirely restored.

To external appearance, both eyes were perfectly healthy. The vision of the left eye was perfect, but that of the right eye was limited to qualitative perception of light.

Ophthalmoscopic examination showed that the vitreous body of the right eye was universally turbid. It presented the appearance of a white fog, through which no trace of the papilla or the retinal vessels was discernible.

The patient was ordered to rest the eyes, and to take gr. j of blue pill, with gr. $\frac{1}{4}$ of opium, every night and morning; and gr. iv. of ammonio-citrate of iron, with gr. v. of iodide of potassium, and gr. ijss. of chlorate of potash, three times a day, after meals, in half a tumbler of barley water.

Four days later, she reported slight improvement; with some trouble, she could decipher No. 200 of Snellen's test types. Four days later still, her gums showed a mercurial line, and she could read No. 50 with facility. The vitreous humour had cleared sufficiently to allow details of the fundus to be obscurely seen; and it became manifest that the outline of the papilla was irregular. The mercurial pill was ordered to be taken at night only, and the mixture to be continued.

By the end of the following week, the vitreous humour was perfectly clear, and the patient could read No. 2. No further improvement was obtained; and the irregular appearance of the papilla was found to be due to a patch of choroidal atrophy, probably the result of the disease two years before. The patient said that her sight was quite as good as before the last attack.

Membranous opacities, left behind by inflammation, are not only in themselves impediments to vision, but they involve danger of producing, by their contraction, separation of the retina.

Von Gräfe records a case of extensive membranous opacity, in which the patient, a girl of 19, could only count fingers at 18″ distance; and, with a 6″ lens, could read, with difficulty, No. 20 of Jäger's test types at 2″. Von Gräfe introduced a cataract needle on the outer side of the globe, just in front of the equator, and cut the membrane in several directions. Immediate improvement followed, the membrane retracted and became absorbed, and, ten months after the operation, vision was nearly perfect.

The treatment of Ametropia, which resolves itself into the proper selection and use of spectacles, has already been partially described by English writers. Some papers by Mr. J. Z. Laurence, in the *Medical Times and Gazette* for 1862, and the work, already mentioned, of Mr. Soelberg Wells, will be found to contain much information; and a translation of the work of Professor Donders "On disorders of the refraction and accommodation of the eye," is about to appear among the publications of the New Sydenham Society.

Astigmatism, like ametropia, requires suitable spectacles for its correction; spectacles with lenses that are cylindrical instead of spherical, and that restore the equilibrium between the differing meridians. The principle is very simple; but the details of its application are somewhat complicated. Partly because astigmatism is not very common, and partly because a considerable apparatus and some experience are required in order to estimate its degrees correctly, general practitioners will usually prefer to send such cases to an ophthalmic surgeon. For this reason, I have not thought it requisite to occupy space by details little likely to be useful, and that may be found, by those who need them, in the special treatise of Professor Donders, of which a French translation, by Dr. Dor, of Vevay, has been published by Messrs. Baillière.

ERRATA.

Page	1,	line	1,	for	*marks*	read	*makes.*
„	1,	„	9,	„	*Heinrich*	„	*Herrmann.*
„	53,	„	20,	„	*focus*	„	*focal length.*
„	67,	„	2,	„	*refracted*	„	*reflected.*

In page 128, in the last paragraph, continued upon page 129, the reader will observe that the word *pale* is used not only in contradistinction to *dark*, but also in contradistinction to *sheathed*. The German word (*blass*) is the same throughout; and as the fibres, on losing their sheaths, would assume a pale aspect, it was perhaps intended to be so. It is more probable, however, that *blass*, where placed in opposition to *sheathed*, is a misprint for *blöss*, which signifies *bare* or *uncovered*.

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